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Technical Article

A computational tool for hydrosedimentological and statistical calculations

Ferramenta computacional para cálculos hidrossedimentológicos e estatísticos

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ABSTRACT

This paper presents a new computational tool called NH SEDIMENT AND STATISTIC which performs hydrosedimentological and statistical calculations using Visual Basic. This computational tool was developed for studies related to calculations of sediment transport in rivers. The tool includes hydrosedimentological methods for calculating suspension loads, bed loads, and total solid discharge. In addition, it provides the user with the possibility of performing statistical tests such as the Kolmogorov-Smirnov normality test, F test and χ^2 test of variance, Student's *t*-test, non-parametric Wilcoxon test, and statistical parameter calculations. The NH SEDIMENT AND STATISTIC automatically calculates and provides the main results for each of the methods, allowing the user to draw their own conclusions. This proposed computational tool supports hydrosedimentological studies, and is reliable and easy to use, contributing to the reduction of sediment-related problems in the areas of hydraulic engineering, geology, and soil and water conservation. Furthermore, this tool may be used in transdisciplinary scientific areas for complete planning and management of water resources.

Keywords: sedimentology; sediment-transport; statistic; software.

RESUMO

Este artigo apresenta uma nova ferramenta computacional chamada *NH SEDIMENT AND STATISTIC*, que realiza cálculos hidrossedimentológicos e estatísticos usando o Visual Basic. Essa ferramenta computacional foi desenvolvida para estudos relacionados a cálculos de transporte de sedimentos em rios. A ferramenta inclui métodos hidrossedimentológicos para calcular cargas de suspensão, cargas de leito e descarga total de sólidos. Além disso, fornece ao usuário a possibilidade de realizar testes estatísticos, como o teste de normalidade Kolmogorov-Smirnov, teste F e teste de variância do χ^2, teste T de *Student*, teste não paramétrico de Wilcoxon e cálculos estatísticos de parâmetros. O NH SEDIMENT AND STATISTIC calcula e fornece automaticamente os principais resultados para cada um dos métodos, permitindo que o usuário tire suas próprias conclusões. Essa ferramenta computacional proposta suporta estudos hidrossedimentológicos e é confiável e fácil de usar, contribuindo para a redução de problemas relacionados a sedimentos nas áreas de engenharia hidráulica, geologia, conservação de solo e água. Além disso, essa ferramenta pode ser usada em áreas científicas transdisciplinares para um planejamento e gerenciamento completos dos recursos hídricos.

Palavras-chave: sedimentologia; transporte de sedimentos; estatística; *software*.

INTRODUCTION

There has been a growing demand for knowledge on processes related to sediment dynamics in water resources in recent decades due to their significance to many issues, such as siltation and transport of sediment-bound pollutants (OEURNG; SAUVAGE; SÁNCHEZ-PÉREZ, 2010; SUN *et al*., 2016). Therefore, sediment dynamics have been studied and the possible interactions of these particles in the environment are current topics in different scientific areas, such as hydraulic engineering, geology, soil and water conservation, and water resources planning.

The study of hydrosedimentological processes involves the determination of suspended load (Qss), bed load (Qsa), and total solid discharge (Qst), however it is difficult to obtain due to the numerous variables involved. According to Vercruysse, Grabowski and Rickson (2017), despite decades of research, the factors and process interactions underlying sediment transport in rivers have not yet been fully captured and understood.

Sedimentometry involves measuring water discharge, suspended and bed material, water temperature, energy line slope, among others (GRAY; LANDERS, 2014). Suspended sediment concentration is a fundamental parameter in determining deposition rates and sediment flow, and estimating them accurately is essential for understanding their behavior in the water column and solid discharge prediction (GARTNER, 2004; XAVIER *et al*., 2014). For this reason, several approaches and methods have been developed for sediment discharge

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(ALONSO; NEIBLING; FOSTER, 1981; STEVENS; YANG, 1989; SCAPIN; PAIVA; BELING, 2007; GRAY; SIMÕES, 2008; VERCRUYSSE; GRABOWSKI; RICKSON, 2017). Nagy, Watanabe and Hirano (2002), for example, used artificial neural networks (ANN) to estimate the solid discharge in rivers. However, the most traditional indirect measurement is made by collecting samples, either in suspension or bed material, determining the watercourse characteristics and particle size analysis of the sediment, enabling the calculation of Q_{SA} and Q_{ST} using different methods and formulas (ALONSO; NEIBLING; FOSTER, 1981; GRAY; SIMÕES, 2008; SANTOS *et al.*, 2012).

Methods for Q_{ST} calculation, such as the Colby's method (COLBY, 1957) and others, require abacus analysis, which make the calculation subjective, varying according to personal interpretation. Computational tools in these situations are essential, as they assist hydrosedimentological calculations, reducing systemic errors from these interpretations. WinTSR (ROSA; BELING, 2002), Colby_W (CARVALHO, 2008), and SEDIM 2.0 (CAMPEÃO; HORA, 2019) are examples of software that help achieve solid discharge. However, they have limitations such as the fact that they are incompatible in some recent systems, need data that is not required for some methods, and require unitary calculations which are time-consuming in situations where there are many sections. Therefore, there is a lack of adequate and easy-to-use tools for studying sediment transport-related processes.

Moreover, sediment monitoring is crucial for understanding hydrosedimentological processes, requiring the amount of data that necessarily needs statistical calculations and using a computer as a work tool. Thus, due to the few options of free and open access statistical software such as R (THE R FOUNDATION, 2019), we developed an easy-to-use publicly available computational tool that integrates statistical and hydrosedimentological calculations. It is worth mentioning that R is a software that requires minimal knowledge of the R language, as well as downloading packages to perform statistical tests.

In this paper, the aim was to introduce a Visual Basic for Applications (VBA) computational tool called NH SEDIMENT AND STATISTIC, which provides a free, easy-to-use, and efficient solution for hydrosedimentological and statistical calculations. It provides the possibility to calculate suspended loads, bed loads, and total loads and performs important statistical tests, such as the Kolmogorov-Smirnov normality test, Fisher-Snedecor, and Student's *t* parametric tests, Wilcoxon non-parametric test, and statistical parameter calculations. The tool also enables agility in the calculations, as it has distinct modules that allow the user, who has little statistical domain, to apply their results obtained in the hydrosedimentological module directly in the statistical module without needing to purchase or acquire other software.

OVERVIEW OF THE NH SEDIMENT AND STATISTIC

General considerations

NH SEDIMENT AND STATISTIC (NHSS) is a computational tool developed for engineers and professionals involved in projects related to sediment transport in water resources, which allows the user to perform hydrosedimentological and statistical calculations (Figure 1). The computer routine has been written in Visual Basic for Applications. We opted for this kind of language for its richness and flexibility in functionality, and especially as it is easy to access, user-friendly and has an intuitive user interface, including an interactive component with databases.

The interface of the computational tool was divided into two different modules: hydrosedimentological and statistical. This makes the application objective and organized with smaller program coding and better understanding, which favors script changes and saves computational memory on calculations.

The hydrosedimentological module was developed for calculating suspended loads (Qss), bed loads (Qsa), and total solid discharge (Qst) required for various sedimentological studies. The implementation of these methods is related to time optimization since the tool allows Qss, Qsa, and Qst calculations of multiple sections in one step, while in other software, obtaining these parameters is unitary from section to section. Moreover, unlike hydrosedimentology software, the computational tool developed is a multidisciplinary software that also performs statistical calculations.

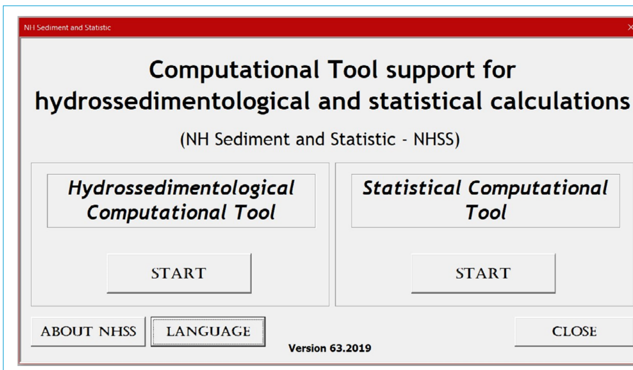
The statistical module is recommended for applications of the Kolmogorov-Smirnov's test for normality, variance test, mean test, nonparametric median test, and calculation of statistical parameters. It is possible to use the statistical module in other types of data such as hydrological, rainfall, fluviometric, and even information from other areas that require statistical analysis, confirming the multidisciplinarity of the tool.

The user license is free, and the script, manuals, and guides are available on the website for this paper acknowledging the implementation of other methods as needed and changes to the existing ones. The use of the computational tool NHSS does not require prior knowledge of computational language and allows the user to work with statistical tests and methods of hydrosedimentological calculations, which is unique in this case.

Hydrosedimentological module of NHSS

The hydrosedimentological module of the NHSS computational tool allows the user to choose the appropriate solid discharge calculation method according to the data they have and their objectives. The calculation of suspended solid discharge is based on the method presented by National Water Agency (ANA, 2012). Having data of water discharge ($m^3.s^{-1}$) and suspended solids concentration ($mg.L^{-1}$ or ppm), Qss is calculated through Equation 1 which synthesizes the conservation of sediment mass up to a certain moment.

$$Qss = 0.00864 \times Q \times SSC \quad (1)$$



Source: elaborated by the authors.

Figure 1 – Main screen of NH SEDIMENT AND STATISTIC (NHSS).

Where:
Qss = suspended load or suspended solid discharge [$t.day^{-1}$];
Q = water discharge [$m^3.s^{-1}$];
SSC = suspended solid concentration [$mg.L^{-1}$].

Regarding the bed load, the codification of the Meyer-Peter and Muller (1948), which considers the solid load in permanent contact with the riverbed, was based on Equations 2 to 5.

$$\gamma.\frac{Q_s}{Q}\left(\frac{K_s}{K_r}\right)^{3/2}.p.S = 0.047.\gamma'_s.D_m + 0.25.\left(\frac{\gamma}{g}\right)^{1/3}.q_{sa}^{2/3} \quad (2)$$

$$K_s = \frac{1}{n_s} \quad (3)$$

$$K_r = \frac{26}{(D_{90})^{1/6}} \quad (4)$$

$$\gamma'_S = \gamma_S - 1 \quad (5)$$

Where:
γ = Specific weight of water [$t.m^{-3}$];
Qs = part of water discharge influencing the bed river [$m^3.s^{-1}$];
Q = total water discharge [$m^3.s^{-1}$];
Ks = Strickler's roughness coefficient;
n_s = Manning's roughness coefficient;
Kr = particle roughness coefficient;
D_{90} = diameter of the particle in which 90% of a sample's mass is smaller [m];
p = mean depth [m];
S = energy line [$m.m^{-1}$];
γ'_s = specific weight of submerged sediment [$t.m^{-3}$];
γ_s = specific weight of sediment [$t.m^{-3}$];
D_m = mean diameter of particles [m];
g = gravitational acceleration [$m.s^{-2}$];
q_{sa} = bed load per unit width [$t.s^{-1}m^{-1}$].

Due to the amount of data required, some of which were difficult to obtain, we prioritized facilitating the estimation of the Qsa. Then, we implemented an area for calculation of the mean particle diameter (Equation 6) in this bed load module. In addition, we allowed the user to choose the form of calculation: with known or unknown energy gradient (S), where in this second option, S is calculated by the Manning formula (Equation 7).

$$D_m = \sum D_{si} i_f \quad (6)$$

Where:
D_m = mean diameter of particles;
D_{si} = geometric mean diameter between two diameters of a particle size range;
i_f = particle size fraction between the two diameters, usually presented in %.

$$S = \left(\frac{Q \cdot n_s}{A \cdot R^{2/3}}\right)^2 \quad (7)$$

Where:
S = energy line [$m.m^{-1}$];
Q = water discharge [$m^3.s^{-1}$];
A = section area [m^2];
R = hydraulic radius [m];
n_s = Manning's roughness coefficient.

The NHSS computational tool also allows the calculation of total solid discharge by the simplified Colby (1957) method (Equation 8).

$$Qst = Qsm + Qnm \quad (8)$$

Where:
Qst = total solid discharge or total load [$t.day^{-1}$];
Qsm = measured solid discharge [$t.day^{-1}$];
Qnm = unmeasured Solid Discharge [$t.day^{-1}$].

The measured solid discharge (Qsm) can be obtained by calculating the suspended solid discharge (Equation 1) while the unmeasured solid discharge (Qnm), which represents an integration of bed load with the unmeasured solid discharge, is estimated with the aid of an abacus (Supplementary Figures S1 and S2 - http://abes-dn.org.br/wp-content/uploads/2021/04/SupplementaryFIle_atualizado.pdf) from velocity ($m.s^{-1}$), mean depth (m), concentration ($mg.L^{-1}$), and section width (m) data (Equation 9).

$$Q_{nm} = q'_{nm} \cdot k \cdot L \quad (9)$$

Where:
q'_{nm} = unmeasured solid discharge per meter of width [$t.day^{-1}.m^{-1}$];
L = width of sampled section [m];
k = correction factor [adimensional].

Representative equations for Abacus 1 to 3 were obtained using Engauge Digitizer software, developed by Mitchell (2019), which recovers chart data points automatically, so as to obtain equations that could be encoded in VBA language (Equations 10 to 12). This tool is used in various areas of knowledge, such as mathematics and chemistry (BEN-TAL; SHAMAILOV; PATON, 2014; OCAYA, 2014; DOUZIECH *et al.*, 2018).

$$\log q'_{nm} = 3.340 \cdot \log V + 1.617 \quad (10)$$

$$\log Cr = A \cdot \log V + B, \quad (11)$$

$$\log k = 0.4819 \cdot \log Re + 0.0739, \quad (12)$$

Where:
Cr = Relative suspended sediment concentration [$mg.L^{-1}$];
A and B = linear and angular coefficients that vary as a function of depth (Supplementary Table S1);
Re = availability ratio;
k = correction factor.

Statistical module of NHSS

The user has an option to perform the Kolmogorov-Smirnov test for normality, test of variances (χ^2 test or F-test), means tests (one-sample, independent samples with equal or different variances, or paired Student's *t*-test), and Wilcoxon non-parametric test for median. VBA has ready algorithms for calculations involving the means and variance tests that can be accessed directly in the programming code. However, the Kolmogorov-Smirnov and Wilcoxon tests do not have reliable equations available in the VBA. Then, the respective equations and approximations used in the normality test are in agreement with Lilliefors (1967), Stephens (1974), and Dallal and Wilkinson (1986). For the Wilcoxon test, we used equations presented by Wilcoxon (1945), Mann and Whitney (1947) and Conover (1999). We emphasize that the respective main equations and approximations for these tests implemented at NHSS can be checked in Supplementary Tables S2 and S3 (http://abes-dn.org.br/wp-content/uploads/2021/04/SupplementaryFIle_atualizado.pdf).

In this module, statistical parameters were also implemented for model efficiency evaluation and data comparison. We chose to enter NHSS equations for calculations of Adjustment coefficient (AC) (Equation 13), Efficiency (EF) (Equation 14), Coefficient of Residual Mass (CRM) (Equation 15), Root Mean Square Error (RMSE) (Equation 16), Maximum Error (ME) (Equation 17), and Mean Difference (MD) (Equation 18), which can be used in various studies as validations of models of soil nutrient dynamics, comparative analysis of different methods of obtaining variables, comparison of different models of estimation of infiltration rates or methods of solid sediment discharge, among others (LENGNICK; FOX, 1994; SENTELHAS *et al.*, 1997; ALVES SOBRINHO *et al.*, 2003; BRITO *et al.*, 2009; SANTOS *et al.*, 2012; BIELENKI JUNIOR *et al.*, 2018; MARQUES *et al.*, 2019).

$$AC=\frac{\sum_{i=1}^{n}(O_i-\bar{O})^2}{\sum_{i=1}^{n}(P_i-\bar{O})^2} \quad (13)$$

$$EF=\frac{\sum_{i=1}^{n}(O_i-\bar{O})^2-\sum_{i=1}^{n}(O_i-P_i)^2}{\sum_{i=1}^{n}(O_i-\bar{O})^2} \quad (14)$$

$$CRM=\frac{[\sum_{i=1}^{n}(O_i)-\sum_{i=1}^{n}(P_i)]}{\sum_{i=1}^{n}(O_i)} \quad (15)$$

$$RMSE=\sqrt{\frac{\sum(O_i-P_i)^2}{n}} \quad (16)$$

$$ME=\max|O_i-P_i| \quad (17)$$

$$MD=\frac{\sum_{i=1}^{n}(O_i-P_i)}{n} \quad (18)$$

Where:
i = index of O;
Oi = observed value;
Pi = estimated value;
Ō = mean of the observed values;
n = sample size.

CASE STUDY AND NHSS COMPUTATIONAL TOOL VERIFICATION

The computational tool NHSS was tested on the reservoir of the Mogi-Guaçu Small Hydroelectric Power Plant (SHP) (22°22'45.6" S; 46°53'59.1" W) and Guariroba basin, located between the parallels 20°28' and 20°43' S, and the meridians 54°11' and 54°11' W.

Mogi-Guaçu SHP is a 7.2 MW installed potency and 5.73 km^2 reservoir located between the municipalities of Mogi-Guaçu and Mogi-Mirim (São Paulo, Brazil). Originally designed for flood control and hydropower generation purposes, the reservoir also serves as the main water supply for two nearby cities (ESTIGONI; MIRANDA; MAUAD, 2017). Soils are mainly Latosols and major land uses are agriculture, forest, pasture, and silviculture (62.8, 15.3, 10.9, and 5.4%, respectively). The climate is Cwa according to Köppen, humid, warm in the summer and temperate in the winter, with an average annual rainfall of approximately 1,300 mm year^{-1} (Environmental Company of the State of São Paulo — CETESB, 2017). Further information about Mogi-Guaçu SHP and Mogi-Guaçu basin can be found in Estigoni, Miranda and Mauad (2017), Foundation for Research Increase and Industrial Improvement (FIPAI, 2015), Mogi Guaçu River Basin Committee (CBH MOGI, 2018) and Santos *et al.* (2019).

We measured hydraulic characteristics, suspended concentration of sediments, turbidity and temperature in two campaigns in 2014 along the reservoir. The hydraulic characteristics obtained through Acoustic Doppler Current Profiler (ADCP) (Model M9, Sontek) provide the hydraulic data of width, depth, total section area, velocity, water discharge, among other information. Moreover, the LISST-100X (Sequoia Scientific, Inc.) and multiparameter YSI 6,600 probe (YSI Inc.) mounted in a protective cage was lowered through a water column measuring volumetric suspended concentration of sediments (μL.L^{-1}), turbidity (NTU), and water temperature (°C). Simultaneously, water-sediment samples were collected at the surface approximately 1 m deep and close to the bottom using a Van Dorn bottle to compare with those obtained with the other equipment. These samples were then sent to the laboratory where the gravimetric concentration of suspended sediments was determined by the gravimetric method following the procedures proposed by the Standard methods for examination of water and wastewater of the American Public Health Association (APHA, 1995). All data measured and used in this paper are available in Supplementary Tables S4 to S10 (http://abes-dn.org.br/wp-content/uploads/2021/04/SupplementaryFIle_atualizado.pdf).

The other case study area was the Guariroba River Basin, which has 36,200 ha and is located in the rural side of Campo Grande, Mato Grosso do Sul State, Brazil. This watershed is the main water supply, as it provides about 50% of the total water consumed by the urban area of Campo Grande, Mato Grosso do Sul, Midwestern Brazil (SONE *et al.*, 2019). According to Köppen, the climate is Aw, described as Brazilian Cerrado and characterized by a low temperature of 18°C. The wet season starts in October and ends in May while the dry season runs from June to September. Further information about the Guariroba river basin can be found in Colman *et al.* (2018), Almagro *et al.* (2019), Sone *et al.* (2019). In this case, we measured hydraulic data and the bed sediment particle size between 2017 and 2019 of three sections of the Guariroba river with distinct characteristics using ADCP (Riversurveyor Model M9, Sontek) and BLM-84 sampler for bed loads, among others (Supplementary Table S11 - http://abes-dn.org.br/wp-content/uploads/2021/04/SupplementaryFIle_atualizado.pdf).

All data obtained were applied in the NHSS and we compared the results obtained in the hydrosedimentological module from the proposed tool with WinTSR software (ROSA; BELING, 2002) and SEDIM 2.0 (CAMPEÃO; HORA, 2019). Furthermore, the results obtained from the statistical module of the computational tool were compared with the results provided by the R environment.

Simulations in the computational tool: Hydrosedimentological Module

The calculation of suspended load (Qss) and total load by the simplified Colby's method using the computational tool developed was done for some sections of the Mogi-Guaçu reservoir. This is illustrated, respectively, in Figures 2 and 3. However, the bed load calculation using the Meyer-Peter and Muller method was performed with observed data from the Guariroba basin where the bed sediment transport is more significant than a reservoir (Figure 4). In all cases, the solid discharge calculations provided by the NHSS computational tool were consistent.

The NHSS was used in the evaluation because it allows the calculations of statistical parameters used in the most method comparisons. For the bed load (Figure 5A) and total solid discharge (Figure 5B), the values of the statistical parameters were satisfactory, mainly efficiency (EF close to 1) and coefficient of residual mass (CRM close to 0). We emphasize that the solid discharge results obtained with the pieces of software, WinTSR and SEDIM 2.0, can be found in Supplementary Table S12 and S13 (http://abes-dn.org.br/wp-content/uploads/2021/04/SupplementaryFIle_atualizado.pdf).

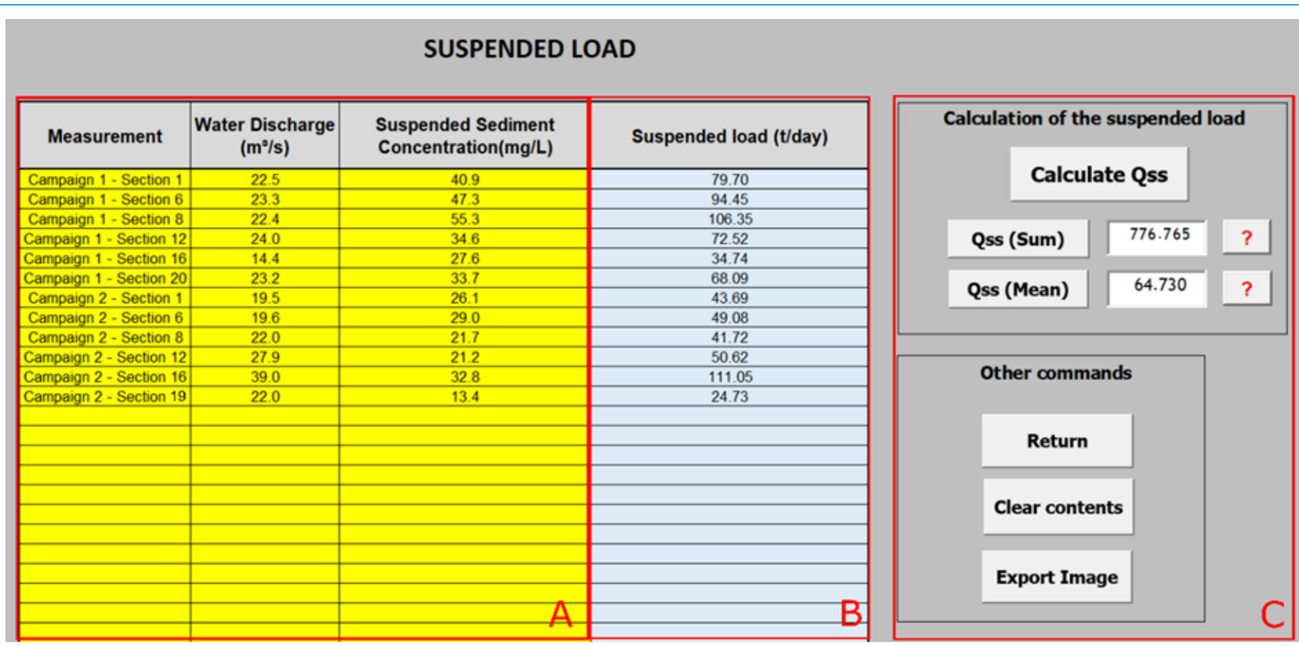
Our results indicate that the NHSS tool presents total and bed load values similar to the results computed by using WinTSR and SEDIM. Although the main equations involving sediment transport calculation methods are the same, there are slight variations between the pieces of software. Some factors can be listed, such as: different approximations for the equations obtained in the total load calculation abacus, and even different approximations for calculating variables, such as the energy line or Manning's coefficient for calculating the bed load. However, we strive for the developed computational tool better approximations in all cases, which do not affect the interpretation of the results. We also remember that the NHSS optimizes time by calculating such parameters for multiple sections with a single command, while WinTSR and SEDIM require data entry to calculate solid discharge in one section at a time.

Simulations in the computational tool: statistical module

All simulations involving the NHSS statistical module were performed based on measured suspended sediment concentration data (SSC), estimated concentration of turbidity data (SSC C1), estimated concentration of volumetric data provided by LISST-100X (SSC C2), and water temperature in the Mogi-Guaçu reservoir. Then, it was possible to perform several normality tests (Figure 6), variance tests (Figure 7), the mean comparison test (Figure 8), and the non-parametric median comparison test (Figure 9), emphasizing that the data were previously organized and adjusted to apply the statistical tests correctly.

The accuracy of the statistical results and p-values of the tests was performed by comparing it with the results provided by the R environment using statistical parameters. All results obtained by both programs can be viewed in Supplementary Tables S14 to S17(http://abes-dn.org.br/wp-content/uploads/2021/04/SupplementaryFIle_atualizado.pdf). We found that, in general, the statistical tests of the developed computational tool presented adequate and similar results to those presented by the software R (Table 1), mainly because they presented low CRM and RMSE, and AC and EF close to 1.

Although the statistical tests are the same between the R and NHSS computational tools and, in theory, have the same equations, the algorithms are different. This small variation was expected mainly for the calculation of p-value in the Kolmogorov-Smirnov test and in the Wilcoxon statistics calculation where we worked with analytical methods of approximation. In relation to the F-Fisher and the T-Student tests, despite the minimal difference, the ME between the p-values obtained was not greater than 0.0038 for the F test and 0.007 for the *t*-test. Therefore, even for a statistical study adopting the significance level of 0.01, there would be no problems with false conclusions in the tests.



Qss: suspended load.
Source: elaborated by the authors.

Figure 2 – Suspended load calculation screen on NH SEDIMENT AND STATISTIC: (A) input data area for suspended load calculation; (B) output data area of suspended load; (C) panel control area.

Total Solid Discharge

Colby's Simplified Method - Colby (1957)

n	Measurement	Water Discharge (m^3/s)	Mean Velocity (m/s)	Width (m)	Depth (m)	Suspended Sediment Concentration (mg/L)	Measured Solid Discharge - Qss (t/day)	Unmeasured Solid Discharge - Qnm (t/day)	Total Solid Discharge - Qst (t/day)
1	C1-S1-1	24.22	0.064	61.29	6.450	40.855	85.493	3.012	88.504
2	C1-S1-2	21.83	0.060	58.57	6.339	40.855	77.056	2.506	79.563
3	C1-S1-3	21.65	0.058	60.10	6.316	40.855	76.421	2.391	78.812
4	C1-S1-4	22.31	0.064	57.74	6.198	40.855	78.751	2.837	81.588
5	C1-S6-1	22.64	0.086	48.02	5.907	47.324	92.570	4.772	97.342
6	C1-S6-2	22.95	0.081	49.40	6.210	47.324	93.837	4.318	98.155
7	C1-S6-3	24.93	0.086	50.41	6.102	47.324	101.933	5.010	106.943
8	C1-S6-4	22.50	0.076	51.27	6.247	47.324	91.997	3.909	95.906
9	C1-S8-1	21.77	0.066	58.53	6.725	55.269	103.957	3.888	107.846
10	C1-S8-2	22.03	0.057	57.04	6.686	55.269	105.199	2.774	107.972
11	C1-S8-3	22.89	0.062	56.81	6.711	55.269	109.305	3.304	112.609
12	C1-S8-4	22.83	0.059	58.91	6.666	55.269	109.019	3.083	112.102
13	C1-S12-1	27.61	0.045	117.56	6.223	34.622	82.590	2.506	85.096
14	C1-S12-2	22.76	0.040	120.81	6.132	34.622	68.082	2.001	70.083
15	C1-S12-3	24.80	0.042	118.59	6.178	34.622	74.184	2.181	76.365
16	C1-S12-4	20.76	0.038	128.80	5.926	34.622	62.100	1.911	64.010
17	C1-S16-4	21.77	0.013	667.56	4.402	27.557	51.833	0.544	52.377
18	C1-S20-1	27.39	0.033	160.11	5.356	33.714	79.785	1.364	81.149
19	C1-S20-2	24.87	0.038	158.68	5.395	33.714	72.444	1.843	74.288
20	C1-S20-3	22.06	0.026	152.33	5.594	33.714	64.259	0.989	65.248
21	C1-S20-4	22.62	0.037	154.81	5.685	33.714	65.890	2.142	68.032
22	C2-S1-1	21.090	0.051	51.310	7.544	26.064	47.4927	1.505	48.998
23	C2-S1-2	16.800	0.050	54.800	7.463	26.064	37.8320	1.403	39.236
24	C2-S1-3	20.450	0.051	56.830	7.363	26.064	46.0515	1.518	47.570
25	C2-S6-1	20.010	0.051	52.130	6.688	28.984	50.1092	1.466	51.575
26	C2-S6-2	19.380	0.056	55.440	6.454	28.984	48.5316	1.734	50.266
27	C2-S6-3	19.370	0.054	54.360	6.625	28.984	48.5065	1.726	50.233
28	C2-S8-1	20.780	0.053	58.540	6.884	21.698	38.9568	1.554	40.511
29	C2-S8-2	20.720	0.053	56.930	7.230	21.698	38.8444	1.511	40.355
30	C2-S8-3	24.360	0.060	57.770	7.107	21.698	45.6684	1.997	47.665
31	C2-S12-1	28.530	0.042	113.270	6.792	21.159	52.1574	1.810	53.968
32	C2-S12-2	26.500	0.038	118.210	6.500	21.159	48.4462	1.383	49.830
33	C2-S12-3	28.670	0.040	112.930	6.745	21.159	52.4133	1.627	54.040
34	C2-S16-1	40.380	0.022	616.410	3.151	32.788	114.3922	1.004	115.396
35	C2-S16-2	35.210	0.024	625.810	2.993	32.788	99.7462	1.249	100.995
36	C2-S16-3	41.260	0.021	622.870	3.272	32.788	116.8852	0.911	117.796
37	C2-S19-1	24.510	0.025	258.300	6.135	13.359	28.2895	0.987	29.276
38	C2-S19-2	23.470	0.015	264.950	5.932	13.359	27.0892	0.339	27.428
39	C2-S19-3	18.080	0.018	264.920	5.955	13.359 A	20.8680	0.500	21.368 B

Commands

Calculate (Qst)

Export Image

Return

C

Qst: Total load; C1: Campaign 1; C2: Campaign 2; SX-Y: Section X-Y, where X is the sampled section number and Y is the sampled repeat number.
Source: elaborated by the authors.

Figure 3 – Total load calculation screen on NH SEDIMENT AND STATISTIC: (A) input data area for total solid discharge calculation; (B) output data area of measured and unmeasured solid discharge, and total solid discharge; (C) panel control area.

BED LOAD

Meyer-Muller and Peter (1948)

Measurement	Velocity (m/s)	Width (m)	Depth(m)	Manning's coefficient	Mean diameter of the bed material composition - Dm (m)	Particle characteristic diameter - D90 (m)	Energy Line (m/m)	Bed load - Qsa (t/day)
Section 1 - 27/04/2017	0.66	5.00	0.68	0.024	0.000181	0.000460	0.00042	10.770
Section 1 - 27/10/2017	0.56	4.80	0.47	0.024	0.000181	0.000460	0.00049	7.069
Section 1 - 29/08/2017	0.52	4.80	0.41	0.024	0.000168	0.000450	0.00051	5.928
Section 1 - 23/01/2018	0.62	5.80	1.01	0.024	0.000177	0.000470	0.00022	7.906
Section 1 - 31/01/2019	0.55	4.00	1.54	0.024	0.000172	0.000450	0.00010	2.528
Section 2 - 27/04/2017	0.52	8.40	0.76	0.024	0.000092	0.000280	0.00022	7.022
Section 2 - 27/10/2017	0.37	8.50	0.69	0.024	0.000173	0.000450	0.00013	1.428
Section 2 - 29/08/2017	0.45	8.50	0.67	0.024	0.000169	0.000430	0.00020	4.030
Section 2 - 23/01/2018	0.66	10.30	0.73	0.024	0.000134	0.000410	0.00038	21.826
Section 2 - 31/01/2019	0.41	9.30	0.65	0.024	0.000098	0.000310	0.00017	3.590
Section 3 - 27/04/2017	0.57	8.00	1.16	0.024	0.000169	0.000430	0.00015	7.010
Section 3 - 27/10/2017	0.41	12.00	0.80	0.024	0.000169	0.000450	0.00013	3.240
Section 3 - 29/08/2017	0.60	8.00	0.83	0.024	0.000166	0.000460	0.00027	11.057
Section 3 - 23/01/2018	0.61	12.90	0.92	0.024	0.000153	0.000410	0.00024	17.353
Section 3 - 31/01/2019	0.63	7.80	1.01	0.024	0.000173	0.000430	0.00023	10.914
							A	B

Main Commands

Known energy line

Unknown energy line

Calculate Bed Load - Qsa

Other Commands

Clear Contents

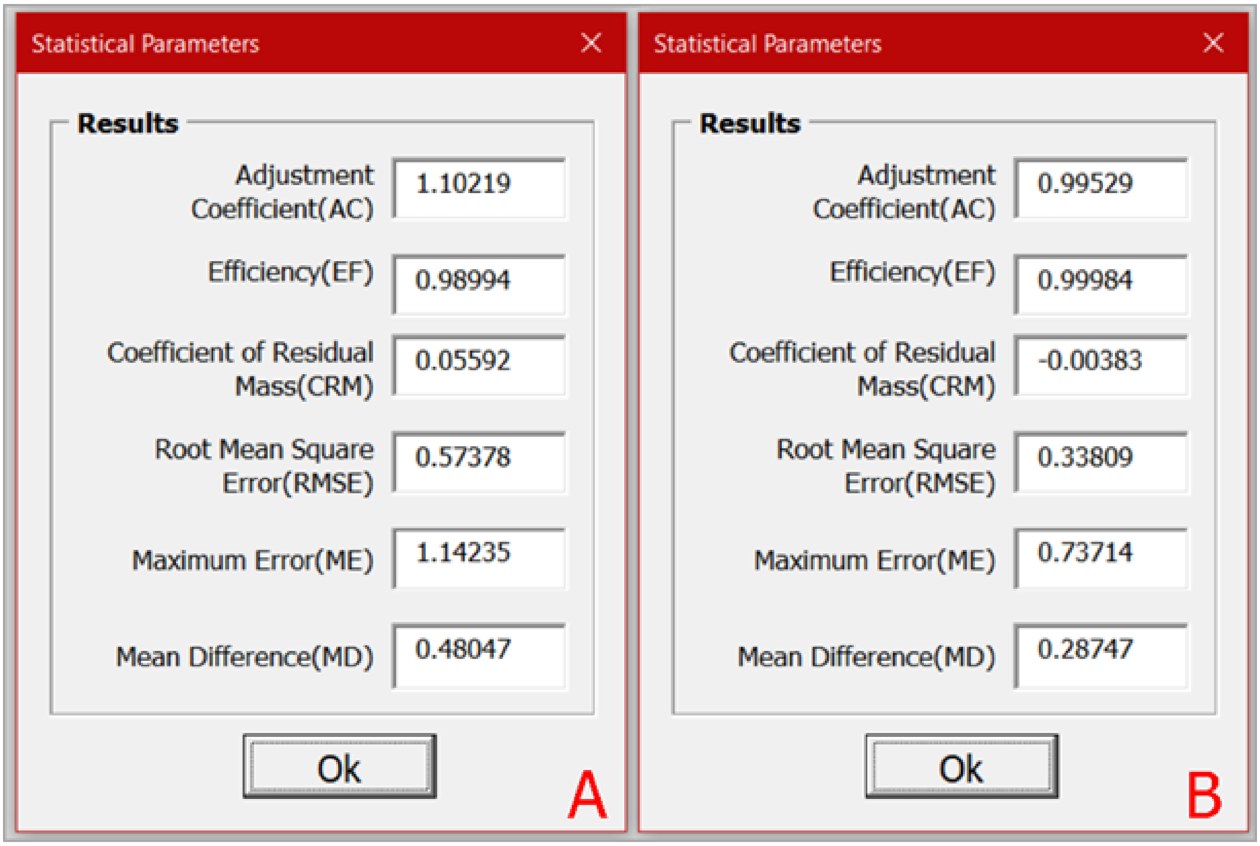
Export Image

Return

C

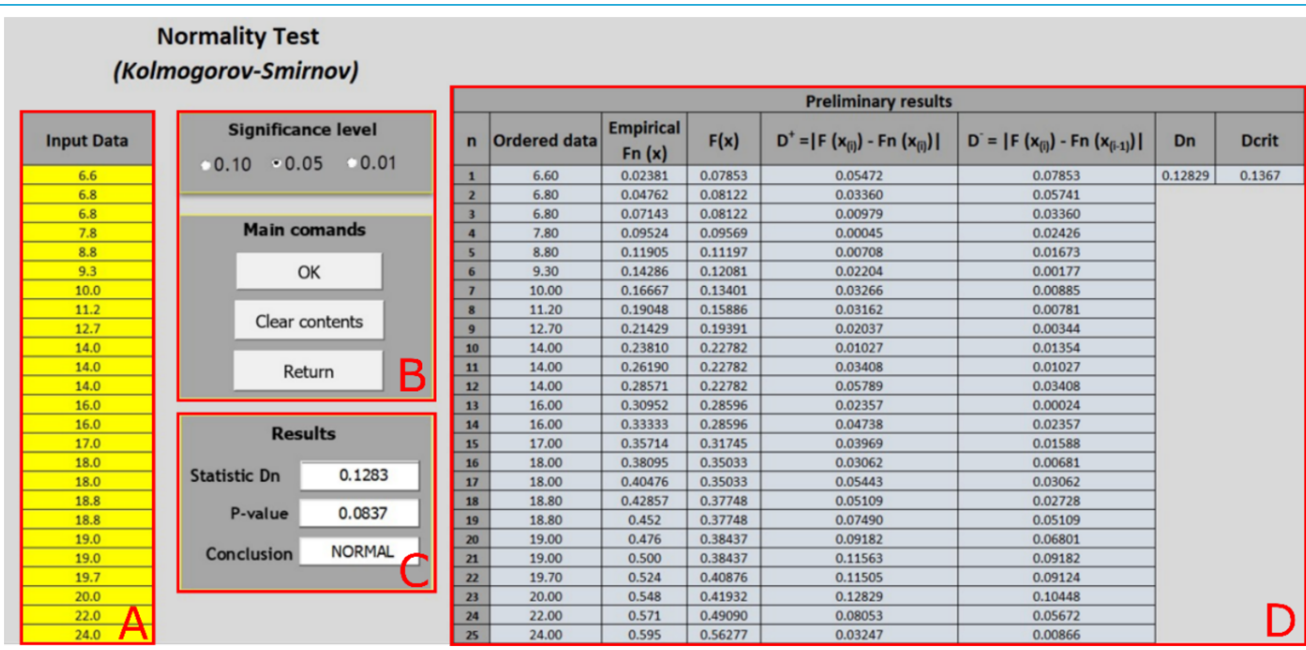
Source: elaborated by the authors.

Figure 4 – Bed load calculation screen on NH SEDIMENT AND STATISTIC: (A) input data area for bed load calculation; (B) output data area; (C) panel control area.



Source: elaborated by the authors.

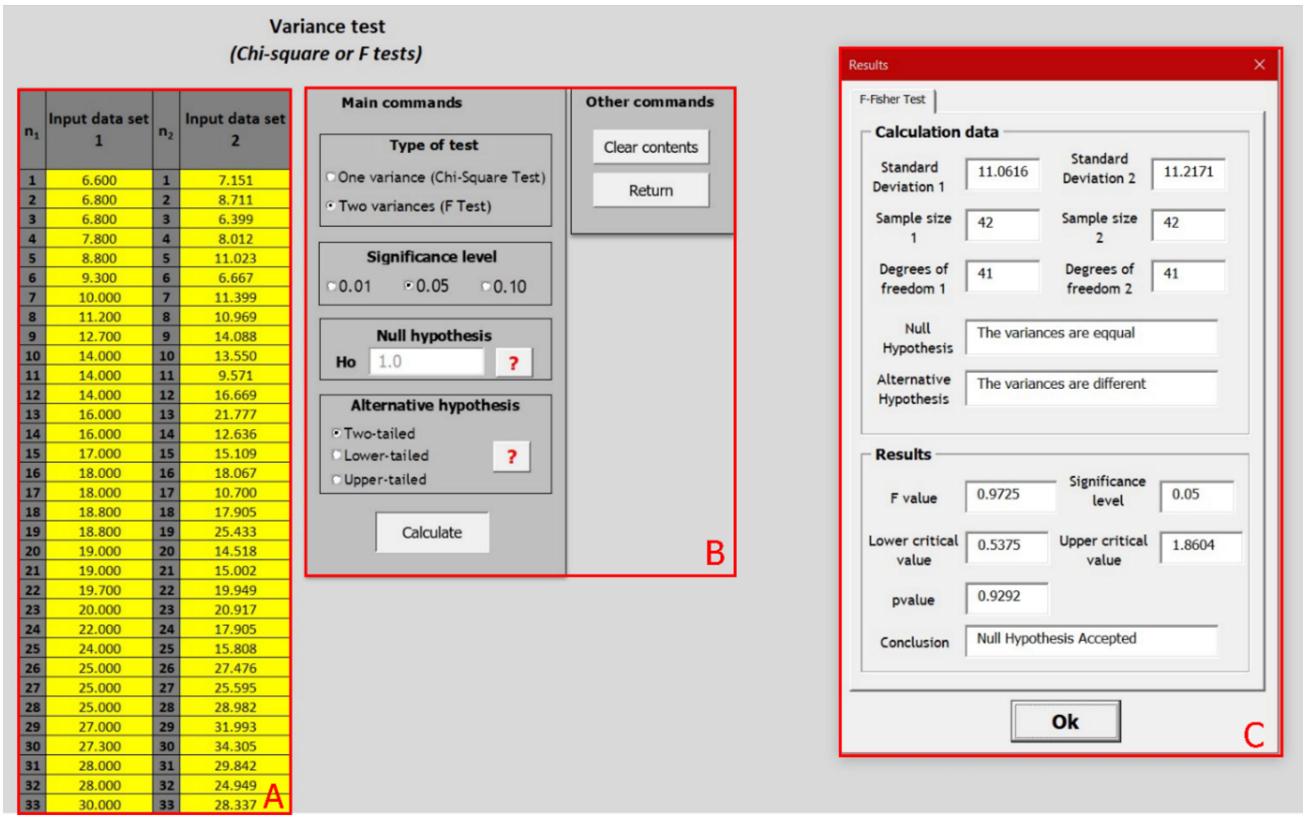
Figure 5 – Statistical parameters: (A) bed load comparison results; (B) total load comparison results.



n	Ordered data	Empirical Fn (x)	F(x)	$D^+ = \lvert F(x_{(i)}) - Fn(x_{(i)}) \rvert$	$D^- = \lvert F(x_{(i)}) - Fn(x_{(i-1)}) \rvert$	Dn	Dcrit
1	6.60	0.02381	0.07853	0.05472	0.07853	0.12829	0.1367
2	6.80	0.04762	0.08122	0.03360	0.05741		
3	6.80	0.07143	0.08122	0.00979	0.03360		
4	7.80	0.09524	0.09569	0.00045	0.02426		
5	8.80	0.11905	0.11197	0.00708	0.01673		
6	9.30	0.14286	0.12081	0.02204	0.00177		
7	10.00	0.16667	0.13401	0.03266	0.00885		
8	11.20	0.19048	0.15886	0.03162	0.00781		
9	12.70	0.21429	0.19391	0.02037	0.00344		
10	14.00	0.23810	0.22782	0.01027	0.01354		
11	14.00	0.26190	0.22782	0.03408	0.01027		
12	14.00	0.28571	0.22782	0.05789	0.03408		
13	16.00	0.30952	0.28596	0.02357	0.00024		
14	16.00	0.33333	0.28596	0.04738	0.02357		
15	17.00	0.35714	0.31745	0.03969	0.01588		
16	18.00	0.38095	0.35033	0.03062	0.00681		
17	18.00	0.40476	0.35033	0.05443	0.03062		
18	18.80	0.42857	0.37748	0.05109	0.02728		
19	18.80	0.452	0.37748	0.07490	0.05109		
20	19.00	0.476	0.38437	0.09182	0.06801		
21	19.00	0.500	0.38437	0.11563	0.09182		
22	19.70	0.524	0.40876	0.11505	0.09124		
23	20.00	0.548	0.41932	0.12829	0.10448		
24	22.00	0.571	0.49090	0.08053	0.05672		
25	24.00	0.595	0.56277	0.03247	0.00866		

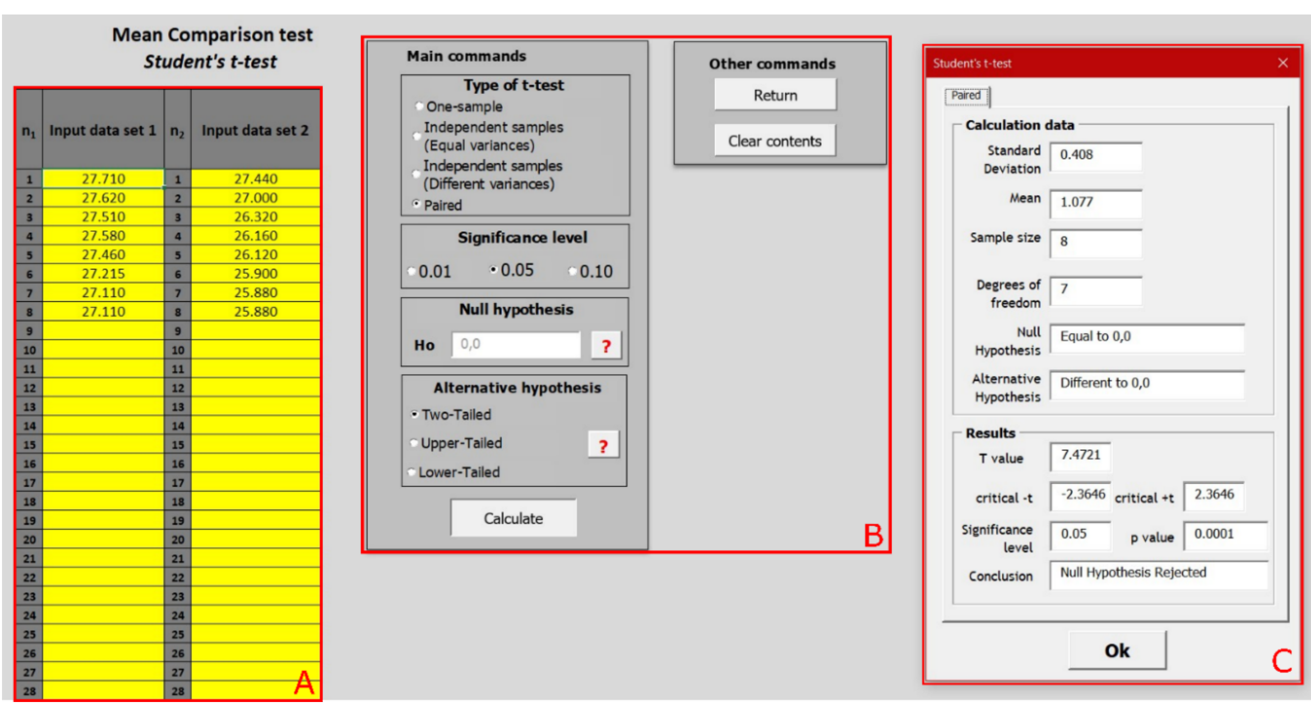
Dn: value of the Kolmogorov-Smirnov statistic; Dcrit: critical value for the Kolmogorov-Smirnov normality test; Fn(x): empirical cumulative data distribution function; F(x): assumed cumulative data distribution function; *edited screen to highlight results only.
Source: elaborated by the authors.

Figure 6 – Normality test applied to the SSC data showing the main results provided by the NHSS: (A) input data area; (B) panel control area; (C) output data area; (D) preliminary results area*.



Ho: null hypothesis; *edited screen to highlight results only.
Source: elaborated by the authors.

Figure 7 – F-Fisher test applied to compare measured and estimated suspended sediment concentration data showing the main results provided by the NHSS: (A) input data area; (B) panel control area; (C) output data window*.



Ho: null hypothesis.
Source: elaborated by the authors.

Figure 8 – Paired Student's t-test applied to compare the means of temperatures from profiles of the Mogi-Guaçu reservoir: (A) input data area; (B) panel control area; (C) output data window.

While R is primarily a statistical tool, the NHSS allows the user to work with statistical tests and hydrosedimentological calculation methods, which is unique in this case. Finally, the developed computational tool is an open and free-to-use source and allows the user to modify the equations and enter any other statistical tests they may need.

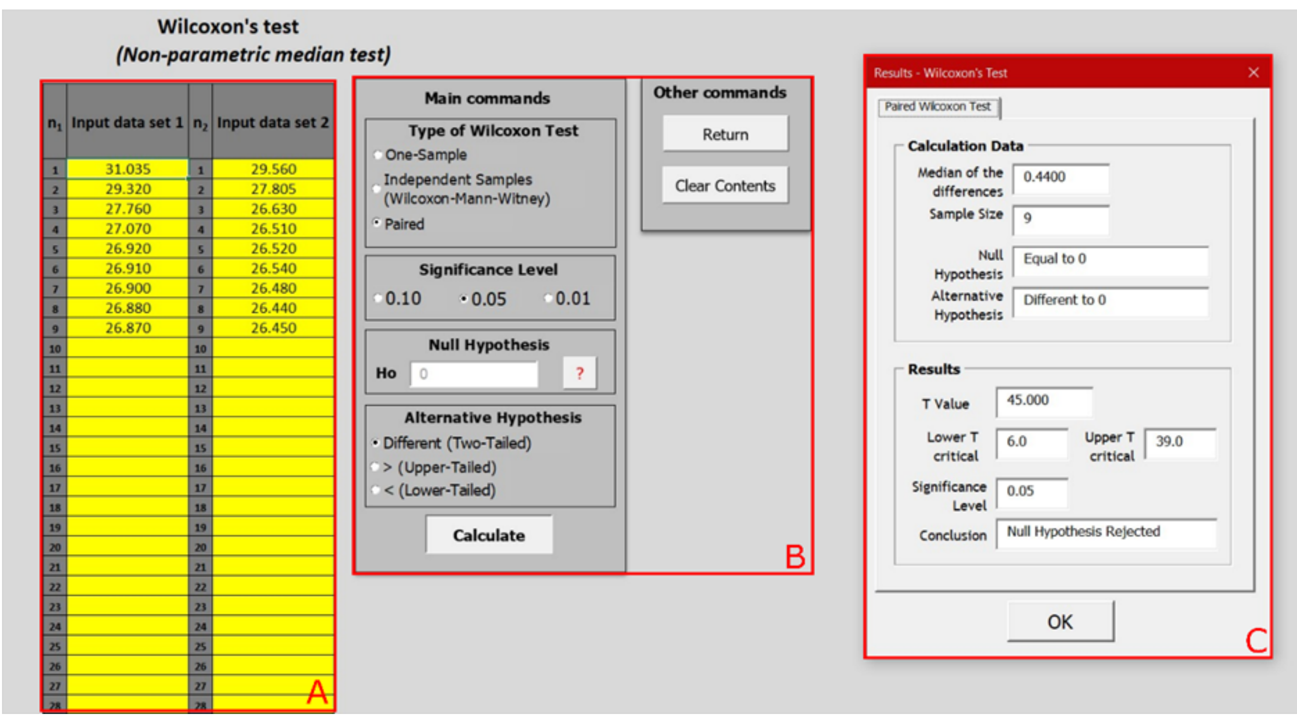
CONCLUSIONS

Hydrosedimentology and statistics are fundamental sciences for the knowledge of processes related to sediment dynamics in water resources and are directly related to their planning and management. Due to the few options available for free and open access statistical software, which are easy to apply and focused on hydrosedimentological studies, we developed the NHSS computational tool in Visual Basic for programming language applications.

The user license is free, and the script, manuals, and guides are available online, acknowledging the implementation of other methods as needed and changes to the existing ones. The NHSS computational tool does not require prior knowledge of computational language and allows the user to work with statistical tests and methods of hydrosedimentological calculations, which is unique in this case.

Distinct modules in the tool allows the user, even with little domain in statistics, to apply their results obtained from the hydrosedimentological module directly in the statistical module. Moreover, we strive with NHSS to optimize time without needing to purchase other software to perform statistical analysis.

Finally, this article shows the applicability of the computational tool for hydrosedimentological and statistical studies, as well as the possibility of using it in any study area, contributing to the reduction of sediment-related problems in the areas of hydraulic engineering, geology, soil, and water conservation, and water resources planning.



Ho: null hypothesis.
Source: elaborated by the authors.

Figure 9 – Paired Wilcoxon's test applied to compare the medians of temperatures from different profiles of the Mogi-Guaçu reservoir: (A) input data area; (B) panel control area; (C) output data window.

Table 1 – Comparison of main statistical test results between NHSS and R software using statistical parameters.

Test	Compared Results	AC	EF	CRM	RMSE	ME	MD
Normality Test	Dn	1.00345	0.99996	0.00061	0.00067	0.00252	0.00037
	P value	1.07917	0.99728	0.00530	0.00494	0.01240	0.00346
F-Fisher test	F value	0.99126	0.99998	-0.00107	0.00391	0.01330	0.00160
	P value	0.99664	0.99997	0.00067	0.00145	0.00380	0.00100
Student's test	T value	1.00039	0.99999	0.00079	0.00765	0.01870	0.00512
	P value	0.99080	0.99992	-0.00350	0.00252	0.00700	0.00131
Wilcoxon's test	T+ value	1.00278	1.00000	0.00110	0.40825	1.00000	0.16667

AC: adjustment coefficient; EF: efficiency; CRM: coefficient of residual mass; RMSE: root mean square error; ME: maximum error; MD: mean difference.

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COMPUTER CODE AVAILABILITY

NH SEDIMENT AND STATISTIC, 2020. Lastest version: 71.2019, File Size: 6MB. Recommended Hardware configuration: 64-bit(x64) processor and 4GB memory. Software requirements: Microsoft Office 2010 (or recent), 64-bit and Microsoft Visual Basic for Applications 7.1. Other details can be found at: https://sites.google.com/view/santosbb/nh-sediment-and-statistic

AUTHORS' CONTRIBUTIONS

Santos, B. B.: Conceptualization, Data curation, Formal Analysis, Project administration, Methodology, Software, Validation, Writing — original draft. Mauad, F. F.: Conceptualization, Funding acquisition, Investigation, Project administration, Methodology, Resources, Supervision, Visualization, Writing — review and editing. Miranda, R. B.: Methodology, Software, Validation, Writing — original draft. Alves Sobrinho, T.: Funding acquisition, Resources, Visualization, Writing — original draft. Oliveira, P. T. S.: Funding acquisition, Resources, Project administration, Writing — review and editing.

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