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A HYDROSEDIMENTOLOGICAL RESPONSE UNITS MAP TO SOUTH AMERICA

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RESUMO – O uso de modelagem numérica para transporte de vazão e descarga sólida em rios é aceita como uma grande ferramenta na resolução de problemas hidrológicos e hidrossedimentológicos. O MGB-SED é um modulo de sedimentos acoplado ao modelo de grande escala MGB, que é discretizado em unidades que representam os fatores de maior influência nos processos hidrológicos, as Unidades de Resposta Hidrológica (URH). Com o desenvolvimento do módulo de sedimentos, foi necessário modificar os principais fatores de influência na produção de sedimentos para se obter um modelo melhor e aprimorar a calibração de futuras aplicações na área de sedimentos. Nesta linha, este artigo apresenta um mapa das Unidades de Respostas Hidrossedimentológicas, que poderá ser utilizado tanto para modelagem hidrológica quanto para modelagem hidrossedimentológica. Para compor o mapa, foram utilizadas informações de textura de solo e uso e cobertura vegetal do solo. Os dados de textura foram retirados do mapa da FAO, IBGE e INTA. O mapa de cobertura e uso do solo foi retirado do Portal GlobCover da ESA, para os anos de 2005 e 2009. Finalmente, este artigo apresenta dois mapas de URHSed para os anos de 2005 e 2009, divididos em 12 classes.

ABSTRACT – The use of numerical modeling of flow and sediment transport in rivers could be accepted as a great research tool in hydrological and hydrosedimentological problems. The MGB-SED is a sediment generation and transport model coupled into the MGB, a large-scale model, which the watershed is divided into units that represents the factors with major influence on the hydrologic, the Hydrologic Response Units (HRU). With the development of the sediment module, it was necessary to modify the major factors of influence in the sediment yield to have a better model and improve the calibration process of next applications in the sediment research. This paper aims to present a Hydrosedimentological Response Units Map that could be used both in the hydrologic and hydrosedimentologic models. To compose the map, it was used soil texture and land use cover information. The soil texture map used to the base was from FAO, and in more details from IBGE and INTA. The land use cover map used was the GlobCover from ESA, in both the years 2005 and 2009. Finally, the paper presents two maps in two different years (2005 and 2009) with 12 classes of Hydrosedimentological Response Units.

Palavras-Chave – HRUSed; Modelagem Hidrossedimentológica; MGB

INTRODUCTION

According to Wu (2007), in the last decades, the use of numerical modeling of flow and sediment transport in rivers has been applied as a major research tool to explain and resolve river

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engineering problems. In nowadays, there are a range of models that differ in complexity, considered process and required data for model calibration and use (Merritt *et al.*, 2003).

In large scale hydrologic and hydrosedimentological models, it is very common the approach of watershed discretization into Hydrologic Response Units (HRU). The watershed is divided into units that represents the factors with major influences on the hydrologic and hydrosedimentological processes (Xu *et al.*, 2012). The typical combination in many researches to a hydrologic approach, according to Xu *et al.* (2012), is the land use and the soil types. This is the typical combination map used in works with the models SWAT (Arnold *et al.*, 1998) and MGB (Fan e Collischonn, 2014).

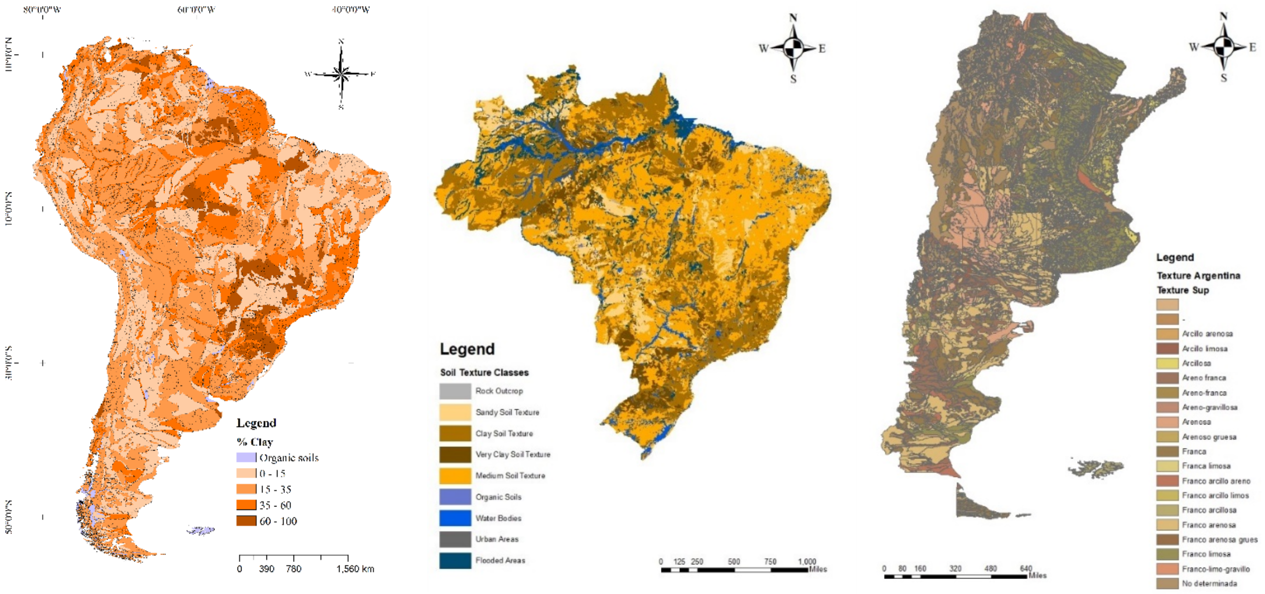
With the development of a hydrosedimentological model coupled in the MGB (Collischonn *et al.*, 2007) by Buarque (2015) (MGB-SED), the HRU map, developed by Fan *et al.* (2015), was applied in large scale hydrosedimentological modeling researches (Buarque, 2015; Buarque *et al.*, 2013; Fagundes *et al.*, 2019; Fagundes, 2018; Rossoni *et al.*, 2018). However, these studies pointed to the necessity of the use of a new watershed discretization, where the parameters would be focused in the sediment model calibration, because it was necessary to modify the factors of influence to have a better model and improve the calibration process.

In this perspective, this paper aims to present a Hydrosedimentological Response Unit (HRUSed) map that could be used both to calibrate a hydrologic model as well as hydrosedimentological models within South America continent.

HYDROSEDIMENTOLOGICAL RESPONSE UNIT (HRU) MAP DEVELOPMENT

The proposed watershed discretization approach was done according to the soil texture and land use information. This approach was chosen because some models, as SWAT (Arnold *et al.*, 1998), USLE (Wischmeier and Smith, 1978) and MGB-SED (Buarque, 2015) use the Erodibility Factor (K), from USLE (Wischmeier and Smith, 1978) and MUSLE (Williams, 1975) equations, obtained from soil texture characterization.

The FAO Soil Texture Map (*http://data.isric.org/geonetwork/srv/eng/catalog.search#/metadata/3a9ed87d-affc-4f72-aa6e-72db4fefec40*) was used as the base to the South America soil texture (Figure 1a). The coordinate system was WGS84 (World Geodetic System 1984) at scale 1:5.000.000. However, with the objective of obtaining greater detail, regional maps from two countries were used. The Brazilian Soil Texture Map (*ftp://geoftp.ibge.gov.br/informacoes_ambientais/pedologia/vetores/escala_250_mil/recorte_milionesimo/*) from IBGE (Instituto Brasileiro de Geografia e Estatística) was available in the coordinate system SIRGAS2000 (Geocentric Reference System for the Americas 2000) at scale 1:250.000 (Figure 1b).



(a) Texture soil map from FAO, used to the South America; (b) Texture soil map from IBGE, used in the Brazil; (c) Texture soil map from INTA to the Argentina.

Figure 1. Soil texture maps

The Argentinian Soil Texture Map (*http://www.geointa.inta.gob.ar/2013/05/26/suelos-de-la-republica-argentina/*) from INTA (Instituto Nacional de Tecnología Agropecuaria) was available in the coordinate system WGS84 at scale 1:500.000 in the most part of the country and 1:1.000.000 in the cities Neuquén, Mendoza, San Juan, La Rioja, Chubut and Santa Cruz (Figure 1c). All maps were unified and that which had the best resolution were in the top of the soil texture map composition.

The FAO Map had 5 legend entries, the Brazilian map had 320 legend entries and the Argentinian map had 20 legend entries. All the classes were simplified into six classes: “Water Bodies”, “Sandy Soil”, “Medium Soil”, “Clay Soil”, “Semi-Waterproof Soil” and “Flooded Areas”. The Figure 2 presents the final soil texture map to Latin America.

Besides the soil texture information, it was also used the coverage and land use data. This map was obtained from the ESA GlobCover Portal (*http://due.esrin.esa.int/page_globcover.php*) and the map composites use as input observations from the 300 m MERIS sensor on board the ENVISAT satellite mission. There was used the two available maps: from December 2004 to June 2006 and the map to the 2009 year. The coordinate system is WGS84 and the spatial resolution is 300 meters. The Figure 3 present the maps.

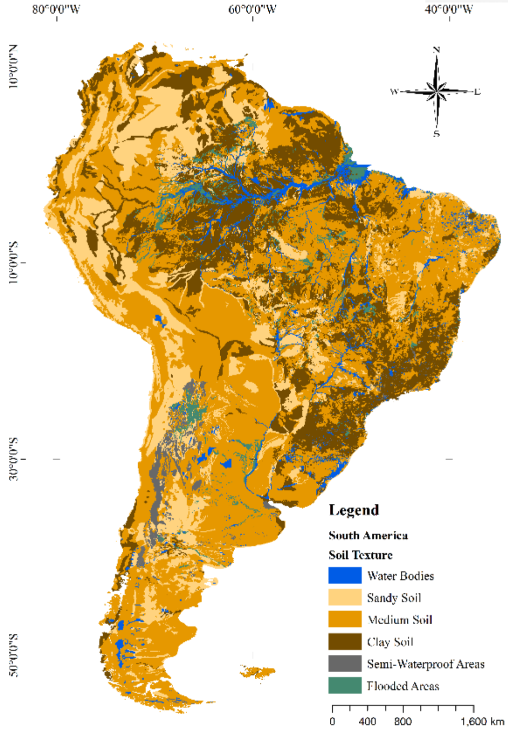
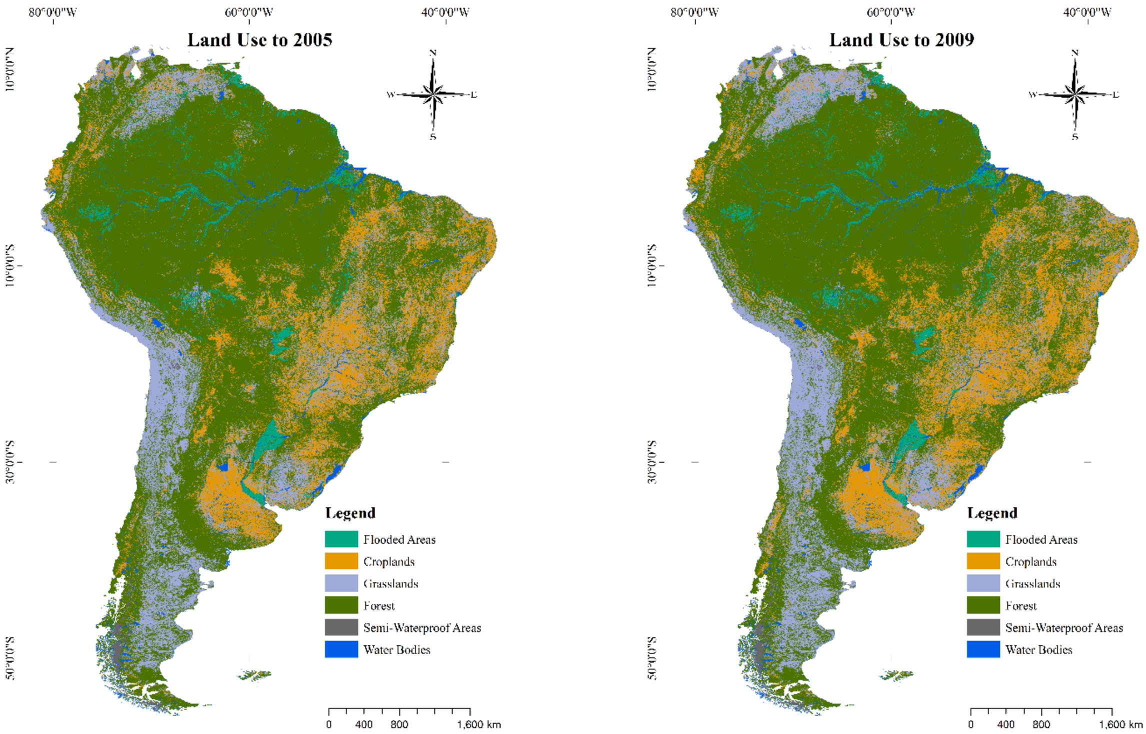


Figure 2. Texture soil map to the South America used to develop the HRUSed map



(a) Land use map to the year 2005 (b) Land use map to the year 2009

Figure 3. Land use map from GlobCover to the years 2005 and 2009

The Globe Cover Map had 22 classes of land use and cover. The map was reclassified into six classes: “Flooded Areas/Meadow”, that was included post-flooding or irrigated croplands, regularly and permanently flooded forests and shrubland and grassland or woody vegetation on regularly flooded; “Croplands”, that was included rainfed croplands and mosaic of cropland (50 to 70%) and vegetation; “Grasslands”, that was included mosaic of vegetation (grassland/shrubland/forest – 50 to 70%) and cropland, mosaic of grasslands (50 to 70%) and forest/shrubland, closed to open herbaceous vegetation, sparse vegetation and bare areas; “Forest”, that was included closed to open semi-deciduous forest, closed and open deciduous forest, closed and open evergreen forest, closed to open mixed broadleaved and needle leaved forest, mosaic of forest/shrubland (50 to 70%) and grassland and closed to open shrubland; “Semi-Waterproof Areas”, that was included artificial surfaces, urban areas and permanent snow and ice areas; and “Water Bodies”.

The Land Cover and Use Map and the Soil Texture Map were combined in the ArcMap 10.5.1 to generate the classes of the Hydrosedimentological Response Units. Altogether, 66 classes were generated. The classes which had the same conformation (e.g. “Water bodies”, “Semi-waterproof areas” and “Flooded areas/meadow”) were placed in the same classes. Aside from these, other classes were stipulated: “Croplands in sand soil texture”, “Croplands in medium soil texture”, “Croplands in clay soil texture”, “Grasslands in sand soil texture”, “Grasslands in medium soil texture”, “Grasslands in clay soil texture”, “Forests in sand soil texture”, “Forests in medium soil texture” and “Forests in clay soil texture”.

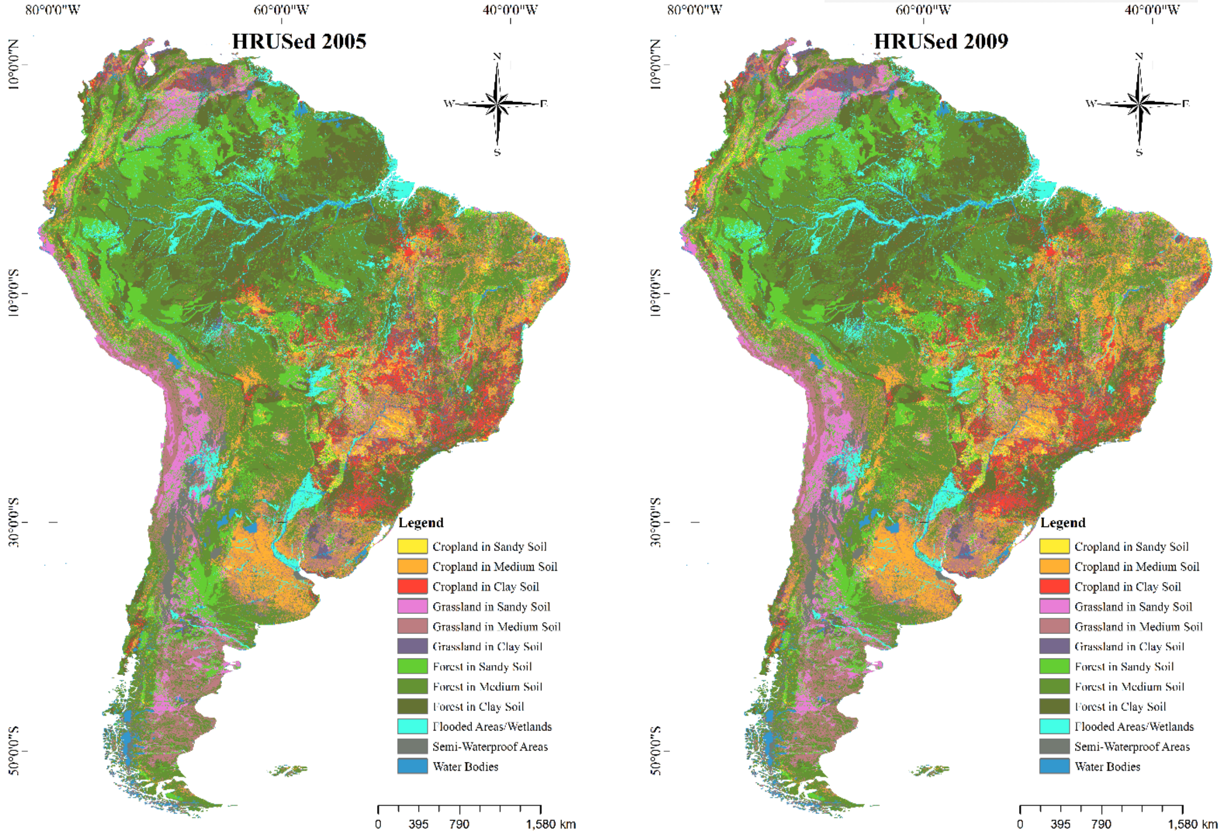
The Table 1 present the data information synthesized.

Table 1. Data used to develop the Hydrosedimentological Response Units map

Data	**Scale/Grid Spacing**	**Source**	**Year**
Soil Texture base map to the South America	1:5.000.000	FAO Soil Texture Map (BATJES, 2005)	1998
Soil Texture base map to Brazil	1:250.000	IBGE Downloads (IBGE, 2018)	1970-1985
Soil Texture base map to Argentina	1:500.000; 1:1.000.000	GeoINTA (INTA, 2013)	1990
Land use and cover map to South America	300 m	ESA GlobCover 2009 (ESA, 2018)	2009

RESULTS AND DISCUSSION

The Figure 4 presents the Hydrosedimentological Response Units (HRUSed) Map to the South America. The final map has 300 meters of spatial resolution and the coordinate system is in WGS84. The Figure 4a and Figure 4b presents the HRU map to the year 2005 and 2009, respectively. The HRUSed map have 12 classes. We developed one different map each different year, because we can analyze the changes in the soil use through time if wanted, in next applications.



(a) Hydrosedimentological Response Unit Map to the year 2005

(b) Hydrosedimentological Response Unit Map to the year 2009

Figure 4. HRUSed to the years 2005 and 2009

After the development of the HRUSed map, we evaluated the map with simulations in the Taquari-Antas River Basin for streamflow modelling. In these simulations, the model presented coherent estimations of discharges. To the 13 gauge-stations that we are evaluating in this paper, 10 presented BIAS results between -10 and 10%. Besides that, 8 gauge-stations presented values of Kling-Gupta Efficiency (KGE) greater than 0.75.

The simulated hydrograph as well are coherent with the observed hydrograph, estimating the flow peaks. The model was calibrated focusing in the rain and flow events, because they are the most important to generate sediment yield.

The Figure 5 present a map with ranges of values to the efficiency metric BIAS found with the calibration and the hydrographs corresponding at selected gauge-stations. The Figure 6 present the performance of model to the efficiency statistic KGE and the hydrograph at other selected gauge-stations.

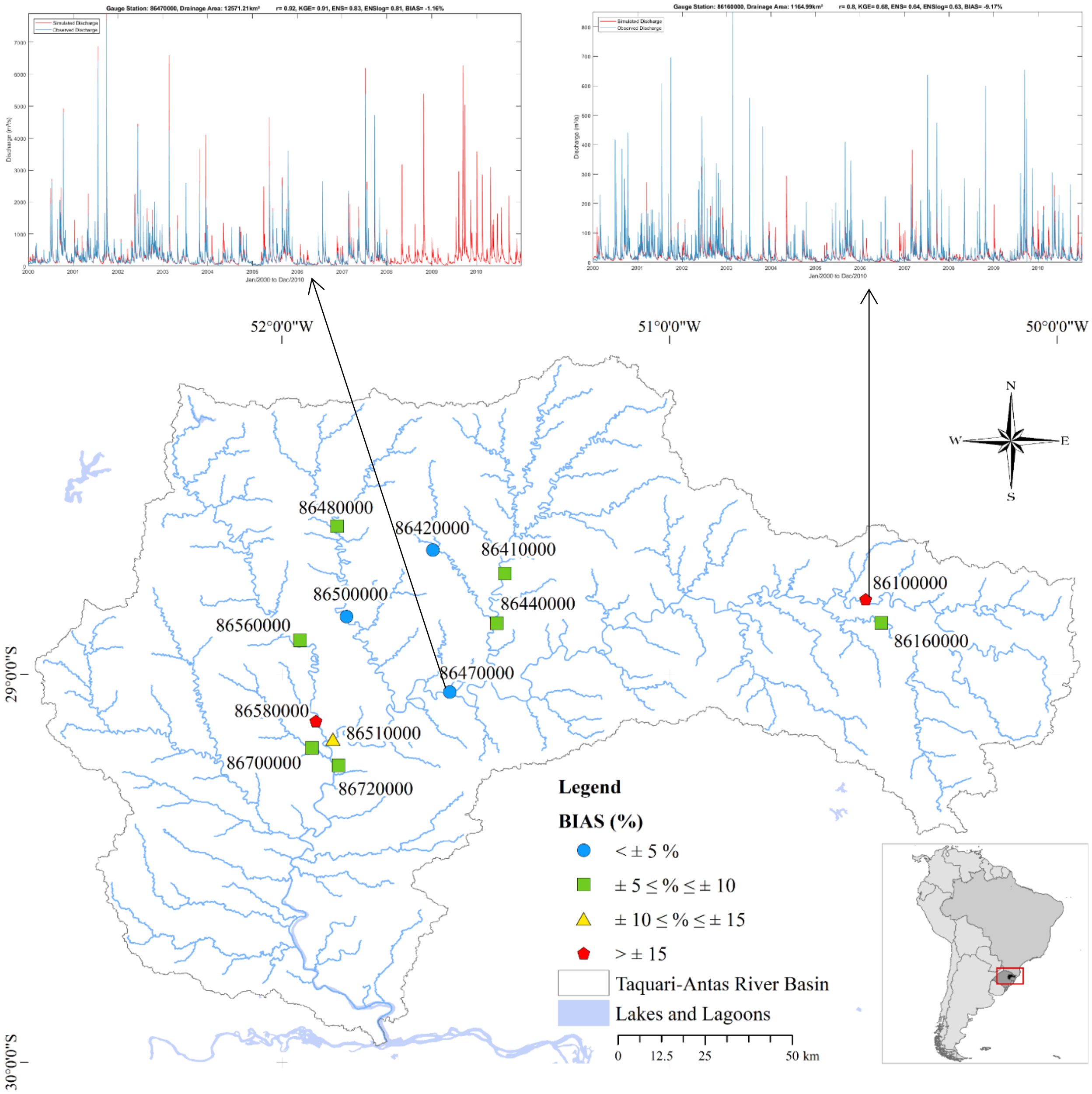


Figure 5. Map from Taquari-Antas River Basin, presenting the model evaluation (BIAS) to the simulated period. The closer to zero, the better the fit of the model; the hydrographs represent the gauge-station 86470000 and 86100000.

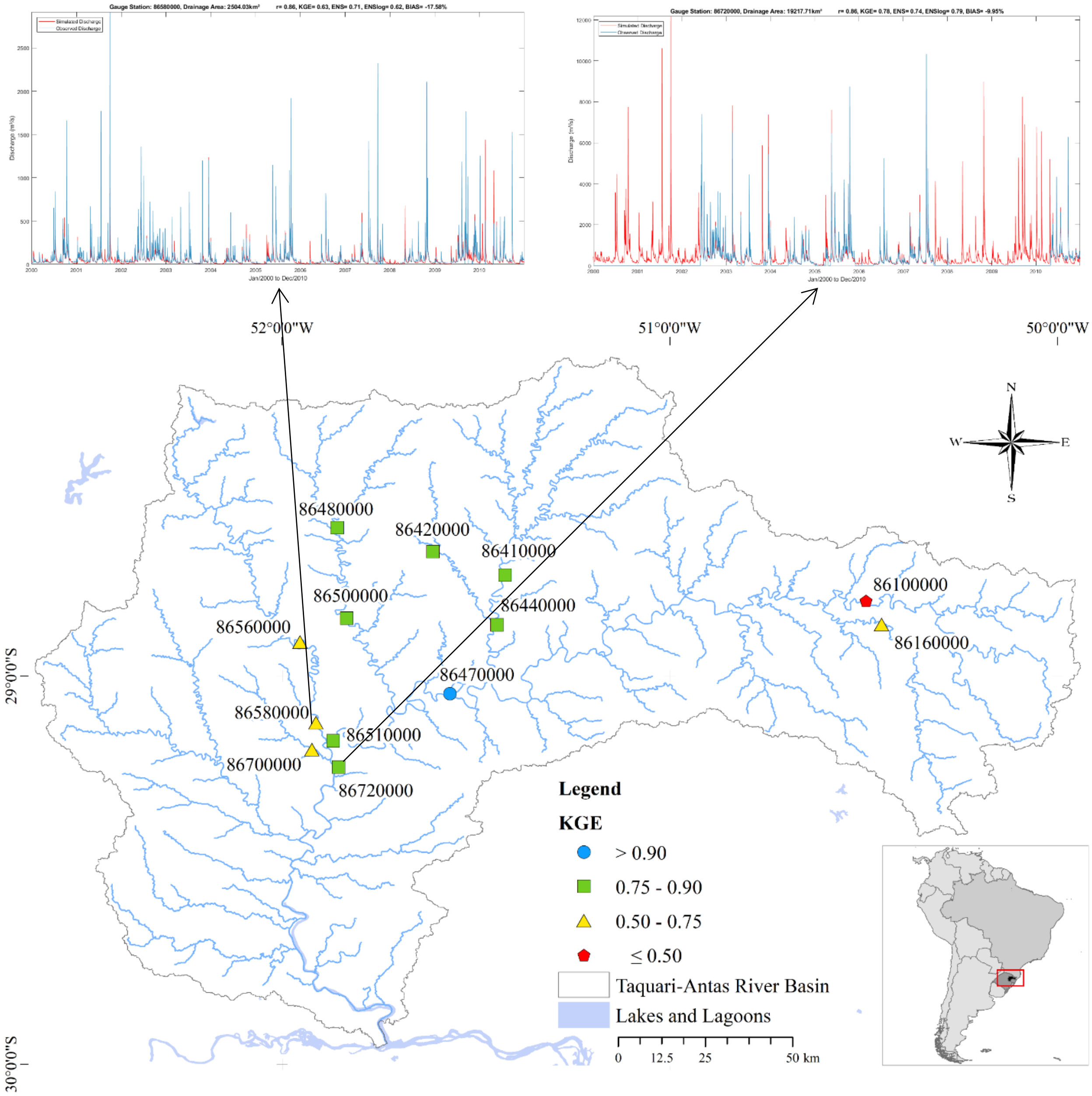


Figure 6. Map from Taquari-Antas River Basin, presenting the model evaluation (KGE) to the simulated period. The closer to 1 (one), the better the fit of the model; the hydrographs corresponding to the gauge-stations 86580000 and 86720000.

CONCLUSIONS

To improve the hydrosedimentological modeling, we developed a Hydrosedimentological Response Units (HRUSed) map and applied it in the MGB model to evaluate the use of this new discretization in modeling for streamflow simulation. The results demonstrate that it is possible to use the new map in the hydrological modeling. We found coherent results to the hydrographs in many gauge-stations of the basin and the efficiency metrics presented values that could be considered satisfactory to the modeling. This map could help in future applications of hydrosedimentological modeling to different models, studies areas and applications. In large scale, these maps could help to understand the hydrological processes in the great rivers and continental estimates of solid discharge. These applications will be next steps of the present research.

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