XXXV Congresso Brasileiro de Ciência do Solo
CENTRO DE CONVENÇÕES - NATAL / RN
O SOLO E SUAS MÚLTIPLAS FUNÇÕES
02 a 07 DE AGOSTO DE 2015

# Characteristics, distribution and phosphorus release from fluvial sediments in a mixed land use catchment, southern Brazil[1]

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**ABSTRACT:** During past two decades, the increase in animal production in South America has ranked second globally and as result phosphorus (P) export from soil surface along with sediments has increased. The study area Guapore catchment is located between latitudes 29.2 S and 28.2 S and longitude 52.4 W and 51.8 W in Southern Brazil with basin area of 2500 km$^2$. A total of 11 points under different anthropic disturbances including conventional tillage (CT) and no-tillage (NT) systems were selected. At each monitoring point the SS were collected in November, 2013. The Hedley P fractionation scheme was followed to separate different P fractions.The phosphorus fractionation results showed an overall trend of the P forms was NaOH-P (Fe and Al bound P) >> Residual-P > HCl-P (Ca bound P) > $NaHCO_3$-P (labile P) > Resin-P (bioavailable P). Across different land-use systems, CT showed greater retention of the P as well as desorbed more bioavailable P during ecologically sensitive periods. The results demonstarte hat the soil application of manure must be based on P availability and not on total P basis to minimize hazardous environmental impacts.

**Keywords:** Phosphorus; sediment; fractionation; P-release.

## INTRODUCATION

Phosphorus (P) is widely regarded as a limiting nutrient for phytoplankton growth, and excessive P concentration is deemed the most common cause of eutrophication in water bodies. The release of phosphorus from sediment is a vital nutrient source that will induce continuous eutrophication in water bodies even if external inputs are reduced. In most aquatic environments, the sediment plays an important role in P cycling because it is able to store a large part of the P that settles out from the water body, either to be buried permanently or recycled into the water. This process makes the internal loading of P from sediments a key factor during eutrophication, so the conditions that regulate the recycling of P from sediments have received considerable interest (Ahlgren et al., 2005). However, not all the phosphorus fractions can be released from sediments into the overlying water to lead to eutrophication (Knapp et al., 2002). The potential release of P from sediments to the water depends to a large extent on the form of P in the sediments (Zhang et al., 2008). Therefore, a comprehensive understanding of P in fluvial sediments and its contribution to the water requires detailed species information.

Since the 1990s, studies in Brazil have primarily focused on concentration of TP and Pi and their transformation by P fractionation in soil and manure. However, little is known about the species and dynamics of P species in the sediments. In this study, the Guapore catchment was selected as a typical representative area for investigation of sediment P compounds. The specific objectives of this study were to detect the P compounds in surface sediment by chemical p fractionation and study the relationship between P in sediment and water quality. This study provides useful information pertaining to the compounds, bioavailability and dynamics of P in fluvial sediments from areas with diverse land use and management.

## MATERIAL AND METHODS

### Study catchment and its characteristics

The Guapore catchment is located in the northeastern region of Rio Grande do Sul state and with a drainage area of 2,000 km2 and the monitored section is located at coordinates 28°54′41″S and 51°57′10″W (Fig. 1). It covers part of the physiographic regions of the middle plateau (upper third of the basin) and the lower northeastern slope (intermediate and lower thirds of the basin). The Guapore river is a tributary of river Taquari, and Taquari river is part of the Regional Hydrographic Guaiba river. The altitude of the basin varies widely, from 40 m near its confluence with the river Taquari to 800 m in north at the starting part of the right portion of the basin. Climate is classified as Cfa according to the Koppen climate classification.

Average annual rainfall varies between 1,400 and 2,000 mm, and the average annual temperature is 17.4 °C. Geology is characterized by volcanic lava flows, and topography is undulating to hilly.

Due to variations in landscape, several classes of soils (i.e., Entisols, Luvisol, Cambisol, Oxisol, Chernosol, Ultisol) and rocky patches can be found in the catchment. The land use is highly heterogeneous. In the upper third of the catchment where the terrain is characterized by gentle hills, there is a clear dominance of soybean (*Glycine max*) cultivated under NTS. In the other two-thirds of the catchment land use and soil management is very heterogeneous. The main land uses are tobacco (*Nicotiana tabacum*) and maize (*Zea mays*) crops, areas that have been reforested with Eucalyptus (*Eucalyptus* spp.), as well as pastures for dairy cattle and pig production. In the lower part native plant erva-mate also covers considerable area. In these areas it is possible to identify different types of soil management, mainly, conventional and minimum tillage. In areas of greater steepness, especially riversides, there are large portions of native forest area as well as small towns and urban areas.

**Identification, selection and collection of representative sediments**

To collect representative water, suspended, rain event and bed sediment samples topographic map, aerial photographs, and field work using a GIS with ArcView program 10.1 were defined and identified. The 6 monitoring stations were identified and installed on sub-catchment scale and 5 monitoring station were identified on the main river (Fig. 1, Table 1). The principal areas selected as sub-catchment includes; i) sub-catchment with high anthropic pressure and point sources with city and house effluent, sewage sludge; ii) sub-catchment with dominated by soybean with NT system; iii) sub-catchment with tobacco cultivation and CT system; iv) sub-catchment with tobacco under CT and maize cultivation under CT system; v) Sub-catchment wit tobacco cultivation under CT and erva-mate (Ilex paraguariensis) plantations; and vi) sub-catchment with natural forest which served as control. On the main river 5 monitoring station was installed in areas showing maximum pig/poultry ordiffuse sources inputs (Fig. 1; P0, P1, P4, P5 and P6) to cover the spatial variability until catchment out let where principal hydrological and sedimentological monitoring station was installed. The representative suspended sediment samples were collected during November 2013 by using time-integrated suspended sediment samplers (Phillips et al., 2000).

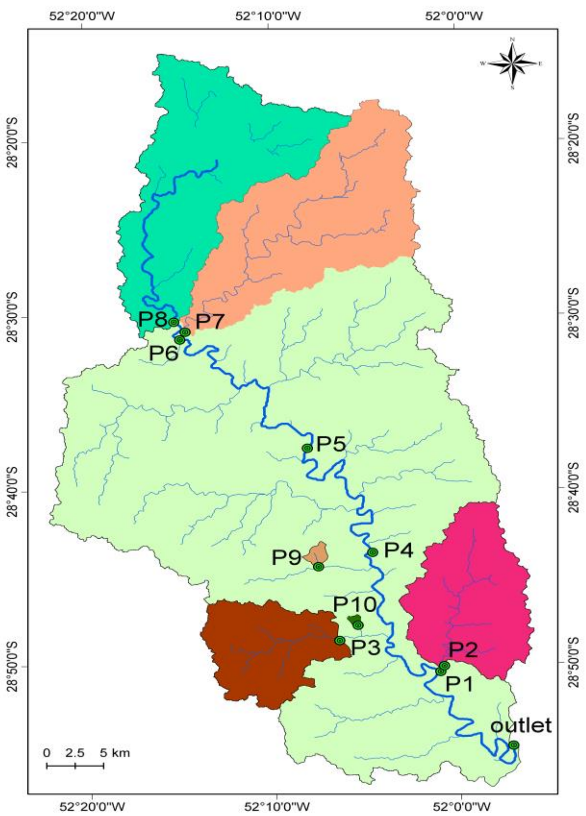


**Figure 1 –** The location of study catchment Guapore, in RS-Brazil with 11 monitered points.

**Table 1 –** The land use and managment charcteristics of monitered points in Guapore catchment RS-Brazil.

| Monitoring station | Coordinate E | Coordinate S | Description |
|---|---|---|---|
| 0 (outlet) | 407170 | 6801390 | Catchment Outlet (exutorio) |
| 1 | 400749 | 6809187 | Main river receiving diffuse sources |
| 2 | 401071 | 6809790 | Tobacco cultivation with CTS |
| 3 | 391861 | 6812458 | Tobacco cultivation with CTS and erva-mate |
| 4 | 394744 | 6821782 | Main river receiving diffuse sources |
| 5 | 389008 | 6832785 | Main river- high poultry/pig manures |
| 6 | 377786 | 6844236 | Main river (mixed input) |
| 7 | 378257 | 6845049 | Point source city effluent |
| 8 | 377260 | 6846103 | Dominated by soybean with NTS |
| 9 | 389998 | 6820260 | Tobacco-CTS and maize |
| 10 | 393475 | 6814063 | Evergreen forest (control) |

**Phosphorus fractionation and extraction**

The sediment P forms were estimated by modified fractionation scheme as described by Hedley et al. (1982).The modifications made are briefly described as follows: in each step, 10 ml of extractant was added to 0.5 g of sediment samples, 3 replicates in 15 ml centrifuge tubes and the tubes were shaken in an end-over-end shaker at 25 °C for 16 hours. Sequentially, the extractants used were: (1) anion exchange resin and water; (2) 0.5 mol $L^{-1}$ $NaHCO_3$ at pH 8.5; (3) 0.1 mol $L^{-1}$ NaOH; (4) 1.0 mol $L^{-1}$ HCl; and (5) 0.5 mol $L^{-1}$ NaOH. After the extractions, the residual material was dried at 50 °C and the (6) content of residual P was estimated by digestion of 0.25 g of residues with $H_2SO_4$ + $H_2O_2$ at 200 °C for 2 h (Olsen & Sommers, 1982). In the alkali extract of $NaHCO_3$ and NaOH, total P was estimated by digestion with $H_2SO_4$ and ammonium persulphate in an autoclave at 121 °C (US-EPA, 1971), and subsequent P determination according to Murphy & Riley (1962) method. In the same alkaline extracts, the IP content was determined according to Dick & Tabatabai (1977). The OP was measured as diffrence of IP from TP.

**Hydro-sedimentological parameters**

Suspended sediment concentration (SSC) was recorded by the evaporation and filtration method (Shreve and Downs, 2005). Water flow rate (Q) was performed with water level measurements using a limnigraph and rainfall (R) from weather station installed in catchment.

## RESULTS AND DISSCUSION

The phosphorus fractionation results are shown in Fig. 2. An overall trend of the P forms was NaOH-P (Fe and Al bound P) >> Residual-P > HCl-P (Ca bound P) > $NaHCO_3$-P (labile P) > Resin-P (bioavailable P). The highest bioavaliable P (101.4 mg P $kg^{-1}$)was recorded in P7 after city effluent, followed by the P2 with CTS (63.5 mg P $kg^{-1}$) when compared to the P8 (35.6 mg P $kg^{-1}$ ) under NTS and minimum in the sediments from native forest P10 with 32.6 mg P $kg^{-1}$. Within the same site, the fraction of NaOH, $NaHCO_3$ and Residual P showed larger variation while HCl and bioavailable P showed little variation except P7 (Fig. 2).

Comparing the PT, Po and Pi in the sediments from various soil management systems, again total P was highest (1814 mg P $kg^{-1}$) in the P7, while the sediments from monitoring stations under NTS showed lower TP export then under CTS (Table 3). Similarly highest 319 mg P $kg^{-1}$ Po content (18% of PT) was present in the P7 and this concentration is at par with the Po contents of P5. However lowest organic P (8% of TP) was recorded in P8 under NTS. The results also showed that the maximum inorganic P concentrations were recorded in P8 (92% of TP) followed by the P0, P9 and P1 with 91, 89, and 88% IP out of TP, respectively.

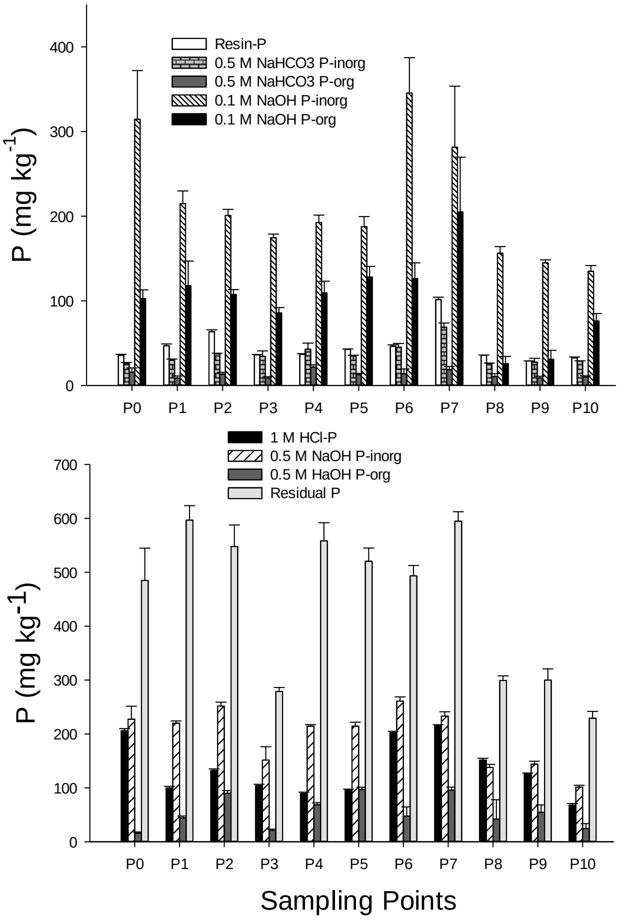


**Figure 2 –** Summary of distribution of contents of P species (mg $kg^{-1}$ d.w.) characterized by cmmical fractionation in the $H_2O$, $NaHCO_3$, HCl, NaOH and residual fractions.

**Table 2 –** Phosphorus concentration (PT, $P_o$ and $P_{ing}$) in sediments with different land management and land use types.

| Monitored Points | P-Total | P-Org | P-Inorg |
|---|---|---|---|
| | (mg $kg^{-1}$) | | |
| P0 | 1428 | 134 (9)* | 1294 (91) |
| P1 | 1379 | 171 (12) | 1208 (88) |
| P2 | 1444 | 211 (15) | 1234 (85) |
| P3 | 894 | 115 (13) | 779 (87) |
| P4 | 1333 | 199 (15) | 1134 (85) |
| P5 | 1333 | 238 (18) | 1096 (82) |
| P6 | 1581 | 187 (12) | 1393 (88) |
| P7 | 1814 | 319 (18) | 1495 (82) |
| P8 | 884 | 78 (8) | 806 (92) |
| P9 | 865 | 94 (11) | 771 (89) |
| P10 | 705 | 111 (16) | 594 (84) |

* Values in parentheses represent % contribution contribution of $P_{org}$ and $P_{inorg}$ in TP.

**Table 3 –** Rainfall, $EI_{30}$ and sediment yield in at the outlet in the Guapore catchment during 2013.

| Time Month/Year | R | $EI_{30}$ | SY |
|---|---|---|---|
| | mm | MJ mm $ha^{-1}$ $h^{-1}$ | t $km^{-2}$ |
| January/13 | 87 | 336 | 0.72 |
| February/13 | 171 | 934 | 2.68 |
| March/13 | 195 | 1145 | 17.21 |
| April/13 | 94 | 376 | 2.44 |
| May/13 | 124 | 573 | 3.26 |
| June/13 | 106 | 453 | 13.01 |
| July/13 | 73 | 257 | 4.62 |
| August/13 | 305 | 2257 | 43.45 |
| September/13 | 201 | 1199 | 10.41 |
| October/13 | 130 | 615 | 15.17 |
| November/13 | 182 | 1031 | 13.10 |

Table 3 presents the results of rainfall monitoring as well as estimates of erosion, runoff coefficient, and sediment yield for the period January 2013 to November 2013. The results show large intra-annual variability governed primarily by the volume of rain. The period from August to November were characterized by extreme situations, both by rainfall events of great magnitude that generated high values of Q and SSC and also by long periods of drought. Due to the occurrence of a long wet period, in August showed highest levels of sediment yield, runoff coffecient and rainfall which consequently will contributed to higher discharges (Table 3).

## CONCLUSIONS

Catchment scale estimation of suspended sediments associated P showed that majority (80-93 % of TP) of P was present as IP.
Conventional tillage system showed maximum losses of applied P, However, NT area also significantly contributed into P loading.
On an average 7-18 % of TP was available as BAP which can be crucial during the ecologically sensitive periods.
The results emphasize that moderation of the P fluxes from sediments requires considerable reductions of P load from land based sources.

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