

Italian Fluvial Sediment Transport Database: A Comprehensive Hub for Archiving and Analyzing Hydrological Data

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44 Abstract

45 Fluvial sediment transport plays a key role in geomorphological and hydrological processes,
46 influencing river morphology, watershed and coastal sediment balances, and the
47 environmental response to climatic and anthropogenic changes. In Italy, the availability of
48 homogeneous and long-term data is strongly limited due to the discontinuity of monitoring
49 activities and the fragmentation of existing sources. This study presents the development of a
50 relational database and web application specifically designed for the collection, storage, and
51 consultation of sediment transport data, aimed at integrating and enhancing heterogeneous
52 datasets from both historical and contemporary monitoring networks: the Italian [Fluvial](#)
53 Sediment Transport Database ([ITASEDISTD](#)). The database architecture, developed in
54 PostgreSQL with the PostGIS extension, enables a direct link between observational data and
55 their associated geographical, instrumental, and methodological metadata, ensuring
56 traceability, interoperability, and the possibility to perform multi-temporal analyses. The web
57 interface, built using open-source technologies, allows controlled data entry and interactive
58 data exploration through maps, tables, and export functions. Analysis of the archived datasets
59 highlights strong instrumental, temporal, and spatial heterogeneity: some physical-chemical
60 parameters (e.g., pH and electrical conductivity) show standardized measurement protocols,
61 whereas sediment transport variables exhibit high methodological variability. Time series range
62 from sub-daily to annual observations, with denser coverage in northern Italian basins (e.g., Po,
63 Adige, Piave, Tagliamento) since 1924. Despite these inconsistencies, integration within a
64 unified relational framework enhances the value of a largely underused data heritage. The
65 experience gained through this project enabled the identification of both the limitations and
66 the potential of Italy's sediment monitoring system, providing operational guidance for
67 methodological standardization, metadata improvement, and data harmonization at the

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68 national scale. The ~~ITASEDISTD~~ represents a concrete step toward establishing a shared
69 sedimentological archive that supports scientific research, environmental management, and
70 sustainable river basin planning.

71 **Keywords:** Sediment transport database, Fluvial monitoring, Data standardization, Hydro-
72 sediment dynamics, Italian river basins

73 1 Introduction

74 Sediment transport in rivers plays a key role in geomorphological and hydrological processes,
75 shaping the morphological evolution of fluvial environments, influencing the sediment
76 balances at the catchment scale and in coastal areas (Fortesa et al., 2021; Vercruysse et al.,
77 2017; Zarfl & Dunn, 2022). Sediments carried by rivers contribute to the genesis of floodplains,
78 deltas, and sediment replenishment in coastal systems, processes that have significant
79 ecological and economic implications (Leatherman et al., 2000; Luppichini & Bini, 2025; K.
80 Zhang et al., 2004). Their dynamics result from a complex interplay of multiple watershed local
81 characteristics, including climatic conditions, geomorphological features, geological
82 substrate, vegetation cover, and anthropogenic activities (Cox et al., 2021; Wei et al., 2023; J.
83 Zhang et al., 2024). This interdependence among the aforementioned factors is central to the
84 study of fluvial systems and represents a critical research field for understanding the
85 mechanisms driving these phenomena and for developing targeted strategies for sustainable
86 land management (Asselman, 1995; Gurnell et al., 2002; Hooke, 2006; Naik & Jay, 2011).

87 The extent and nature of these interactions vary considerably ~~across watershed across basins~~.
88 For example, climatic fluctuations, including changes in precipitation patterns and
89 temperature, along with the intensification of natural disturbances, directly affect sediment
90 mobilization and transport by ~~modifying-modifying~~ both sediment availability and the transport
91 capacity of river flows (Jadhav et al., 2024). Furthermore, anthropogenic activities such as
92 afforestation-deforestation dynamics, urban expansion, infrastructure development, in-
93 channel sediment mining and water resource management have profoundly modified
94 sediment transport regimes. These interventions can ~~intensify-alter~~ erosional processes in
95 mountainous catchments, disrupt natural sediment ~~fluxes flows~~ through the construction of
96 dams, ~~and~~ weirs ~~and check-dams~~, and ~~reduce-modify~~ sediment transport capacity via water
97 abstraction or river channelization and training (Asselman, 1995; Favaro & Lamoureux, 2015;
98 Naik & Jay, 2011; Rodríguez-Blanco et al., 2016; Surian & Rinaldi, 2004; Thodsen et al., 2008).

99
100 ~~Despite the importance of these phenomena, a comprehensive understanding of the~~
101 ~~interactions between climatic and anthropogenic factors is often hampered by a lack of~~
102 ~~systematic monitoring data and the fragmented accessibility of existing records. This~~
103 ~~condition, with some degree of variability, is widely observed at the global scale~~ Fare clic o
104 toccare qui per immettere il testo. ~~In particular, the scarcity of long, continuous, and coherent~~

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time series represents a significant obstacle to quantifying the specific contribution of each factor to total sediment transport and to accurately predicting how climatic changes or anthropogenic pressures may alter sediment balances in the future. Despite the importance of these phenomena, a comprehensive understanding of the interactions between climatic variability, anthropogenic pressures, and sediment dynamics is often hampered by the lack of systematic monitoring data and by the fragmented accessibility of existing records. This limitation is particularly critical because fluvial sediment transport is not a single, uniform process, but results from the combination of different components, mainly two fractions (suspended load and bedload), which are controlled by partly distinct mechanisms. Therefore, such fractions and may respond differently to natural and human-driven pressures. Suspended sediment transport is generally more directly linked to the mobilization of fine material from hillslopes (featuring different land uses), floodplains and channel banks, and agricultural or urbanized areas, and is strongly influenced by precipitation intensity, runoff generation and vegetation cover, soil erosion, and catchment connectivity (Battista et al., 2020; Fryirs, 2013; Vercruysse et al., 2017). In comparison to the suspended fraction, bedload transport, instead, depends more strongly on the availability within the catchment of mobile coarser fractions, as well as on their connectivity within and to the channel network. Additional important factors for bedload fluxes and mobility of coarser material, are channel morphology, grain-size distribution, transport thresholds, and the occurrence and legacy of high-energy flow events. Both suspended and bedload transport, in different manner, are (Surian & Rinaldi, 2004)

For this reason, the use of undifferentiated or poorly documented sediment datasets can limit the interpretation of hydro-sedimentary processes and may lead to misleading estimates of total sediment transport. Properly separated datasets for suspended load, bedload, and, where available, total load are therefore needed to distinguish the processes involved, evaluate the role of natural and anthropogenic drivers, and assess sediment budgets at the catchment scale. This requirement is particularly relevant for long-term analyses, where changes in monitoring methods, sampling frequency, instrumentation, and metadata completeness can strongly affect data comparability. This condition, with some degree of variability, is widely observed at the global scale (Walling & Fang, 2003). In particular, the scarcity of long, continuous, and coherent time series represents a significant obstacle to quantifying the specific contribution of climatic and anthropogenic factors to the different components of sediment transport and to accurately predicting how future environmental changes may alter riverine and coastal sediment balances (Luppichini et al., 2024; Syvitski et al., 2005)

In Italy, this issue is particularly pronounced. From the 1930s to the 1990s, the Italian Hydrographic and Ocean Service (*Servizio Idrografico e Mareografico Italiano*, SIMI) played a crucial role in systematically collecting suspended sediment transport data from major rivers

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145 across the country. However, with the dissolution of the service in the 1990s, the responsibility
146 for monitoring was transferred to regional authorities, which faced significant challenges in
147 maintaining continuity (Billi & Spalevic, 2022). ~~Nonetheless, m~~Monitoring activities
148 ~~nevertheless persisted in some basins and research observatories, although often with limited~~
149 ~~resources and reduced operational capacity. Examples include long-term or repeated~~
150 ~~monitoring experiences in the Adige basin, in the Piave basin and Rio Cordon instrumented~~
151 ~~catchment, and in other northern Italian basins such as the Po and Tagliamento, where~~
152 ~~sediment transport and related hydrological variables continued to be investigated through~~
153 ~~regional monitoring activities and research-based initiatives~~ (Bonfrisco et al., 2025; Pellegrini
154 et al., 2023a; Rainato et al., 2017, 2025a). ~~In central Italy, additional datasets from rivers such~~
155 ~~as the Arno, Ombrone, and Versilia further document the persistence of local monitoring and~~
156 ~~research efforts, although generally with more fragmented spatial and temporal coverage~~
157 (Francalanci et al., 2013a, 2013b). ~~In some virtuous cases, monitoring activities persisted but~~
158 ~~often with limited resources and reduced operational capacity~~. This has led to a highly
159 fragmented data landscape: on one hand, there are paper-based historical records that are
160 difficult to access and are not fully exploited; on the other hand, more recent data have been
161 collected sporadically by public agencies or research groups, often without national-level
162 coordination. The lack of a centralized platform designed to collect and harmonize these
163 datasets has hindered their use for long-term analyses and to support water and land
164 management policies.

165 To address this critical issue, the present work ~~has addresses~~ two main objectives. The first is
166 to create and strengthen a network of experts who, both in Italy and abroad, have been
167 collecting data on sediment transport for several decades. Establishing this network aims to
168 foster knowledge exchange and best practices, encouraging greater collaboration among
169 institutions, universities, and land management authorities. The second objective is to develop
170 a centralized database designed to store both historical and future data, integrating them into
171 a single, accessible, and well-structured repository. ~~Although the database is centred on~~
172 ~~sediment transport, it was designed with a broader hydro-sedimentary perspective and~~
173 ~~therefore also includes associated hydrological and physicochemical variables, such as flow~~
174 ~~rate, flow height, temperature, pH, electrical conductivity, and major ions. These variables~~
175 ~~provide essential context for interpreting sediment dynamics and for analysing the~~
176 ~~relationships between river flow conditions, water properties, and sediment transport~~
177 ~~processes. As part of this process, a web-based dedicated data call for sediment transport data~~
178 ~~was launched (in 2025) to collect existing sediment transport and related hydrological datasets~~
179 ~~from public institutions, research groups, river basin authorities, and monitoring agencies. In~~
180 ~~this study, the term “data call” refers to a targeted request for available datasets and metadata,~~
181 ~~especially for data not already accessible through open repositories or standardised national~~
182 ~~platforms. This step was also intended to consolidate the expert network mentioned above and~~
183 ~~to identify dispersed or poorly accessible datasets suitable for harmonisation within the~~
184 ~~proposed database.~~

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185 Comparable harmonization efforts have long been implemented in hydrology through
186 international initiatives such as the Global Runoff Data Centre (GRDC) (Färber et al., 2025) and
187 the Global Streamflow Indices and Metadata archive (GSIM) (Do et al., 2018). These databases
188 integrate streamflow records from multiple national agencies and research institutions,
189 applying standardized metadata structures and quality-control procedures to ensure
190 consistency and comparability across regions. In contrast, sediment transport data are still
191 largely fragmented, often dispersed among individual research projects or local monitoring
192 programs. The development of the present database represents a first step toward a similar
193 level of coordination in the field of fluvial sediment monitoring, promoting interoperability and
194 long-term data accessibility.

195 The adopted IT infrastructure, ~~consisting of the database architecture, server environment, and~~
196 ~~web-based interface, combines a solid and well-organized backend with a flexible~~
197 ~~and comprising the database architecture, server environment, and web-based interface,~~
198 ~~combines a solid, well-organised backend with a flexible,~~ intuitive frontend. This approach
199 ensures not only data security and integrity but also broader dissemination of information,
200 making it accessible to both technical experts and users with limited expertise. The availability
201 of a centralized platform marks a significant step forward in addressing the current gaps in
202 sediment transport monitoring, providing a valuable tool for land management and scientific
203 research. In the long term, this initiative could facilitate greater integration of sediment data at
204 the European level, contributing to a more comprehensive understanding of sediment
205 dynamics in response to climate change and anthropogenic pressures.

206

2 Material and Methods

207 The conceptual and logical design of the database and its graphical interface was carried out
208 in close collaboration with the research groups and technical partners involved; to understand
209 their specific needs for storing and accessing sediment transport data. This participatory
210 process supported the development of a pragmatic and shared standardization strategy, aimed
211 at organizing heterogeneous datasets within a common relational structure while preserving
212 the traceability of original data sources, measurement methods, instruments, units, and
213 access conditions. The rationale behind this strategy was not to define a universal standard for
214 sediment transport data, but to provide a flexible and reproducible framework suitable for the
215 available datasets and adaptable to future contributions from different institutions or
216 monitoring traditions. ~~This participatory process enabled the identification of the most~~
217 ~~effective approaches to standardize data formats and ensure consistency and interoperability~~
218 ~~across heterogeneous datasets. The design of the database and its graphical interface was~~
219 ~~carried out in close collaboration with the research groups and technical partners involved, to~~
220 ~~understand their specific needs for storing and accessing sediment transport data. This~~
221 ~~participatory process supported the development of a pragmatic and shared standardization~~
222 ~~strategy, aimed at organizing heterogeneous datasets within a common relational structure~~
223 ~~while preserving the traceability of original data sources, measurement methods, instruments,~~

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224 ~~units, and access conditions. The rationale behind this strategy was not to define a universal~~
225 ~~standard for sediment transport data, but to provide a flexible and reproducible framework~~
226 ~~suitable for the available datasets and adaptable to future contributions from different~~
227 ~~institutions or monitoring traditions. The physical model of the database were~~
228 ~~was subsequently stored in implemented as~~ PostgreSQL database, while ~~their data~~ entry,
229 consultation, and updating were managed through a custom-developed web application
230 designed to provide a structured and user-friendly tool for data management and integrated
231 analysis.

232 Before being uploaded to the database, the datasets underwent a data-curation workflow
233 aimed at harmonising heterogeneous sources while preserving their original traceability.
234 Candidate datasets were selected according to their relevance to sediment transport or
235 associated hydrological and physicochemical variables, the availability of temporal
236 information, and the possibility of linking the observations to a river, monitoring station, and
237 watershed. Parameter names were harmonised using the internal database vocabulary, so that
238 equivalent terms from different sources could be stored under a common parameter definition.
239 Measurement units were checked against the units associated with each parameter in the
240 database; when necessary, values were converted to the adopted standard unit, while the
241 original source and methodological information were retained to preserve traceability. Missing
242 metadata, such as instrument type, measurement method, sampling frequency, or access
243 conditions, were not reconstructed when unavailable, but were explicitly recorded as missing
244 or unknown. Potential duplicated observations were checked using combinations of station,
245 parameter, date/time, value, and source information before upload. This workflow allowed
246 heterogeneous historical and recent datasets to be integrated into a common relational
247 structure while documenting the main limitations inherited from the original sources.

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248 2.1 PostgreSQL Database

249 The database was developed in PostgreSQL and installed on a server machine accessible via
250 the HTTPS protocol (<https://lca.dst.unipi.it/>). PostgreSQL is an open-source relational
251 database management system (RDBMS), known for its adherence to SQL standards and
252 advanced features. It is designed to handle workloads ranging from small individual databases
253 to large-scale management systems, typical of complex applications. PostgreSQL has been
254 extended with the PostGIS library, which adds support for geospatial data, making it an
255 advanced tool for storing, managing, and analyzing spatial and geographic data. It complies
256 with the standards of the Open Geospatial Consortium (OGC), including the Simple Features
257 for SQL and SQL/MM Spatial (Strobl, 2008).

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258 The relational schema is shown in [Figure 1](#)~~Figure 4~~. The information has been divided into 15
259 tables that allow for the storage of highly varied data.

260 The "watershed" table represents the highest level of the geographic system and describes the
261 watersheds, which represent the fundamental territorial unit for monitoring sediment
262 transport. This table includes spatial information (*geom*), enabling integration with GIS

systems, and descriptive attributes for the 272 main watersheds of Italy (http://sdi.isprambiente.it/geoserver/hy/bacini_principali/wfs?service=wfs&version=2.0.0&request=GetCapabilities). Each watershed is linked to the corresponding river (in the "rivers" table). The "rivers" table represents the main watercourses that flow through the watersheds. Each river is associated with a watershed via the field *id_watershed*. This relationship allows rivers to be organized by their respective watersheds. The monitored rivers are described using a unique identifier (*id*) and a textual description (*description*), useful for identifying the river. The rivers serve as reference points for data acquisitions.

The "acquisition" table is the main repository for the data obtained from river monitoring. Each acquisition is geolocated using coordinates (*coordx*, *coordy* using the WGS84 coordinate reference system). ~~and The table also~~ includes the monitored river (*id_river*), the measured parameter (*id_parameter*), the instrument used (*id_instrument*), the responsible user (*id_user*), additional information such as data availability (*availability*), specific reference (*reference*), and the monitoring section code (*section_code*). The acquisitions are also linked to a detail of the measurement type through *id_meas_type*.

The monitored parameters are defined in the "parameter" table. Each parameter describes a measurable element (e.g., pH, flow rate, velocity, suspended sediment concentration, etc.) and includes a textual description (*description*), a link to a general category through the field *id_categorize*, associated with the "macro_categories" table, which groups the parameters into broader categories (e.g., sediment concentration, river flow, chemical analysis, grain size, etc.). Parameters can be measured using different units of measurement and instruments, as described in the "parameter_has_unit" and "parameter_has_instruments" tables. The "instruments" table lists the tools used to collect field measurements. The "parameter_has_instruments" relationship establishes which instruments are used to measure each parameter. Each parameter is measured in a specific unit (e.g., °C, mg/L), defined in the "meas_unit" table. This n:n association is managed through the "parameter_has_unit" table.

Finally, the collected data are stored in the "data" table, which archives the actual numerical values recorded during acquisitions. Each record in the table includes the measured value (*value*), the collection date (*date*), and a reference to the specific acquisition via *id_acquisition*.

This approach allows for the direct connection of the measured data to the geographical context, the monitored parameter, the instrument used, and the monitoring conditions.

Each data entry is linked to a responsible user (in the "users" table), which contains information about the system users, including personal details (*name*, *surname*, *email*) and technical information (*affiliation*, *associated schema*, *last login date*). It is related to the "user_type" table, which categorizes users based on their role or authorization. Users can be active or inactive (in the "activations" table) and can have different roles (editor or viewer) with varying permissions on the database through the web application management system.

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301 [The database and the web application are hosted on dedicated server machines provided by](#)
302 [the University of Pisa and specifically configured for this project. This institutional hosting](#)
303 [solution allows the platform to operate without direct maintenance costs for individual](#)
304 [researchers and provides a more stable framework than project- or researcher-dependent](#)
305 [storage solutions.](#)

306 [User roles are assigned by the database administrators after registration. By default, newly](#)
307 [registered users are assigned a viewer role, allowing data consultation while preventing](#)
308 [uncontrolled modifications or imports. When a user intends to contribute new datasets, an](#)
309 [exchange with the database administrators is carried out during the account activation or role-](#)
310 [upgrading phase, in order to evaluate the user's affiliation, expertise, type of contribution, and](#)
311 [consistency of the proposed data with the database structure. Users recognized as data](#)
312 [contributors can then be assigned an editor role. This approach is intended to preserve data](#)
313 [integrity while keeping the platform open to future collaborations with institutions, research](#)
314 [groups, and monitoring agencies.](#)

315 [At the present stage, quality control is mainly implemented as a first-level validation based on](#)
316 [data traceability, controlled vocabularies, mandatory metadata fields, and consistency checks](#)
317 [before records are written to the database. For historical datasets, the quality of the archived](#)
318 [records necessarily depends on the completeness and reliability of the original sources and](#)
319 [associated metadata. Therefore, the database does not remove all uncertainties related to past](#)
320 [monitoring activities, but makes them explicit and traceable through the relational structure.](#)
321 [For newly measured data, the same controlled workflow represents a first level of quality](#)
322 [assurance, while the development of more detailed and documented quality-control](#)
323 [guidelines is identified as a priority for future updates of the platform.](#)

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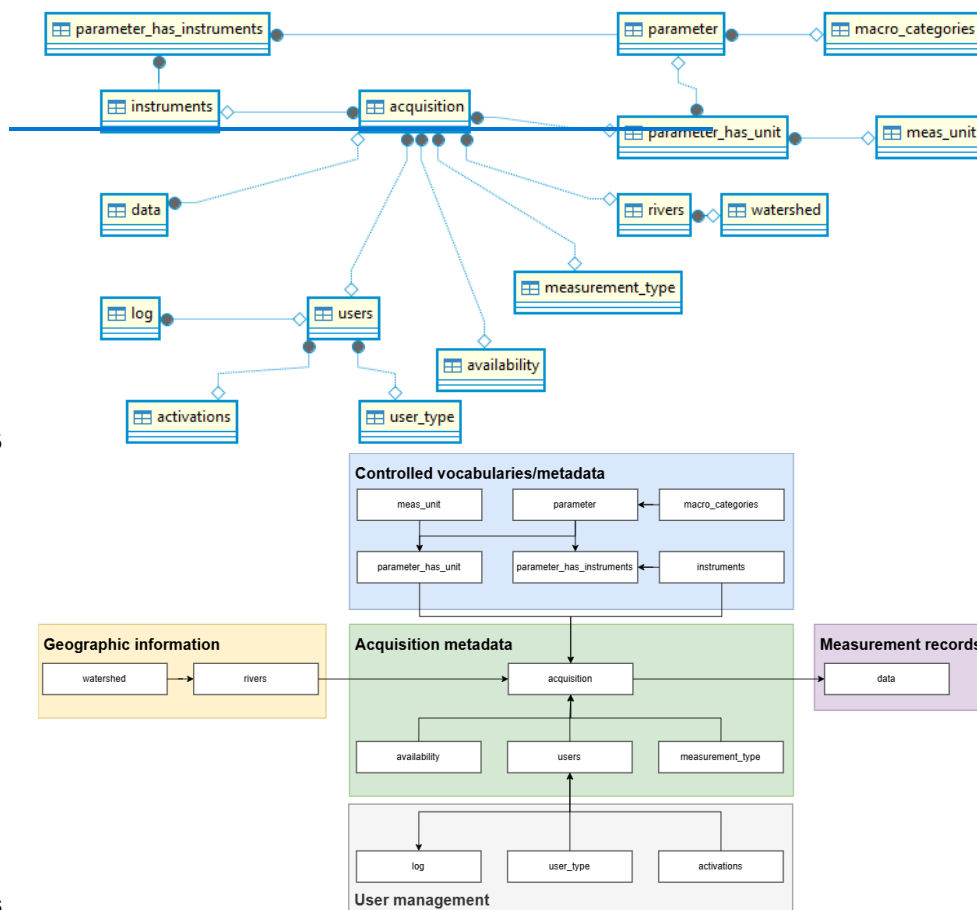


Figure 1 Relational schema of the database PostgreSQL

2.2 Web application

The web application (Figure 2; <https://lca.dst.unipi.it/SedimentTransport>) was developed to facilitate and control the database population and to provide tools for visualizing the data contained within it. It was built using open-source JavaScript and PHP libraries, primarily based on tools such as Bootstrap and OpenLayer. Access to the web application is granted after completing a registration form, during which the user selects their login credentials. Once the user is created, they must be approved by the database administrators, who will assign a user role (editor or viewer).

The application features a two-section layout (Figure 2): on the left, there is a menu with various options (Home, Import Data, View Data), while the main screen is displayed in the center. The homepage provides summary information such as the number of records in the

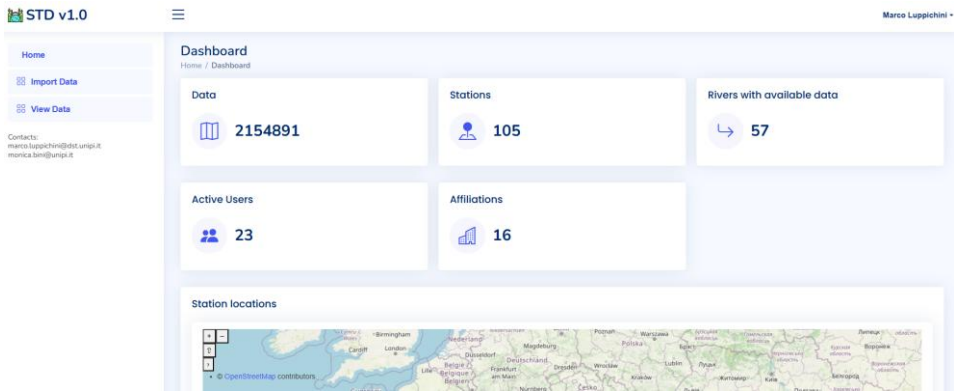
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339 database ("Data"), the number of measurement points ("Stations"), the number of rivers with
340 at least one data entry ("Rivers with available data"), the number of active users in the last six
341 months ("Active Users"), and the number of user affiliations ("Affiliations"). It should be noted
342 that the web platform is continuously updated; therefore, the numbers displayed in the
343 interface may differ from those reported in the Results, which refer to the frozen database
344 version used for the analyses presented in this manuscript.

345 The homepage, which appears as shown ~~Figure 2~~Figure 2, also displays a map with the
346 measurement points available in the database. Additionally, a table is shown summarizing the
347 data in the database. The maps in the web application are interactive: when clicking on the
348 layers, specific information about the measurement site is displayed.

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350

351 *Figure 2* Home page of the web application (accessed on 16 February 2026). The web platform is continuously updated;
352 therefore, the numbers shown in the interface may differ from those reported in the Results, which refer to the frozen database
353 version used for the analyses presented in this manuscript. ~~Home page of the web application (accessed on 16 February 2026)~~

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354 The data entry process is carried out through the "Import Data" page. This feature is visible and
355 accessible only to users with an editor role and consists of an initial form for general
356 information to complete the acquisition table in the database (such as the river, measurement
357 point, measured parameter, etc.). The dropdown menus are interconnected, and the available
358 options change based on previous selections, guiding the user in selecting the correct entries.

359 The second part of the form consists of a tab with two options: "Insert Single Data" or "Insert
360 Multi Data" (~~Figure 3~~Figure 3). The "Insert Single Data" (~~tab~~Figure 3Figure 3) allows the user to
361 enter one record at a time by selecting the date and entering the corresponding value. The
362 "Insert Multi Data" tab allows multiple values to be entered by uploading a Microsoft Excel file
363 containing a specific template (the Excel file template is provided in the Supplementary
364 Materials). The template consists of only two columns: "date" and "value". A data validation
365 procedure is performed on the Excel file before writing data to the database. Any errors or
366 successful operations are displayed to the user via appropriate alerts. The upload validation
367 includes checks on the structure of the input file, the presence and format of the required

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368 fields, the readability of dates, the numeric type of measured values, and the consistency
369 between the uploaded data and the acquisition metadata previously selected by the editor,
370 including parameter, unit, river, monitoring station, and geographic coordinates. The procedure
371 also prevents the upload of records with missing dates or missing values and flags potential
372 duplicated observations based on the combination of acquisition, date, and value. These
373 checks are intended to ensure database consistency and prevent structural errors during data
374 entry.

375 For data consultation and download, the "View Data" page can be used, accessible from the
376 left-hand menu of the application (Figure 4Figure-4). The page contains a map showing the
377 locations of the measurement stations. By clicking on the points, users can access information
378 about the historical time series associated with the selected station.

379 The page also includes a table that lists all the information associated with each data record.
380 Through the provided form, users can query the data by applying filters, and the requested data
381 will be displayed in a table that can be further filtered.

382 Data in the table can be searched using the "Search" function or by applying column filters in
383 the last row of the table. Data can be exported in various formats using the "Copy", "Excel",
384 "CSV", "PDF", or "Print" options.

385 Data imported under a specific availability limit (on request) are only partially visible to users
386 who are not the data owner. However, users can request the full data by contacting the data
387 owner.

The screenshot shows the 'Data entry' page of the STD - beta version web application. The page has a light blue header with the application name and a user profile 'Marco Luppichini'. A left sidebar contains navigation links: 'Home', 'Import Data', and 'View Data'. The main content area is titled 'Data entry' and 'Data / Import Data'. It features an 'Import' form with the following fields: 'Activity' (dropdown menu), 'Category' (dropdown menu), 'X coordinate (EPSG: 4326)' (text input), 'Y coordinate (EPSG: 4326)' (text input), 'Parameter' (dropdown menu), 'Measurement Unit' (dropdown menu), 'Instrument' (dropdown menu), 'River' (dropdown menu), 'Section Code' (text input), 'Location' (text input), 'Availability' (dropdown menu), 'Reference' (text input), and 'Note' (text area). At the bottom of the form, there are two buttons: 'Insert Single Data' and 'Insert Multi Data'. Below these buttons, there is a 'Date' field with a date picker, a 'Value' field, and an 'Insert Data' button highlighted in green.

388
389 Figure 3 Import data page of the web application (accessed on 24 October 2025)

390

View Data

Main Watershed* SERCHIO Parameter* Flow rate

Start Date gg/mm/aaaa End Date gg/mm/aaaa

Availability* On Request, Open Access

Search Data

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25 entries per page

Search:

TYPE	RIVER	INSTRUMENT	PARAMETER	UNIT	LOCATION	SECTION CODE	WATERSHED	DATE	VALUE	AVAILABILITY	USER
River parameters	Serchio	Unknown	Flow rate	m3/s	Vecchiano		SERCHIO	2021-12-15 00:00:00	41.926	Open Access	Marco Luppichini
River parameters	Serchio	Unknown	Flow rate	m3/s	Vecchiano		SERCHIO	2005-07-12 00:00:00	28.313	Open Access	Marco Luppichini
River	Serchio	Unknown	Flow rate	m3/s	Vecchiano		SERCHIO	2009-11-28	56.077	Open Access	Marco

Figure 4 View data page of the web application (accessed on 24 October 2025)

3 Results

Before describing the content of the data records, we provide a spatial overview of the monitoring network included in the database. Figure 5 shows the location of the monitoring stations together with the corresponding river network and watershed boundaries. This representation allows readers to evaluate the geographical distribution of the available observations and to identify the main monitored river basins across the Italian territory.

The monitoring stations are not uniformly distributed across the country, reflecting both the availability of regional monitoring programmes and the heterogeneous development of sediment transport observations in Italy. A higher density of stations is evident in northern and central Italy, particularly along the Alpine and Apennine river systems, where several monitored basins are represented. The map also highlights the connection between individual monitoring points and their upstream drainage areas, providing useful spatial context for the interpretation of the database.

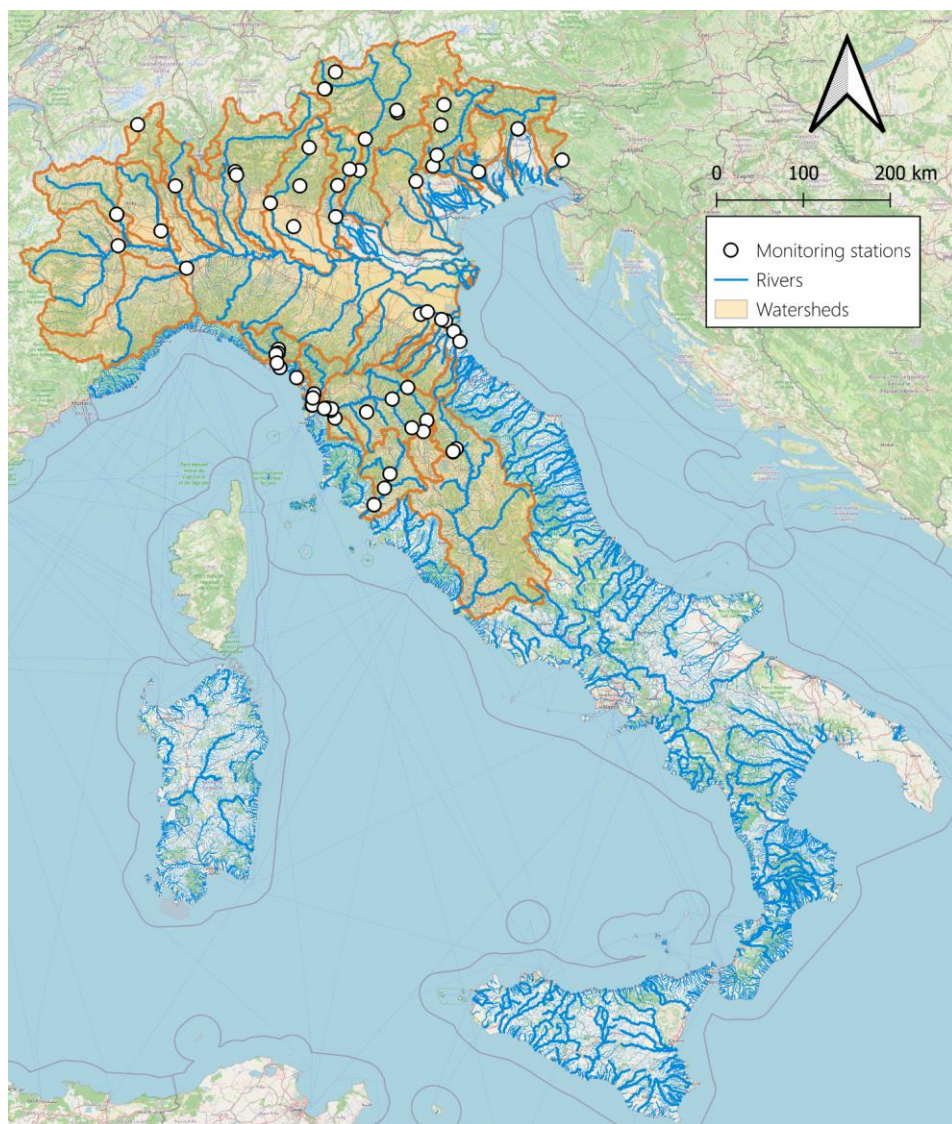


Figure 5 Spatial distribution of the monitoring stations included in the database. White circles indicate monitoring stations, blue lines represent the river network, and orange outlines delimit the corresponding watersheds. The map provides an overview of the monitored river basins and their distribution across the Italian territory.

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411 3.1 Data Records

412 The data collected within the database amount to 1,988,116 records and are characterized by
413 a high degree of spatial, temporal, and instrumental heterogeneity. The database currently
414 includes information from 29 river basins and 39 rivers, distributed across 76 measurement
415 sites. A total of 386 time series are archived. The dataset covers 21 different parameters,
416 acquired using 19 different types of instruments, highlighting the diversity of monitoring
417 approaches and measurement techniques adopted across different hydrological contexts.

418 [To provide a concise overview of the database contents before the detailed analysis of](#)
419 [instruments, sampling frequency, temporal coverage, and spatial distribution, Table 1](#)
420 [summarises the parameters currently populated in the database. For each parameter and](#)
421 [measurement unit, the table reports the number of available records, the number of time](#)
422 [series, the number of rivers and measurement sites represented, and the overall temporal](#)
423 [coverage. Table 1 highlights the heterogeneous structure of the database, both in terms of data](#)
424 [volume and temporal extent. Some variables, such as flow height, flow rate, temperature,](#)
425 [turbidity, and electrical conductivity, are represented by large numbers of records, whereas](#)
426 [several sediment-related parameters, including annual bedload discharge, annual suspended](#)
427 [sediment load, bedload sediment load, and grain-size descriptors, are represented by smaller](#)
428 [datasets. This summary provides a compact reference for interpreting the following figures,](#)
429 [which analyse instrumentation, sampling frequency, temporal coverage, and spatial](#)
430 [distribution in greater detail.](#)

431 [Figure 6](#)Figure 5 shows the percentage distribution of the instruments used to acquire each
432 parameter in the database, expressed as the proportion of total records available for that
433 parameter. The analysis highlights that, in some cases, the instrumentation employed appears
434 to be extremely homogeneous, while in others a considerable heterogeneity emerges, related
435 to the nature of the parameter and the different measurement methodologies available.

436 Parameters closely linked to basic physico-chemical measurements, such as electrical
437 conductivity and pH, show a clear predominance of a specific instrument (the *conductivity*
438 *meter* and the *pH meter*, respectively), with percentages close to 100%. A similar pattern can
439 be observed for parameters derived from annual aggregations, such as Annual Bedload
440 Discharge (ABD), which are exclusively associated with specific calculation methods and
441 measuring instruments (e.g., *geophones*).

442 Conversely, parameters related to instantaneous or monthly sediment transport and hydraulic
443 flow characteristics show greater variability in the instruments used. In particular, the
444 Suspended Sediment Concentration (SSC) was acquired using four different types of
445 instruments (*bottles*, *DH59*, and *acoustic doppler current profilers*). This heterogeneity reflects
446 the coexistence, within the various monitoring networks, of both direct and indirect approaches
447 to measuring suspended sediment concentration, as well as operational differences between
448 monitoring sites and acquisition periods.

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A similar situation can be observed for turbidity, which is measured using optical instruments (e.g., *nephelometers* and *turbidimeters*) but with varying percentages, suggesting differences in both the temporal resolution of the observations and the technological availability of the monitoring sites. Hydraulic parameters such as flow height and flow rate also display a more fragmented distribution, with an alternative use of *radar sensors*, *pressure transducers*, and *float gauges*, consistent with the diversity of environmental conditions and the differing operational choices among monitoring stations.

Overall, there is a clear distinction between parameters that benefit from standardized measurement procedures and dedicated instruments and more complex parameters for which the variety of methodological approaches and operational tools constitutes an intrinsic feature of the acquisition process. This differentiation underscores the importance of a database structure capable of accommodating heterogeneous information while retaining details of the instrumental and methodological context associated with each dataset, thereby ensuring traceability and comparability among data derived from different sources.

It is also noteworthy that seven out of the sixteen analyzed parameters show significant percentages of data associated with an instrument classified as “unknown”. Data associated with an “unknown” instrument should therefore be interpreted with caution. This classification does not necessarily indicate low-quality or unreliable measurements, as many of these records may derive from historical sources or previously processed datasets considered valid by the original data providers. However, the absence of information on the measurement instrument limits the possibility of assessing methodological comparability, instrumental uncertainty, and potential biases among datasets. Consequently, these records can still be useful for exploratory analyses, historical reconstructions, and broad assessments of spatial and temporal data availability, but they are less suitable for detailed comparisons among measurement techniques, uncertainty analyses, or model calibration procedures requiring fully documented metadata. In this sense, the database does not eliminate the limitations inherited from the original data sources; rather, it makes them explicit and traceable, providing a basis for future metadata improvement and data-quality refinement.

Table 1. Summary of the parameters currently populated in the Italian Fluvial Sediment Transport Database. For each parameter and measurement unit, the table reports the number of records, number of time series, number of rivers, number of measurement sites, and temporal coverage. The table provides a compact overview of the database contents and complements the detailed analyses of instruments, sampling frequency, temporal coverage, and spatial distribution shown in the following figures.

Parameter	Measurement Unit	No. of Records	No. of time series	No. of Rivers	No. of measurement sites	Start Date	End Date
Annual Bedload Discharge (ABD)	t/year	6	1	1	1	2014-01-01	2020-01-01
Annual Suspended Sediment Load (ASSL)	t/year	6	1	1	1	2014-01-01	2020-01-01
Bedload discharge	t/day	56	9	6	6	2003-11-03	2019-12-03
Bedload Sediment Load (BSL)	kg/s	159	7	7	7	1987-01-01	2012-11-05

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Electrical potential	mV	34	23	15	22	2011-02-09	2011-12-10
Electric conductivity	S/cm	1	1	1	1	2011-04-23	2011-04-23
Electric conductivity	µS/cm	154686	33	19	27	2011-02-09	2025-03-21
Flow height	m	680983	20	16	16	2003-11-03	2025-08-07
Flow rate	kg/s	1	1	1	1	2023-03-14	2023-03-14
Flow rate	m3/s	145562	51	32	43	1924-01-01	2023-10-18
Grain size - D50	mm	38	4	3	3	2005-04-12	2019-12-03
Grain size - D90	mm	36	4	3	3	2005-04-12	2019-12-03
Major Ions	mg/L	384	27	16	23	2011-02-09	2023-03-31
Monthly Suspended Sediment Load (MSSL)	10^3 tonn	2719	8	5	8	1936-01-01	1995-12-01
Monthly Suspended Sediment Load (MSSL)	Max kg/m3	2770	8	5	8	1931-01-01	2011-02-09
Monthly Suspended Sediment Load (MSSL)	Max kg/s	2709	8	5	8	1936-01-01	1995-12-01
Monthly Suspended Sediment Load (MSSL)	Mean kg/m3	2718	8	5	8	1936-01-01	1995-12-01
Monthly Suspended Sediment Load (MSSL)	Mean kg/s	2718	8	5	8	1936-01-01	1995-12-01
Monthly Suspended Sediment Load (MSSL)	Min kg/m3	2768	8	5	8	1931-01-01	1995-12-01
Monthly Suspended Sediment Load (MSSL)	Min kg/s	2709	8	5	8	1936-01-01	1995-12-01
Monthly Suspended Sediment Load (MSSL)	t/km2	2718	8	5	8	1936-01-01	1995-12-01
pH	NaN	62	28	16	23	2011-02-09	2023-03-31
Reanalysis SSL	kg/s	8860	10	2	2	1924-01-01	2024-10-01
Suspended Sediment Concentration (SSC)	g	70911	2	1	1	2020-01-09	2023-09-20
Suspended Sediment Concentration (SSC)	g/L	94452	25	9	20	2003-11-03	2025-04-16
Suspended Sediment Load (SSL)	kg/s	46	5	5	5	1998-12-22	2012-11-05
Suspended Sediment Load (SSL)	t/year	94288	2	1	1	2020-01-09	2023-09-20
Temperature	°C	323950	35	20	29	2011-02-09	2025-08-07
Total Sediment Load (TSL)	kg/s	46	5	5	5	1998-12-22	2012-11-05
Turbidity	NTU	557906	10	6	7	1987-01-01	2025-08-07

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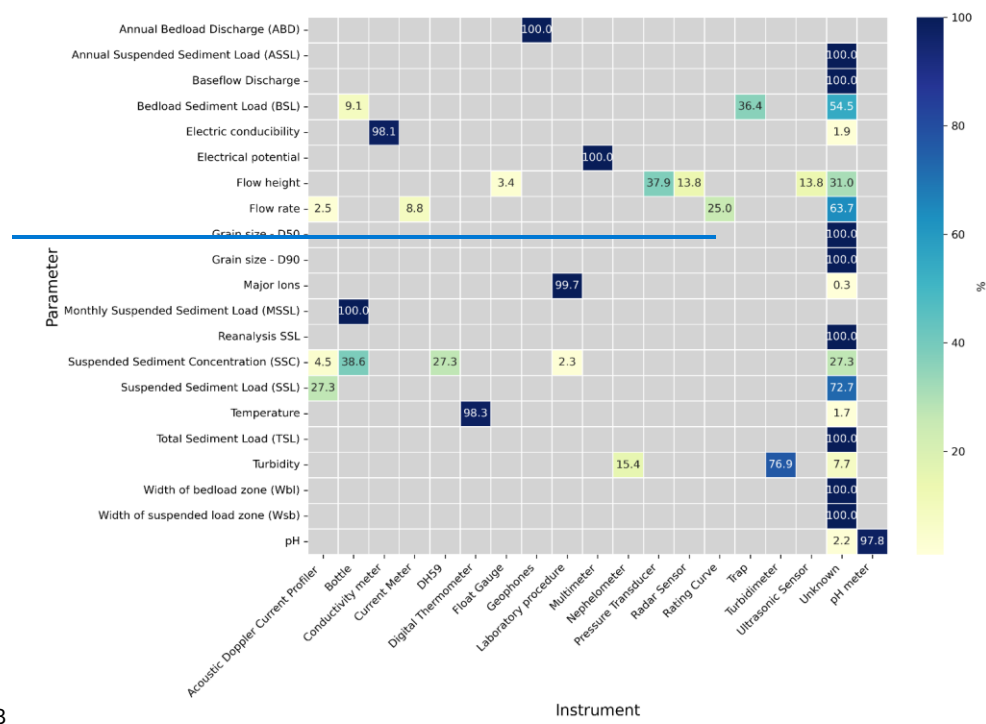
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Width of bedload zone (Wbl)	m	52	7	4	4	2003-11-03	2019-12-03
Width of suspended load zone (Wsb)	m	58	9	6	6	2003-11-03	2019-12-03

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his condition does not result from missing information in the database, but rather from the loss of details regarding the measurement instrument during data collection or transfer. This feature highlights the importance of metadata completeness and instrument traceability for a correct interpretation of hydro-sedimentary datasets.



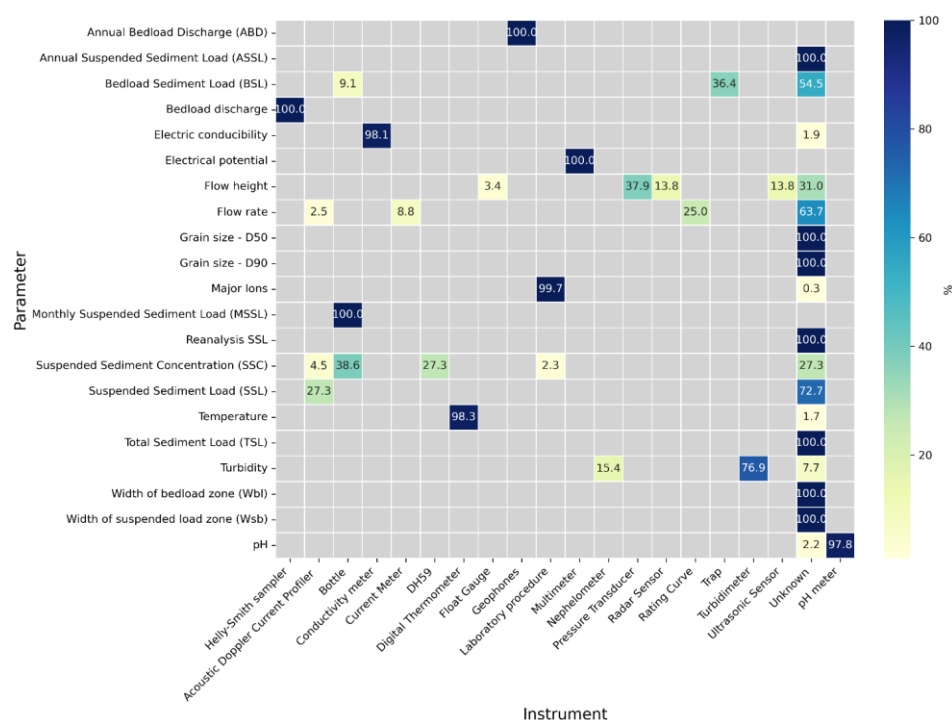


Figure 65 Frequency distribution of instruments used for the acquisition of each parameter stored in the database. Grey cells indicate the absence of values (0%). The figure highlights both homogeneous cases, where a single instrument is dominant, and heterogeneous situations, particularly for sediment transport and hydraulic parameters, where multiple measurement techniques coexist.

Figure 7 summarizes the typical sampling frequencies of the datasets stored in the database. For each parameter, the modal temporal resolution (i.e., the most frequently observed sampling interval) was identified and compared with the full range of observed frequencies, spanning from minimum to maximum values. The cumulative distribution further quantifies the proportion of records associated with each temporal resolution class.

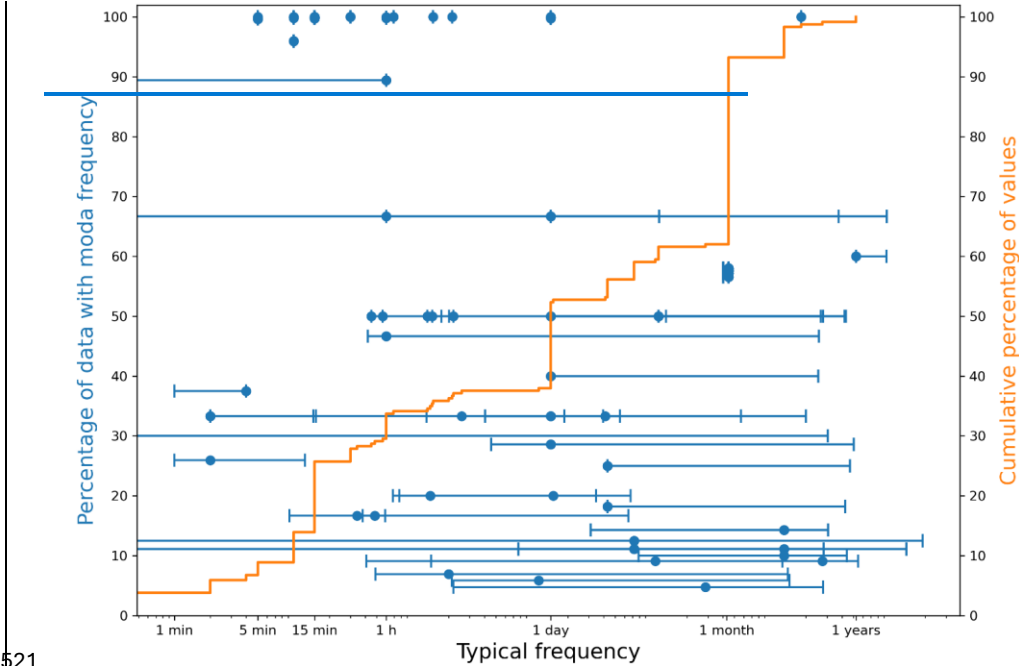
The distribution highlights marked heterogeneity in the temporal resolution of the data, spanning sub-hourly to annual frequencies. Some parameters, particularly those of a physical or hydraulic nature (e.g., flow height), are acquired at high frequencies (2 minutes or 1 hour), consistent with continuous or semi-continuous monitoring activities. Other datasets, especially those related to sediment transport or derived parameters, show daily or monthly frequencies, typical of manual field measurements or periodic sampling associated with laboratory procedures.

The cumulative curve reveals five main acquisition regimes, corresponding to frequencies of 10 minutes, 15 minutes, 1 hour, 1 day, and 1 month, which represent the prevailing operational scales within the monitoring networks considered. The most pronounced steps in the curve

509 occur at these classes, indicating that a substantial portion of the total data is concentrated in
510 these temporal intervals.

511 It is also evident that there is a wide variability in the effective acquisition frequency. This
512 behavior reflects the presence of irregular or discontinuous time series, where the nominal
513 frequency does not always correspond to actual data continuity (for example, hourly series
514 characterized by interruptions or inactive periods). This variability underscores the complexity
515 of harmonizing heterogeneous datasets and highlights the importance of a database structure
516 capable of handling both the nominal sampling frequency and its actual temporal regularity.

517 Overall, the figure illustrates how the collected data integrate multi-temporal information,
518 combining continuous acquisitions with periodic or event-based sampling. This temporal
519 diversity enables a more comprehensive representation of sediment and hydraulic dynamics
520 across different spatial and temporal scales.



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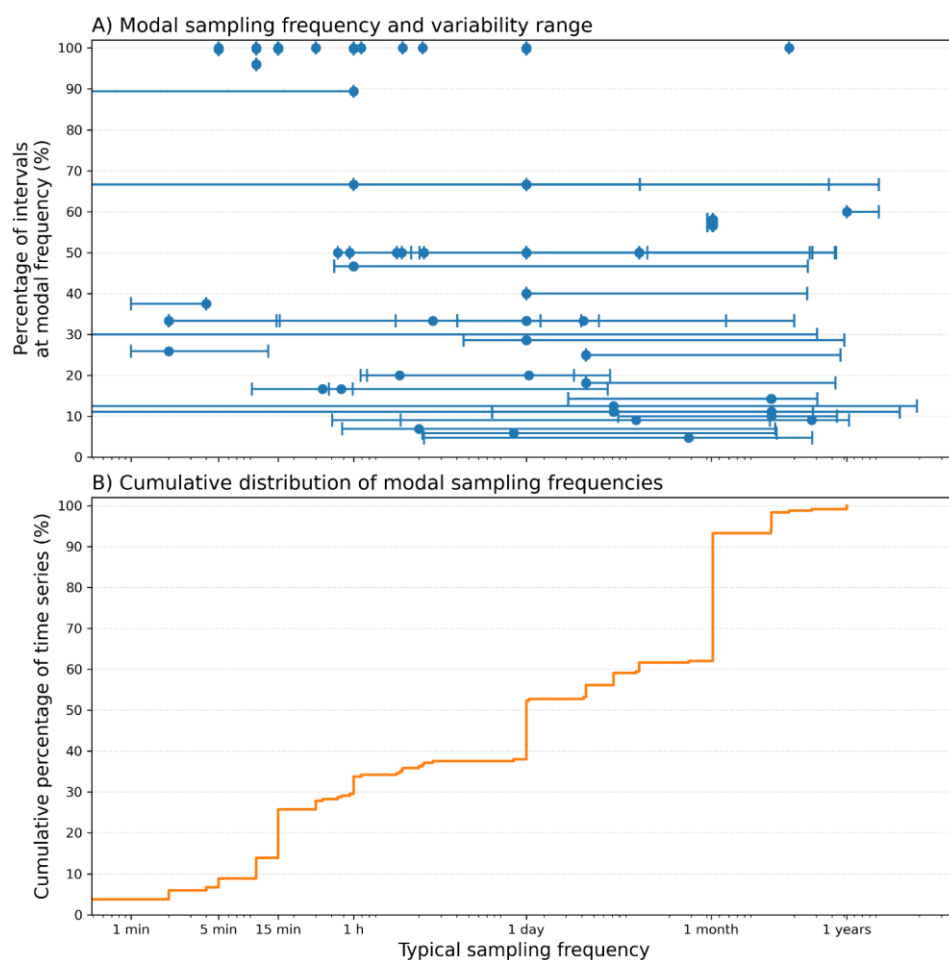


Figure 7 Sampling-frequency characteristics of the time series included in the database. (A) Modal sampling frequency of each time series, expressed as the percentage of intervals corresponding to the most frequent temporal resolution; horizontal bars indicate the variability range of observed sampling intervals. (B) Cumulative distribution of modal sampling frequencies, showing the proportion of time series acquired at temporal resolutions equal to or finer than each frequency class. The figure highlights the coexistence of high-frequency, daily, monthly, and lower-frequency records within the database. Distribution of typical sampling frequencies (blue dots) with minimum–maximum range (horizontal bars) and cumulative percentage of data (orange line). The figure highlights the coexistence of different temporal resolutions, from sub-hourly to annual, and shows that the most represented frequencies correspond to 10 minutes, 15 minutes, 1 hour, 1 day, and 1 month. The width of the ranges indicates that, in several cases, data acquisition is irregular or not continuous over time.

Figure 8 Figure 7 represents the annual temporal coverage of the data available for the parameters included in the database. For each parameter, the number of active time series was calculated for each year, where an active time series is defined as a series with at least one available record in that year. For each parameter, the temporal coverage of the available time series was reconstructed to identify periods of activity and data continuity. The

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total number of time series available for each parameter is reported in square brackets to contextualise the extent of the dataset. The dataset, total number of historical series available for each category is reported to contextualize the extent of the dataset. It should be noted that the bars represent annual data availability and do not imply homogeneous monitoring frequency within or among years.

In this sense, Figure 8 should be interpreted together with the monitoring-frequency analysis reported in Figure 7, which specifically describes the typical temporal resolution of the records included in the database.

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The analysis reveals that the temporal extent of the datasets varies widely across parameters, reflecting the diversity of monitoring networks and measurement techniques adopted over time. Some parameters exhibit very long time series, often beginning in the 1940s or 1950s and continuing up to the present day. This is particularly evident for flow rate, which shows the largest number of series and the longest temporal span, making it one of the most consistently monitored variables in terms of temporal coverage. However, the frequency of observation may vary substantially across stations, parameters, and periods. Older records, in particular, may be less frequent, less regular, or less standardised than more recent datasets, depending on the original monitoring programme and data source. Other hydrological parameters, such as flow height and Monthly Suspended Sediment Load (MSSL), also display extended observation periods and numerous records, partly due to the long-standing tradition of monitoring discharge and sediment dynamics in some of the major Italian river basins (e.g., Arno and Ombrone rivers River, Ombrone River).

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Conversely, parameters of a more specific nature or associated with newer measurement technologies—such as turbidity, electrical conductivity, pH, and major ions—show shorter and more discontinuous time series, often limited to the past two decades. This reflects both the recent introduction of dedicated automatic sensors and the historical heterogeneity in the availability of physicochemical/physic-chemical data.

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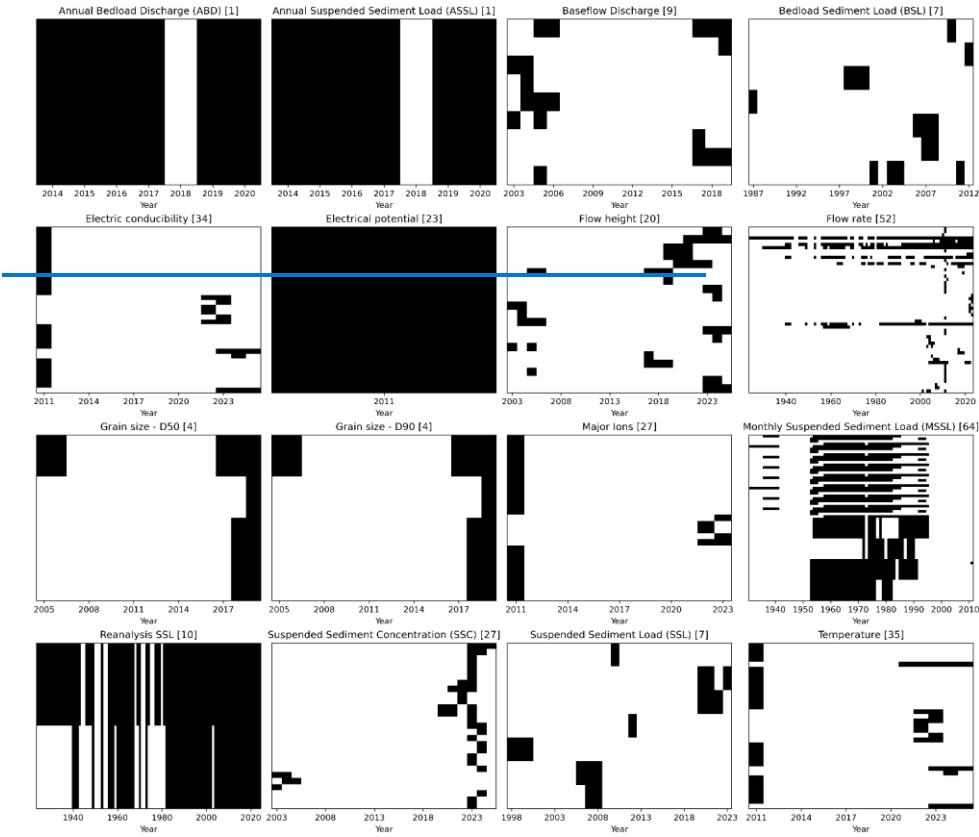
Parameters related to sediment transport also exhibit significant variability. While annual datasets such as ABD and Annual Suspended Sediment Load (ASSL) are generally shorter and concentrated within specific periods, others—such as Bedload Sediment Load (BSL) and SSC—show more fragmented temporal coverage, alternating between phases of intensive monitoring and intervals without data acquisition. In several high-mountain catchments, suspended sediment monitoring is often seasonal, as sensors are removed during winter months (typically from November to May) due to harsh environmental conditions. This pattern reflects not only logistical constraints but also the strong morphoclimatic contrasts that characterise Italy, where monitoring strategies are necessarily adapted to markedly different environmental settings.

Overall, the figure highlights the temporal complementarity among the different types of data: some measurements, such as discharge or flow height, provide long and continuous records, while others, more specialized, offer detailed but discontinuous insights into fluvial dynamics and sediment transport processes. Overall, the figure highlights the heterogeneous temporal coverage among the different types of data: some measurements, such as flow rate or flow height, provide long temporal records, while others, more specialised, offer detailed but discontinuous insights into fluvial dynamics and sediment transport processes. This heterogeneity, and particularly the lack of simultaneous measurements among some parameters and monitoring stations, may limit integrated analyses of hydrological, physicochemical, and sediment transport processes. Therefore, Figure 8 should be interpreted as an aggregated descriptive overview of temporal data availability rather than as a direct measure of uniform monitoring effort or sampling frequency through time. Differences in temporal coverage and monitoring frequency are an inherent characteristic of the compiled database and are further documented by the monitoring-frequency analysis shown in Figure 7. These aspects should therefore be considered when using the dataset for comparative, temporal, integrated, or trend-based analyses.

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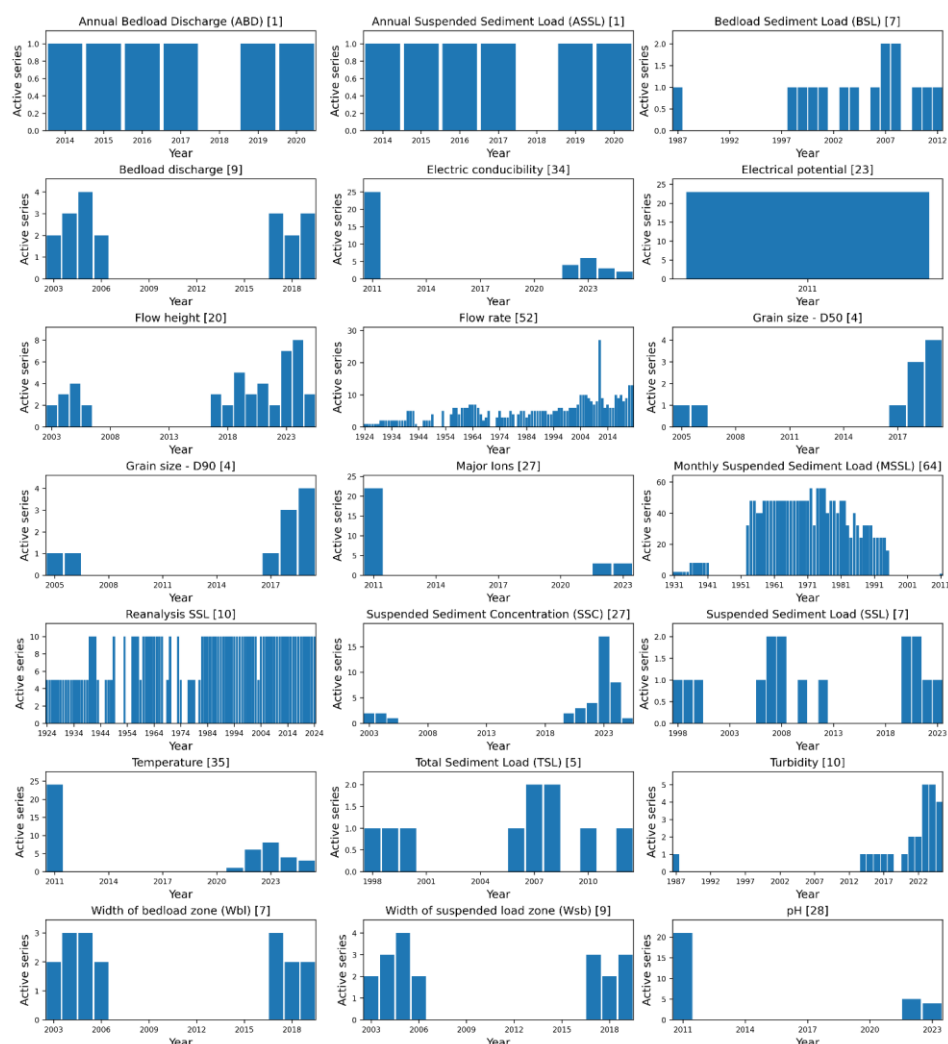


Figure 87 Annual temporal coverage of the parameters included in the database. Each panel refers to one parameter, and the bars indicate the number of active time series for each year, defined as time series with at least one available record in that year. Observation periods for the sixteen parameters included in the database. Each black bar represents the time interval during which a time series is active, while the number in square brackets indicates the total number of series available for each parameter. The figure highlights the marked heterogeneity in the duration and continuity of the datasets, with some hydrological variables (e.g., Flow rate) monitored over several decades and others, of physico-chemical or sedimentological nature, characterized by more recent and fragmented time series.

Figure 9 summarizes the spatial distribution of these data across the analyzed river basins. The four panels respectively show: the number of rivers for which observations are available (top left), the total number data records (top right), the number of monitored parameters (bottom left), and the total number of measurement points in each basin (bottom

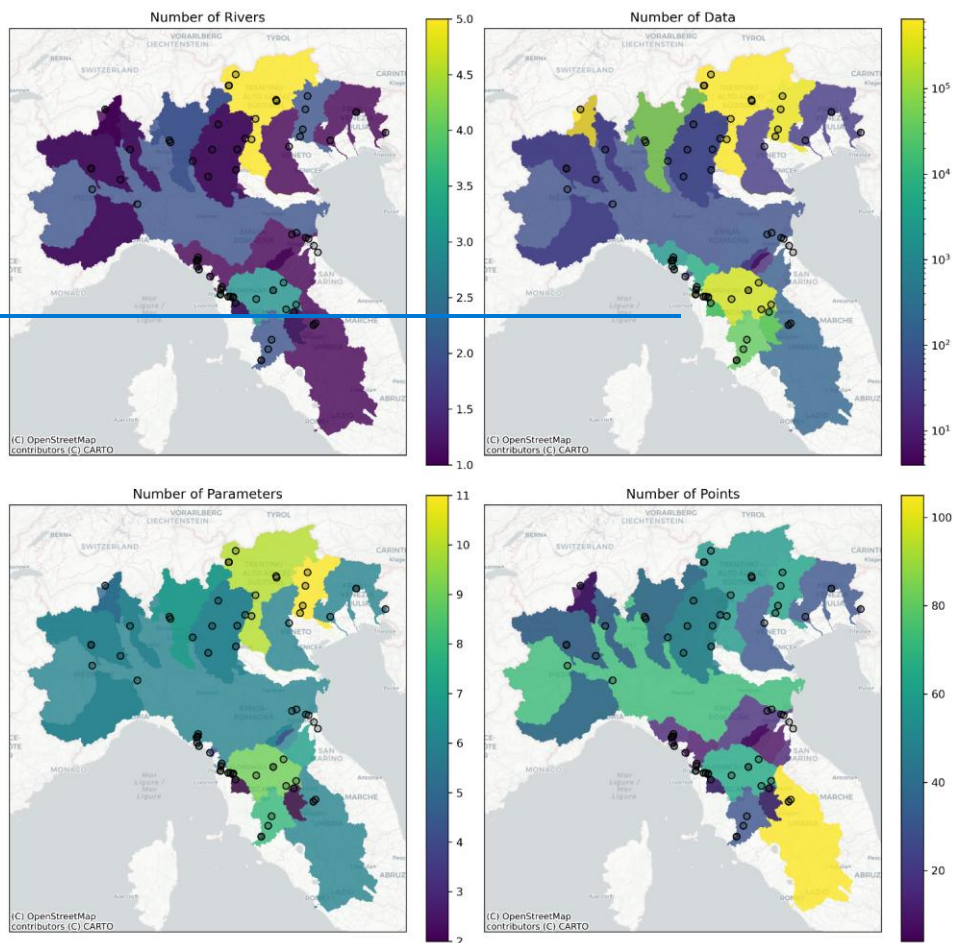
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606 right). The database currently includes data from 29 river basins out of the 272 that cover the
607 entire Italian peninsula. At present, the dataset is primarily populated with basins from
608 northern and central Italy, while southern regions and the major islands remain
609 underrepresented.

610 The analysis reveals a notable heterogeneity in spatial coverage and data density. Some basins,
611 particularly those in northern Italy, such as the Po, Adige, and Tagliamento, show a higher
612 concentration of information, both in terms of the number of measurement points and the
613 range of parameters observed. In these cases, monitoring networks are more complex and
614 include several rivers and sub-basins, reflecting a stronger historical and institutional focus on
615 sediment transport and fluvial dynamics monitoring.

616 Conversely, the basins of central Italy generally have fewer observation points and monitored
617 parameters. In these areas, monitoring activities are more sporadic or limited to short periods,
618 often associated with specific research projects or local management initiatives.

619 The panel showing the total number of data also highlights that the amount of available
620 information depends not only on the number of monitoring sites but also on the temporal
621 frequency of observations. Basins with fewer stations but high-frequency monitoring can,
622 indeed, provide data volumes comparable to those of larger networks with lower-frequency
623 time series.



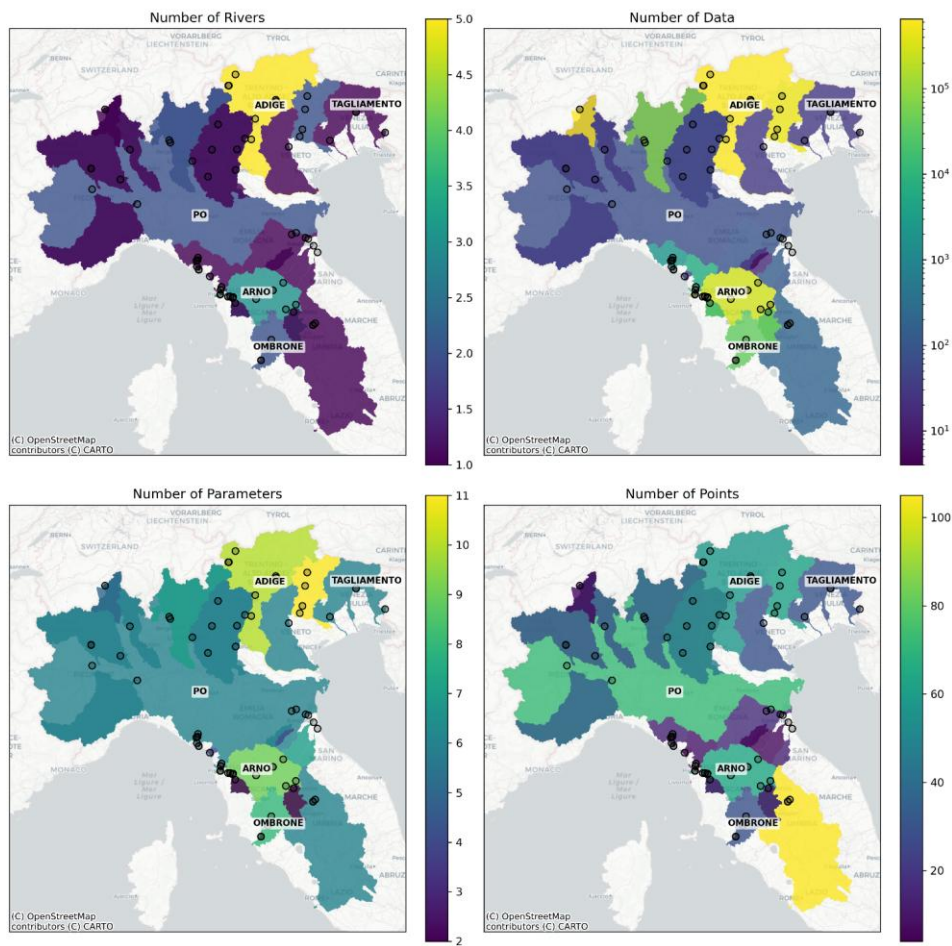


Figure 98 Distribution of sediment transport data by river basin. The panels show (clockwise from top left): the number of rivers analyzed, the total number of recorded data, the number of measurement points, and the number of monitored parameters for each basin. The figure highlights the strong spatial variability in data coverage and density, with higher concentrations in northern Italy compared to central and southern basins. The points indicate the location of the measurement sites.

3.2 Sediment load parameters: basin-scale analysis

The analysis presented in this section focused exclusively on data related to parameters directly connected to sediment transport, including both suspended and bedload components. Specifically, the following parameters were considered: *suspended sediment concentration deviation (SSCD)*, *suspended sediment load (SSL)*, *suspended sediment concentration (SSC)*, *monthly suspended sediment load (MSSL)*, *annual suspended sediment*

load (ASSL), annual bedload discharge (ABD), bedload sediment load (BSL), total sediment load (TSL), total suspended solids (TSS), turbidity, grain size – D50 and grain size – D90.

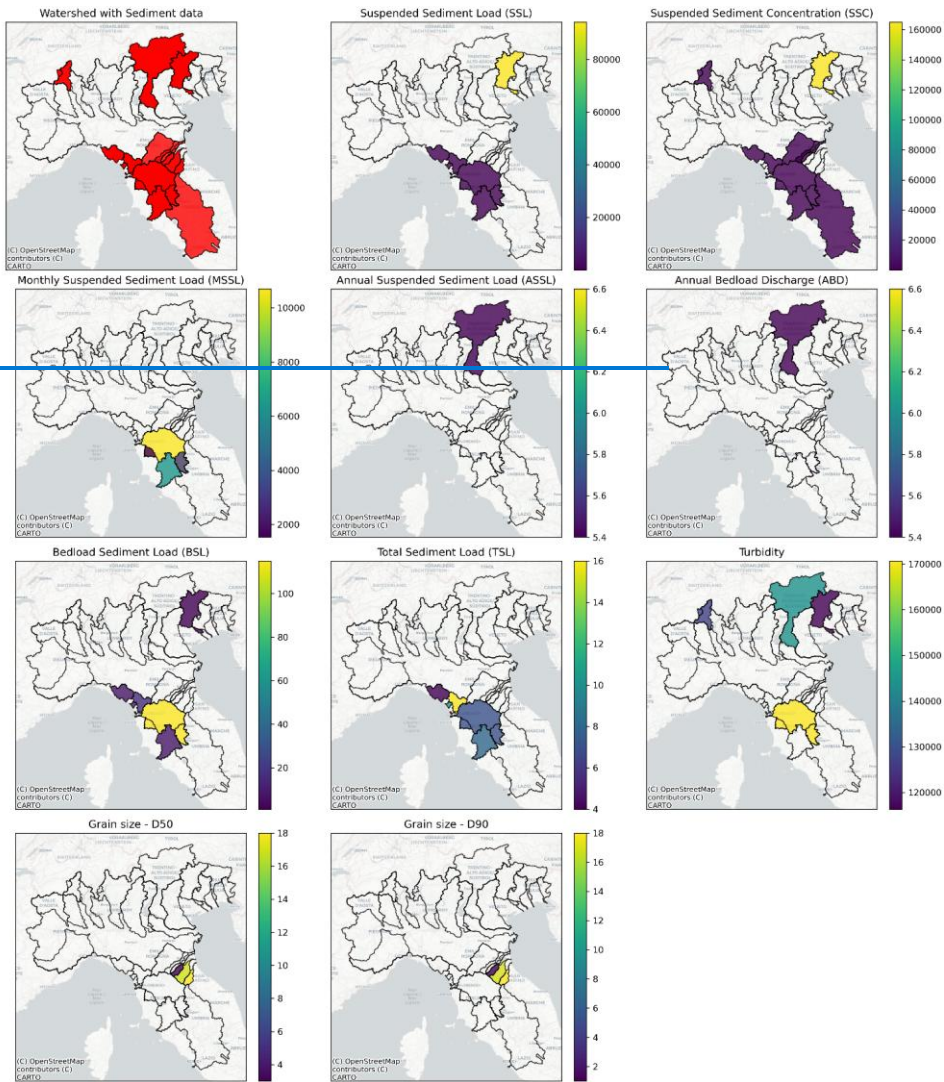
Figure 10 shows the actual distribution of sediment transport data, distinguishing between suspended and bedload components. In the top-left panel, river basins highlighted in red correspond to those for which the database contains at least one sediment transport parameter (watersheds-basins with sediment data), while the remaining basins, outlined in black, are included in the database but associated only with other types of parameters (hydrological, physico-chemical, etc.).

The other panels provide a detailed view of the number of available data for each specific parameter within every river basin, allowing the identification of the most monitored areas. The SSL and SSC are the most commonly represented parameters, with extensive data in the river basins of northern Italy (particularly the Po-Plave and Adige) and central Italy. The MSSL, on the other hand, shows a more localized distribution, with significant values in a few basins, mainly in Tuscany.

Annual parameters such as ASSL and ABD show data concentrated in a single northern basin, reflecting the more complex and resource-demanding nature of these measurements. The BSL shows a similar pattern, with higher values in the Arno basin (central Italy), where direct measurements of bedload transport are available.

The TSL is present only in a limited number of basins, generally derived from the combination of suspended and bedload monitoring data. Finally, turbidity emerges as one of the most widespread parameters in the central and northern basins, due to the greater availability of optical sensors and its direct correlation with suspended sediment concentration.

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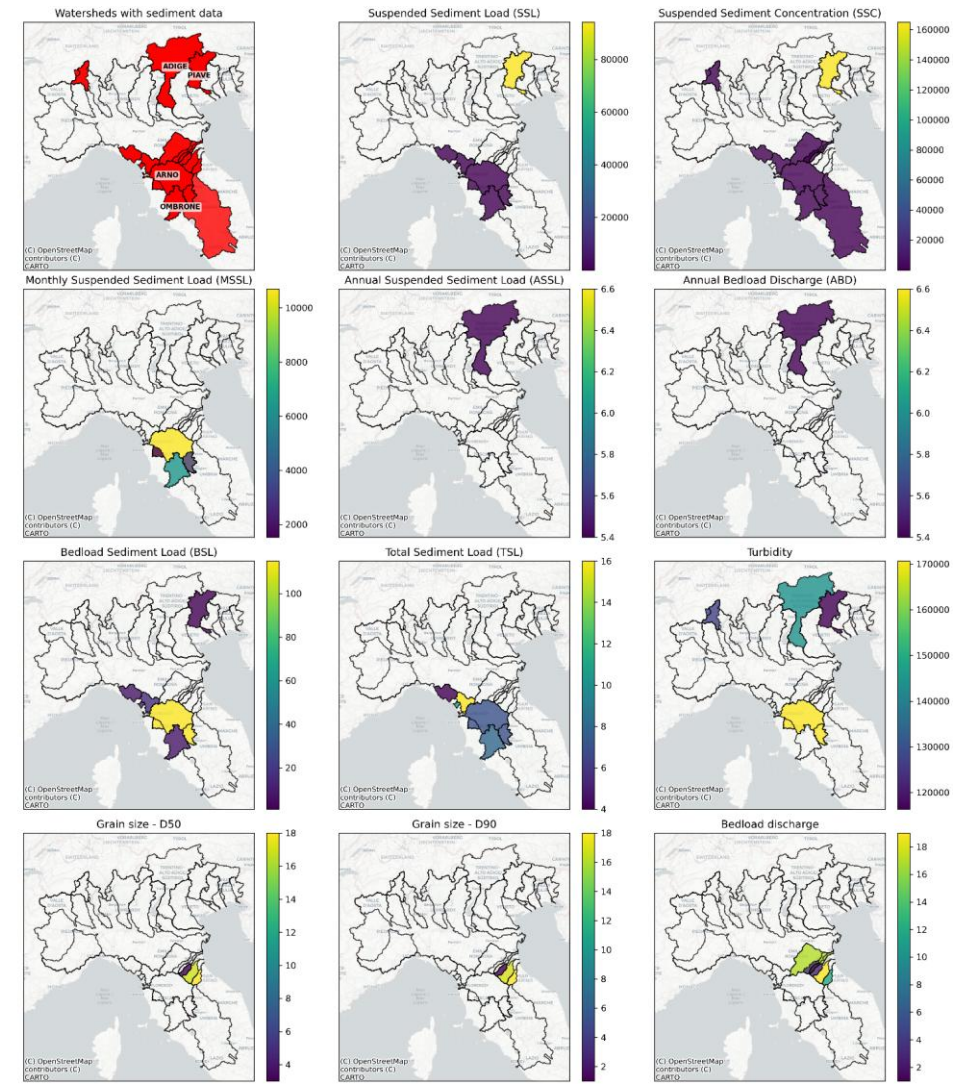
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4 Figure 109 Spatial distribution of sediment transport data for each parameter considered. In the top-left panel, red basins indicate watersheds containing at least one sediment transport parameter, while the remaining basins, outlined in black, are included in the database but associated only with other types of parameters. The other panels show, for each sediment-related parameter, the number of available records within each basin. Colour scales are panel-specific and should not be directly compared across parameters; in each panel, colours represent the number of available records for the corresponding parameter. Spatial distribution of sediment transport data for each parameter considered. In the top-left panel (in red), basins containing at least one sediment transport parameter are shown. The other panels illustrate, for each specific parameter, the total number of data available per basin. The figure highlights the uneven spatial coverage of sedimentological parameters, with a higher concentration of information in the river basins of northern and central Italy.

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673 **54**Discussion and Conclusions

674 The aim of this study was to develop a relational database and a web interface dedicated to the
675 storage, consultation, analysis, and export of fluvial sediment transport data. This initiative
676 responds to the growing need in geosciences and environmental management for information
677 systems capable of integrating, standardizing, and making accessible heterogeneous datasets
678 that are historically fragmented and dispersed (Bailo et al., 2023; Parsons & Fox, 2013; Vitolo et
679 al., 2015). This approach is consistent with European directives and policies on environmental
680 and public-sector data sharing, particularly the INSPIRE Directive 2007/2/EC and the Open
681 Data Directive (EU) 2019/1024, as well as with international open data practices. These
682 frameworks emphasise that interoperability, accessibility, reusability, and metadata
683 completeness are fundamental elements for the effective use and enhancement of
684 hydrological and sedimentological data. This approach is consistent with recent European
685 directives on environmental data sharing and with international open data practices, which
686 emphasize that interoperability and metadata completeness are fundamental elements for the
687 effective use and enhancement of hydrological and sedimentological data. (Cho & Cromptvoets,
688 2019; Jacob et al., 2025; Matthews et al., 2023). The relevance of such an integrated
689 information system also extends to the implementation of the Water Framework Directive
690 (2000/60/EC). The Common Implementation Strategy guidance on integrated sediment
691 management explicitly recognises sediment quantity, continuity, and quality as important
692 components of river basin management and stresses the need for appropriate information to
693 support their assessment within River Basin Management Plans (European Commission,
694 2022). In this context, a harmonised and accessible sediment transport database can provide
695 a valuable knowledge base for assessing sediment dynamics, identifying monitoring gaps, and
696 supporting integrated sediment management at the river-basin scale.

697 In this context, the comparison with established hydrological infrastructures such as GRDC
698 (Färber et al., 2025)- and GSIM (Do et al., 2018) highlights both the relevance and the current
699 gap in sediment data integration. While streamflow monitoring has progressively evolved
700 toward coordinated international frameworks supported by standardized metadata protocols
701 and long-term institutional cooperation, sediment transport data have not yet reached a
702 comparable level of structural organization. This disparity is not only technical but also
703 institutional, reflecting differences in monitoring continuity, data ownership, and
704 harmonization practices. The database developed in this study contributes to reducing this gap
705 at the national scale by providing a structured environment for data standardization and
706 controlled access. Although it does not yet represent a fully institutionalized infrastructure
707 comparable to large international repositories, it establishes the foundational architecture
708 upon which broader coordination and future integration efforts can be built.

709 The results, showing the data distribution in the time interval 1924-2025, revealed marked
710 variability in the instrumentation used to measure and monitor the different parameters. Some
711 parameters, such as electrical conductivity or pH, are characterized by nearly uniform

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instrumentation, reflecting their standardize measurement methods. Conversely, more complex parameters such as Suspended Sediment Concentration (SSC) or Turbidity, show a wide diversification of instruments, indicating the coexistence of direct and indirect measurement approaches. This heterogeneity, while ~~limitating~~ limiting the direct comparability of data, also constitutes an informative resource, as it reflects the diversity of local characteristics and operational contexts in which the monitoring activities were carried out (Fратиanni & Acquaotta, 2017; Fredi & Lupia Palmieri, 2017; Wang et al., 2022).

However, the presence of data without information on the measuring instrument ("unknown instrument") highlights the importance of traceability and metadata completeness, a topic already emphasized in the sediment monitoring literature (Walling, 2006).

The analysis of sampling frequencies and the temporal extent of time series revealed considerable temporal heterogeneity in the datasets. Sampling frequencies range from sub-hourly to annual measurements, while the duration of the series varies from a few years to more than seven decades. This discontinuity limits the possibility of conducting consistent and comparable temporal analyses and represents one of the most common challenges in managing long-term environmental data (Ellingsen et al., 2017; Nejad et al., 2024; Syvitski et al., 2005). It is therefore necessary to distinguish between nominal and effective acquisition frequency, document the actual regularity and completeness of the series, and develop automatic quality control procedures.~~document the actual regularity of the series and develop automatic quality control procedures.~~ In this context, the proposed database supports preliminary data-quality assessment by allowing users to rapidly visualise temporal coverage, acquisition frequency, and data gaps.~~The proposed database provides a useful platform in this regard, allowing for a rapid visualization and analysis of temporal distribution and data gaps.~~ These diagnostics help identify discontinuities, irregular sampling intervals, and periods requiring further verification, thereby providing a basis for documenting the effective completeness of each time series and guiding subsequent quality-control procedures.

From a spatial perspective, the basin-scale analyses showed a high concentration of data in northern Italian Alpine river basins, particularly the Adige (Bonfrisco et al., 2025) and Piave (Pellegrini et al., 2023b; Rainato et al., 2017, 2025b).~~Central Italian basins are less represented, although data are available for some smaller river basins, such as the Versilia River (Francalanci et al., 2013b). Southern Italian basins are almost entirely absent from the database.~~ From a spatial perspective, the basin-scale analyses showed a high concentration of data in northern Italian basins, particularly the Adige (Bonfrisco et al., 2025) and Piave (Pellegrini et al., 2023b; Rainato et al., 2017, 2025b), while central Italian basins are less represented.~~Although data are also available for smaller river basins, such as the Versilia River (Francalanci et al., 2013b) —and southern basins are almost entirely absent.~~ This distribution reflects the historical development of monitoring networks, primarily established in areas with higher anthropogenic pressure and hydrogeological risk, but it also highlights the need for a more balanced territorial coverage. Parameters such as SSC and Turbidity are widespread and well-documented, whereas others, such as BSL or TSL, show limited coverage, being measured only at a few

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locations. This imbalance highlights the technical and operational complexity of bedload measurements and also suggests the need for strategies that combine direct and indirect approaches to broaden the available dataset. It should be noted, however, that the apparent absence of data in southern Italy may reflect both a lower historical monitoring intensity and a limited response to the present data call. Therefore, the current spatial pattern should not be interpreted as a complete lack of sediment monitoring activities in these regions, but rather as an indication of the present state of data collection within the framework of this database. Further engagement with regional institutions may help improve territorial representativeness in future updates. In addition, the database is currently dominated by datasets derived from research initiatives, while data routinely collected by regional and national environmental agencies are still only partially represented. This likely results in a more fragmented picture than the actual potential availability of sediment monitoring data at the national scale, further underscoring the need for stronger institutional collaboration in future database expansions.

[The experience gained in building the database made it possible to identify both the limitations and the potential of the data collection and integration process. Among the main limitations are the difficulty of harmonising pre-existing formats, the lack of uniform metadata, the need for manual data validation procedures, and the dependence on voluntary contributions from individual researchers and institutions conducting monitoring activities. This latter aspect may affect both the completeness and representativeness of the dataset and also raises broader issues related to data responsibility, long-term maintenance, and institutional accountability.](#)

[To address these limitations, future development of the database will focus on several practical steps. First, a minimum metadata template will be defined for new contributions, including information on measurement methods, instruments, units, sampling frequency, temporal coverage, uncertainty, and monitoring conditions. Second, semi-automatic validation procedures will be implemented to identify missing metadata, inconsistent units, duplicated records, anomalous values, and temporal gaps before data are integrated into the database. Third, the platform will be progressively used as an operational reference for data producers, helping them identify data gaps and harmonise future monitoring activities before new field campaigns are planned.](#)

[However, technical solutions alone are not sufficient. The long-term effectiveness of the database will also depend on clearer governance mechanisms, stable institutional involvement, and agreed procedures for data submission, validation, updating, and citation. Bureaucratic constraints, fragmented responsibilities among agencies, and the absence of formal obligations to share sediment transport data may remain major obstacles to the creation of a fully comprehensive national archive. For this reason, one of the future priorities will be to strengthen collaboration with public authorities, river basin districts, regional agencies, and research institutions, with the aim of moving from voluntary data contributions toward more structured and documented data-sharing workflows.](#)

Nevertheless, the relational structure and the developed platform demonstrate the effectiveness of a scalable system capable of integrating heterogeneous information and providing a coherent overview of hydro-sedimentary observations at the national scale. While historical datasets may inevitably retain some limitations inherited from their original sources, future data collected within or in relation to this framework can achieve higher levels of metadata completeness, traceability, quality control, and reusability.

~~The experience gained in building the database made it possible to identify both the limitations and the potential of the data collection and integration process. Among the main limitations are the difficulty of harmonizing pre-existing formats, the lack of uniform metadata, and the need for manual data validation procedures. An additional constraint is that data acquisition currently relies largely on voluntary contributions from individual researchers and institutions conducting monitoring activities, which may affect both the completeness and representativeness of the dataset. Nevertheless, the relational structure and the developed platform demonstrated the effectiveness of a scalable system capable of integrating heterogeneous information and providing a coherent overview of hydro-sedimentary observations at the national scale.~~

The results of this study suggest several methodological guidelines for the future management of sediment transport data. First, it is essential to promote the standardization of instrumentation and measurement protocols, ensuring the traceability of procedures and the comparability of results. Second, the systematic recording and preservation of metadata—, including metadata related to effective acquisition frequency,—should become a consolidated practice. Third, spatial coverage of monitoring networks must be rebalanced by strengthening underrepresented areas and promoting the integration of local data into a coordinated national system. Finally, adopting interoperable and open-source data architectures is key to ensuring the scalability and long-term usability of the system.

In conclusion, this work demonstrates that, despite the fragmentation and gaps in the available data, it is possible to build a coherent and functional database capable of enhancing the existing information assets. The gained experience highlights the need to develop dedicated information infrastructures for an integrated management of sediment transport data, supporting both scientific research and environmental planning. This study, therefore, represents a concrete step toward the creation of a national reference system for the monitoring and analysis of fluvial sediment transport. The developed database provides a robust and effective framework for data organization, harmonization, and accessibility, and it is designed as an open and updatable tool, allowing future uploads and continuous integration of new datasets. Its long-term effectiveness, however, will largely depend on the progressive expansion and completion of the dataset through the inclusion of high-quality data, i.e., datasets accompanied by consistent metadata, clear methodological documentation, and adequate temporal and spatial coverage.

828 **65**Author Contributions

829 Conceptualization: Luppichini M., Bini M., Comiti F.;

830 Methodology: Luppichini M., Bini M., Comiti F.;

831 Software: Luppichini M.;

832 Data curation: Luppichini M., Donnini M., Andreoli A., Innocenti L., Picco L., Chirici D., Brenna

833 A., Billi P.; Longoni L.; [Ciavola P.](#);

834 Formal analysis: Luppichini M., Bini M.;

835 Investigation: Luppichini M.;

836 Visualization: Luppichini M.;

837 Writing – original draft: Luppichini M., Bini M.;

838 Writing – review & editing: All authors;

839 Supervision: Comiti F., Bini M.;

840 Project administration: Bini M., Comiti F.;

841 Funding acquisition: Bini M.

842 **76**Competing Interests

843 The authors declare that they have no conflict of interest.

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847 change (GEOALL)” of the Italian Association of Physical Geography and Geomorphology

848 (AIGeo).

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853 **109** Data availability

854 The Italian Fluvial Sediment Transport Database, described in this paper, is publicly available
855 at Zenodo: <https://doi.org/10.5281/zenodo.18799025> (Luppichini et al., 2026). The archived
856 version (v1.0) represents a frozen and citable release of the PostgreSQL relational database and
857 includes the complete dataset and database structure necessary to ensure reproducibility and
858 long-term accessibility.

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859 The database can also be explored through a dedicated web application
860 (<https://lca.dst.unipi.it/SedimentTransport/>), which provides dynamic access to the data
861 following a brief registration procedure. While the web interface facilitates data consultation
862 and querying, the Zenodo archive constitutes the reference version for citation and
863 reproducibility purposes.

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