

## Supplementary Material

# Geochemical Erosion in Fluvial Channels During Intense Rainfall Events in Southern Brazilian Watersheds

## *Erosão geoquímica em canais fluviais durante eventos de chuvas intensas em bacias hidrográficas do sul do Brasil*

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Received: 17/10/2025; Accepted: 16/01/2025; Published: 03/02/2026

**Abstract:** The high average load of suspended sediments in rivers in southern Brazil is related to soil degradation in agricultural areas due to erosive processes resulting from inadequate management. In this context, understanding the dimensions of transported particles and their biogeochemical dynamics is essential, as well as their transport capacity, load, concentration, deposition potential, and degradation within the fluvial system. This study analyzed hydrological characteristics, particle size, and chemical properties (TOC, NT, PT, P<sub>Org</sub>, Pd) in three river basins in Rio Grande do Sul (2012-2013): Arroio Lajeado Ferreira (1.19 km<sup>2</sup>), Rio Guaporé (1,980 km<sup>2</sup>), and Rio Conceição (804 km<sup>2</sup>), all located in southern Brazil. This research revealed that erosion during heavy rainfall in southern Brazil acts as a selective "geochemical erosion" process, preferentially transporting fine sediments (<63 µm) enriched with nutrients. The dynamics of phosphorus, during intense rainfall events can become predominantly organic (>50%), and quantifying significant loads of bioavailable phosphorus and organic carbon to rivers. The Conceição River Basin stood out with the greatest nutrient loss per area, demonstrating that agricultural practices exacerbate this impact. Suspended sediments (< 63 µm) showed high concentrations of organic carbon, nitrogen, and phosphorus (especially Pd, which is of environmental concern). The particle size D(25), D(50), D(75) did not vary significantly between basins or rainfall events. Phosphorus exhibited a dynamic behavior, at basal flow, it was predominantly inorganic, but during rainfall events, more than 50% could be organic.

**Keywords:** Erosive processes, Gran-Size Analysis, Phosphorus, Carbon, Nitrogen

## Supplementary Table 1. Tables of the physical, chemical, and hydrological data generated in the study of the three watersheds in the state of Rio Grande do Sul, southern Brazil.

### Conceição River Watershed

Date	Time	P (mm)	Q máx (m³ s⁻¹)	Q méd (m³ s⁻¹)	Vol Total (m³)	Vol Esc Sup (m³)	CSS máx (g/l)	CSS méd (g/l)	Sed Prod (kg)	Flow (m³/s)	D 10	D 16	D 25	D 50	D 75	D 84	D 90	Clay	Silt	Sen d	Pt (> 63 µm)	Pt (< 63 µm)	Po (> 63 µm)	Po (< 63 µm)	Pd (> 63 µm)	Pd (< 63 µm)	N % (> 63 µm)	N % (< 63 µm)	C % (> 63 µm)	C % (< 63 µm)
06/07/2012	10:00		15.27	13.63	155421.65	108950.08	0.89	0.25	39.69	14.15	1.51	2.40	4.00	11.6	25.0	30.0	35.8	13.5	85.0	1.36	623.25	1242.69	247.45	177.70		143.14	1.23	0.71	5.16	3.65
06/07/2012	13:15		20.10	17.71	276211.12	208816.67	0.84	0.19	53.19	17.19	1.45	2.40	3.80	10.9	23.0	30.0	34.9	14.0	84.6		521.16	1260.42	371.15	233.89		56.19	0.71	0.72	4.46	3.78
06/07/2012	18:30	84.70	23.54	22.45	808161.25	635868.83	0.57	0.13	102.31	22.06	1.37	2.20	3.60	10.8	23.0	30.0	34.1	15.0	84.3	1.28						56.19	0.79	0.74	4.79	3.77
07/07/2012	11:00		23.54	21.75	1683697.47	1234045.76	0.12	0.08	138.50	22.06	1.49	2.40	4.00	11.3	22.0	28.0	33.3	13.6	85.8	0.32	943.99	1107.29	220.86	254.76		41.99	0.93	1.25	4.33	4.42
08/07/2012	12:00		18.15	13.14	1218035.51	533829.52	0.13	0.07	80.12	12.44	3.21	6.00	0	10.0	20.8	34.0	40.0	43.4	88.7							39.63	1.69	1.76	3.79	3.77
19/09/2012	09:00		80.16	72.29	737321.77	614401.50	1.49	1.39	1026.45	74.51	1.27	2.00	3.60	11.3	23.0	30.0	35.9	16.0	82.3	1.57	842.87	1532.42	435.92	181.59		128.94	0.66	0.39	3.49	3.00
19/09/2012	12:00		87.81	84.58	811964.85	691652.10	1.43	1.26	1021.82	85.65	1.17	1.80	3.00	12.0	28.0	32.4	18.2	81.2								137.81	0.58	0.34		3.56
19/09/2012	14:28	125.40	89.48	82.96	2936721.04	2454323.21	1.09	0.64	1953.34	89.48	1.15	1.80	3.00	10.0	22.0	28.0	34.2	17.9	80.8	0.30	1094.49	1620.66	269.52	226.45		137.81	0.40	0.38	3.18	2.95
20/09/2012	07:58		72.31	62.06	2457767.63	1845900.54	0.15	0.10	260.07	57.18	1.28	2.00	3.40	6	0	2	1	0	2.26	1.14	1253.76	1397.13	267.38	221.65		116.52	0.60	0.58	3.97	3.67
20/09/2012	12:00		55.04	52.87	824706.33	562723.83	0.10	0.07	53.85	52.90	1.56	2.40	4.00	11.1	22.0	28.0	32.5	1	86.4	0.28	800.18	985.37	422.43	700.64		19.52	0.44	0.93	3.43	3.98
02/10/2012	22:30		166.11	145.61	4368435.70	3764531.63	1.08	0.57	2543.60	135.63	1.71	2.80	5.30	14.5	28.0	34.0	39.1	11.7	85.7	2.40	858.53	1320.66	202.67	721.77		136.04	0.55	0.51	3.04	2.81
03/10/2012	07:00		176.86	175.21	4730557.59	4140727.86	1.20	0.76	3567.55	175.75	1.44	2.40	4.30	13.0	28.0	34.0	38.4	14.0	83.5	2.33	739.43	1399.67	438.96	715.67		125.98	0.43	0.40	3.33	3.04
03/10/2012	14:00	121.50	177.76	147.12	6532202.20	5466854.32	0.15	0.08	516.57	163.75	1.49	2.40	4.30	12.8	28.0	34.0	37.8	13.5	84.3	2.04	753.56	1410.07	477.30	746.16		112.38	0.44	0.46	3.02	3.09
04/10/2012	07:00		110.38	91.94	4137314.71	2936498.43	0.05	0.04	180.31	85.65	1.35	2.20	3.80	11.4	23.0	30.0	34.8	15.1	83.6	1.22		1267.58				98.69	0.49	0.48	3.46	3.20
04/10/2012	16:30		78.99	69.22	2408697.32	1396491.29	0.04	0.04	87.90	68.00	1.32	2.00	3.40	10.3	21.0	28.0	32.1	15.8	83.7	0.27	593.90	1315.08	457.47	707.62		118.30	0.48	0.55	3.52	3.30
22/10/2012	21:30		52.83	51.45	493915.18	291542.86	0.94	0.59	290.47	51.30	1.3	2.00	3.80	11.7	23.0	30.0	35.4	15.6	83.1	1.18	879.70	1625.78	223.49	736.91		146.09	0.31	0.32	2.64	2.41
23/10/2012	00:30		52.83	51.03	887863.54	506836.78	0.86	0.23	203.12	50.77	1.24	2.00	3.60	12.2	25.0	32.0	36.7	14.2	84.0	0.37	948.66	1629.40	295.62	687.07		137.81	0.45	0.41	3.29	3.04
23/10/2012	07:00	47.90	50.77	48.88	1143706.01	602378.94	0.12	0.11	121.09	48.65	1.43	2.40	4.00	12.2	25.0	32.0	36.7	14.2	84.0	1.69	872.86	1254.57	19.58	821.56		123.03	0.40	0.52	3.48	4.40
23/10/2012	13:30		55.04	50.56	1273991.42	653935.62	0.09	0.06	73.64	49.64	1.21	1.80	3.20	10.3	0	0	2	9	1	0.33	704.64	1430.58	336.73	780.67		95.82	0.43	0.41	3.41	3.30
23/10/2012	21:00		61.49	58.85	2153863.39	1184809.69	0.05	0.05	102.75	61.08	1.59	2.60	4.60	5	0	0	5	7	1	2.16	950.84	1426.29	609.98	683.18		113.56	0.53	0.50	4.69	4.47
24/10/2012	09:30		54.97	42.75	1821171.15	591083.81	0.04	0.04	67.83	43.85	1.7	3.00	5.30	2	0	0	2	4	2	5.64	2783.72		851.22	790.88		82.81	100.51			
09/03/2013	14:30													30.0	38.0	43.2	11.1	84.0									0.45	0.47	4.32	4.88
09/03/2013	22:00									1.8	3.00	5.60		12.3	25.0	32.0	36.2	13.4	85.1	4.56	688.54	1212.25	371.23	422.21		164.54	0.43	0.45	4.10	4.34
10/03/2013	13:30									1.5	2.40	4.30		4	0	0	3	4	4	1.40	764.29	1203.01	334.48	409.93		144.06	0.36	0.38	3.48	3.78
10/03/2013	17:00									1.16	1.80	3.00		19.0	25.0	31.0	18.1	81.4	0.26	900.95	1398.19	451.22	557.53		114.43	0.40	0.42	3.95	4.27	
24/08/2013	10:20		38.17	31.28	750764.97	374287.89	0.09	0.08	60.78	29.85	1.36	2.20	3.80	4	0	0	9	7	8	1.52	796.67	1576.30	673.26	791.91		195.24	0.43	0.57	2.88	3.45
24/08/2013	17:00		42.39	41.63	1798341.27	1092278.77	0.12	0.08	147.41	41.80	1.92	3.20	6.00	15.3	28.0	34.0	38.1	10.4	87.7	1.85	777.47	1411.02	564.89	676.40		5.43	0.55	0.56	3.47	3.36
25/08/2013	10:30	124.10	68.66	53.31	2175119.06	1474750.04	0.06	0.05	112.05	62.94	1.45	2.40	4.30	12.3	25.0	30.0	34.5	13.9	85.4	0.38	894.31	1629.73	557.20	653.09		214.03	0.40	0.43	2.93	3.15
25/08/2013	15:30		74.50	71.69	4215377.95	3148721.95	0.06	0.05	215.53	72.83	2.38	3.80	6.00	15.1	25.0	32.0	34.9	91.4		0.35	953.83	1351.11	419.95	499.90		152.89	0.65	0.70	3.52	3.73
26/08/2013	19:20		68.39	57.84	5825873.54	3841344.04	0.04	0.03	186.93	72.90	2.16	3.40	5.60	14.2	25.0	32.0	35.1	90.3			1232.77	1297.19	258.55	496.93		143.87	0.64	0.58	3.48	3.50
20/09/2013	18:00		38.17	26.19	1870174.81	914170.53	0.09	0.04	90.95	29.73	1.23	1.80	3.40	10.4	22.0	30.0	34.7	17.0	81.8	1.17	966.50	1475.37	420.70	447.28		158.91	0.25	0.28	2.47	2.72
21/09/2013	14:40	73.40	66.24	55.94	4473318.14	3221854.39	0.05	0.04	161.03	56.30	1.97	3.40	6.00	14.9	28.0	34.0	37.7	10.1	88.1	1.65	1724.65	1285.37	366.83	402.70		137.00	0.38	0.40	2.98	2.98
22/09/2013	14:00		63.97	53.63	4601564.44	3031058.91	0.03	0.03	134.22	54.20	1.58	2.60	4.30	11.4	21.0	25.0	29.8	12.8	86.9	0.14	817.82	1011.21	373.99	294.13		123.83	0.38	0.33	3.24	2.41
24/10/2013	05:20		25.64	23.01	496955.99	60548.45	0.03	0.03	14.13	22.93	1.66	2.80	5.30	14.2	28.0	34.0	38.5	12.1	85.4	2.41	692.78	1326.54	353.69		131.29	0.34	0.37	2.56	2.61	
24/10/2013	11:10	122.00	34.38	31.26	1087692.37	370117.39	0.03	0.03	30.57	29.85	1.46	2.40	4.30	12.4	25.0	32.0	37.1	13.9	83.8	2.06	634.53	1288.74	455.44	471.64		148.44	0.28	0.32	2.35	2.50
25/10/2013	00:30		36.07	35.22	2071153.22	818112.50	0.03	0.03	57.80	36.07	1.83	3.20	6.50	7	0	0	2	8	9	4.82	883.23	1290.43	435.14		157.03	0.33	0.34	2.65	2.62	



### Lajeado Ferreira Micro-Watershed

Date	Time	P (mm)	Q máx (m³ s⁻¹)	Q méd (m³ s⁻¹)	Vol (m³)	Total	Vol Esc (m³)	Sup	CSS (g/l)	máx	CSS méd (g/l)	Prod (kg)	Sed	Flow (m³/s)	D 10	D 16	D 25	D 50	D 75	D 84	D 90	Clay	Silt	Sand	Pt (> 63 μm)	Pt (< 63 μm)	Po (> 63 μm)	Po (< 63 μm)	Pd (> 63 μm)	Pd (< 63 μm)	N % (> 63 μm)	N % (< 63 μm)	C % (> 63 μm)	C % (< 63 μm)	
26/8/12 10:00	10:00		0.04	0.03	646.07		302.21		0.17	0.12		0.08		0.02876	2.23	3.40	5.60	14.5	28.0	34.0	36.9	8.75	90.0	1.23	474.06		370.61	323.40	104.69	106.61	0.71	0.73	3.89	4.10	
26/8/12 15:30	15:30	30.40	0.04	0.04	615.80		285.17		0.15	0.11		0.07		0.03	2.52	3.80	6.00	16.0	32.0	38.0	43.9	7.42	87.4	4.89	0.00										
26/8/12 19:30	19:30		0.03	0.03	458.08		153.46		0.16	0.10		0.04		0.03	2.23	3.40	5.00	11.9	23.0	30.0	34.3	8.72	90.7	0.36	346.26		398.11	313.29	8.87		0.91	0.83	3.89	3.96	
9/9/12 16:52	16:52		0.32	0.32	817.72		457.85		0.32	0.22		0.18		0.03	1.36	1.80	2.80	7.01	19.0	28.0	33.4	6	82.3	0.35	352.69	542.67	221.51	257.98	131.90	131.90	0.32	0.35	1.87	2.10	
9/9/12 17:39	17:39	72.71	0.36	0.34	1362.55		759.01		0.28	0.20		0.27		0.03	1.85	2.80	4.60	15.0	30.0	36.0	40.9	10.94	85.9	3.01	297.93		298.97			159.11		0.41	0.43	2.35	2.60
9/9/12 19:02	19:02		0.36	0.33	1669.48		828.73		0.14	0.13		0.22		0.03	3.29	5.30	8.50	20.0	34.0	40.0	43.7	5.34	90.1	4.39	0.00		294.16			116.16					
17/9/12 22:55	22:55		0.05	0.03	1675.06		0.00		0.61	0.12		0.23		0.03	2.15	3.20	5.30	13.2	25.0	30.0	34.2	9.07	90.4	0.33	273.22		292.19	324.55	44.95	69.59	0.75	0.75	3.01	3.40	
18/9/12 12:55	12:55		0.12	0.04	1109.24		334.18		0.38	0.08		0.17		0.11	1.31	2.00	3.20	8.12	16.0	21.0	25.6	16.35	83.5	0.08	292.06	563.95	254.09	241.48	119.48	119.48	0.39	0.37	2.33	2.13	
18/9/12 13:40	13:40	111.14	0.12	0.10	1281.09		576.54		0.34	0.18		0.25		0.12	1.46	2.20	3.60	10.5	21.0	25.0	30.3	14.54	85.2	0.15	310.90	510.74	278.49	278.38	118.30	118.30	0.30	0.31	2.89	2.93	
18/9/12 19:50	19:50		1.47	0.33	7248.69		5143.87		5.27	0.60		13.14		0.23	1.35	2.00	3.40	10.0	20.0	28.0	31.9	15.55	84.0	0.27	474.17	537.57	312.49	274.90	143.14	143.14	0.56	0.52	3.00	2.85	
12/3/13 11:10	11:10		0.12	0.09	199.31		76.79		0.13	0.06		0.01		0.09	1.34	2.00	3.00	7.83	18.0	25.0	29.6	16.58	83.1	0.21	399.52	763.40	159.34	122.27	232.20	242.01	0.81	0.81	3.54	3.86	
12/3/13 11:49	11:49		0.14	0.13	339.26		200.20		0.17	0.16		0.05		0.14	1.32	2.00	3.40	10.1	22.0	30.0	34.3	15.99	83.4	0.38	473.06	935.37	561.48	549.16	192.73	195.45	0.47	0.54	3.12	3.42	
12/3/13 12:35	12:35	N tinha valores de P	0.20	0.15	655.33		403.45		0.16	0.13		0.09		0.14	1.56	2.40	3.80	10.9	23.0	30.0	34.4	13.22	86.2	0.37	433.93	904.44	407.64	463.61	185.22	185.22	0.69	0.72	3.96	4.12	
12/3/13 14:10	14:10		0.24	0.20	1689.82		1131.33		0.18	0.13		0.22		0.23	1.82	2.80	4.60	12.9	25.0	32.0	35.2	11.13	88.2	0.41	562.28	1032.13	498.64	643.05	172.69	173.94	0.53	0.55	4.44	4.83	
12/3/13 17:14	17:14		0.16	0.15	995.88		494.76		0.08	0.07		0.07		0.14	3.64	5.60	9.00	24.9	45.0	56.0	67.0	4.58	75.4		519.44	886.98	460.83	414.05	119.92	138.20	1.12	1.20	5.32	5.81	
12/3/13 17:53	17:53		0.14	0.14	316.41		128.09		0.07	0.06		0.02		0.14	3.63	5.60	8.50	16.2	30.0	38.0	43.0	4.93	90.3	4.50	494.23	782.08	104.60	26.51	97.06	22.33	1.34	1.46	5.79	6.36	
24/8/13 11:40	11:40													0.05											490.90	862.38	595.71	380.99	232.82	220.30	0.66		3.84		
24/8/13 21:00	21:00													0.05											623.63		417.36	909.25	124.45	170.18	0.84	0.83	3.71	3.60	
24/8/13 12:00	12:00		0.05	2.03	3.20	5.60	13.8		25.0	30.0	34.0	9.84	89.6	0.31	554.75	989.57	410.51	525.66	194.61	207.14	0.66	0.64	3.86	3.30											
25/8/13 3:00	3:00		0.05	1.85	2.80	5.00	13.4		25.0	32.0	35.1	10.99	88.4	0.39	613.32	957.64	551.49	579.82	163.29	202.13	0.72	0.67	4.12	3.52											
25/8/13 10:30	10:30		0.05	1.55	2.60	4.30	12.4		23.0	30.0	34.2	13.09	86.3	0.35	693.41	948.11	657.97	543.14	239.09	178.32	0.64	0.53	4.19	3.77											
20/9/13 14:03	14:03		0.28	0.18	128.31		96.63		0.12	0.12		0.12		1.54	2.40	4.00	11.2	22.0	28.0	31.4	13.42	86.2	0.21	611.83	861.66	164.00	130.58	134.47	135.10	0.50	0.50	4.61	3.75		
20/9/13 14:17	14:17		0.37	0.34	263.41		228.12		0.36	0.36		0.36		1.5	2.40	4.30	11.5	21.0	25.0	30.3	13.56	86.2	0.16	546.32	812.67	458.12	524.12	207.18	209.11	0.37	0.32	3.63	2.66		
20/9/13 14:28	14:28		0.45	0.41	1266.38		1115.08		0.43	0.43		0.43		1.32	2.00	3.40	9.52	18.0	23.0	27.6	15.94	83.9	0.09	623.63	805.52	405.86	321.48	194.94	158.23	0.22	0.19	2.32	1.84		
20/9/13 15:58	15:58	71.01	0.52	0.37	3013.37		2544.95		0.27	0.27		0.27		1.2	1.80	2.80	8.79	19.0	25.0	28.1	18.10	81.7	0.10	737.02	834.95	404.71	341.85	175.12	137.64	0.33	0.31	2.84	2.63		
20/9/13 18:58	18:58		0.58	0.42	3034.26		2521.62		0.33	0.33		0.33		1.45	2.20	3.80	11.0	21.0	25.0	29.2	14.58	85.2	0.09	731.87	942.90	586.48	428.82	168.93	172.69	0.39	0.35	3.15	2.86		
20/9/13 20:00	20:00		0.28	0.24	885.97		594.27		0.24	0.24		0.24		1.82	3.00	5.30	15.1	28.0	34.0	37.2	11.07	87.6	1.27	644.25		138.27	253.75	285.11	205.89	0.65	0.61	4.60	3.45		
26/10/13 15:55	15:55		0.42	0.21	1120.95		783.92		0.12	0.12		0.12		1.25	1.80	3.00	7.5	15.0	18.0	21.0	17.38				668.36	1052.30	573.02	524.26	207.77	205.89	0.28	0.26	2.17	1.91	
26/10/13 17:25	17:25		0.46	0.42	1305.57		1064.02		0.45	0.45		0.45		1.38	2.20	3.80	10.6	21.0	25.0	30.8	14.91	84.7	0.20	750.15	979.37	394.79	286.07	131.97		0.28	0.21	2.83	2.09		
26/10/13 17:40	17:40	31.86	0.46	0.43	856.78		685.71		0.46	0.46		0.46		1.42	2.20	4.00	10.5	19.0	25.0	28.1	14.49	85.4	0.07	601.63	885.60	245.53	233.65	232.87	156.30	0.26	0.18	2.71	1.89		
26/10/13 18:30	18:30		0.37	0.27	1911.78		1173.30		0.33	0.33		0.33		1.29	2.00	3.40	10.2	21.0	28.0	32.3	16.39	83.1	0.28	688.31	1010.62	183.42	126.54	96.41	96.41	0.28	0.25	2.75	2.33		
26/10/13 21:40	21:40		0.20	0.16	1825.83		306.73		0.15	0.15		0.15		1.62	2.60	4.60	13.0	25.0	30.0	33.2	12.61	86.9	0.27	649.40	896.79	93.03	118.61	131.31	131.31	0.42	0.39	3.37	3.09		

**Supplementary Table 2.** Results of statistical tests for outlier detection, data distribution normality assessment, and group comparison (two-tailed significance level of 0.05).

	GRUBBS' TEST						JARQUE-BERA TEST						KRUSKAL-WALLS TEST		
	Conceição		Guaporé		Lajeado Ferreira		Conceição		Guaporé		Lajeado Ferreira		Conceição	Guaporé	Lajeado Ferreira
	N	Z	N	Z	N	Z	JB	p	JB	p	JB	p	H (chi <sup>2</sup> )	HC	p
Clay	38	3.0	16	2.6	28	2.9							0.1395	0.1396	0.9326
Silt	38	3.0	17	2.6	28	2.9	1.7	0.4	0.3	0.9	2.2	0.3	No significant difference between the sample groups.		
Send	38	3.0	16	2.6	30	2.9									

**Supplementary Table 3.** Grain size variation range in suspended sediment samples from the three monitored watersheds during the period from 2012 to 2013.

	D25 ( $\mu\text{m}$ )	D50 ( $\mu\text{m}$ )	D75 ( $\mu\text{m}$ )
<i>Arroio Lajeado Ferreira</i>			
Minimum	2.8	7.0	15.0
Maximum	9.0	25.0	45.0
Mean	4.6	12.4	23.9
Median	4.3	11.5	23.0
<i>Conceição River</i>			
Minimum	3.0	9.2	19.0
Maximum	10.0	21.0	34.0
Mean	4.4	12.0	24.8
Median	4.0	11.8	25.0
<i>Guaporé River</i>			
Minimum	3.2	9.7	20.0
Maximum	6.5	15.6	28.0
Mean	5.1	13.1	24.1
Median	5.3	13.3	25.0