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A long-term dataset on hydrology and suspended sediments in the Kamech catchment from the OMERE Observatory

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Abstract

The Mediterranean region is characterized by a highly variable climate marked by prolonged dry spell interspersed with intense rainfall events mainly in autumn. These climatic extremes exacerbate droughts, flash floods and soil erosion, resulting in significant environmental and agricultural challenges across Mediterranean catchments. The dynamics of water and sediment fluxes in these environments are the result of complex interactions between climate, land use and management. Understanding these dynamics is crucial for recommending effective management strategies to mitigate erosion and runoff impacts. However, high-frequency datasets for both hydrology and sediment fluxes are often lacking for small Mediterranean catchments in North Africa, thus rendering these processes poorly understood.

In this context, the Kamech Critical Zone Observatory was established in 2004 to document high-frequency rainfall, discharge, and sediment fluxes across the 2.63 km² Kamech catchment in Cape Bon, Tunisia, which is dominated by Vertisols. The monitoring system comprises four nested hydrological stations, ranging in scale from the plot to the outlet of the catchment area. The longest time series covers almost 30 years. This article synthesizes the datasets of the observatory related to evaporation, rainfall, discharge and suspended sediment concentration. It describes the methodologies used to collect and process the data, including procedures for assessing data quality. It also suggests additional synthetic time series to facilitate subsequent hydrological analysis. Finally, it presents some preliminary explorations of the datasets and it suggests avenues for further studies. All datasets referenced in this work are openly accessible via the repository: https://doi.org/10.23708/PPPPDL (Raclot and Hamdi, 2025).

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1. Introduction

Mediterranean areas face major challenges linked to soil erosion by water, due to their marked relief, frequently sparse vegetation caused by drought or fire, high frequency of intense rainfall and lithologies that are sensitive to meteorological conditions (García-Ruiz et al., 2013). These challenges are also induced by a long history of human occupation with cultivation prone to erosion such as vineyards (Cerdan et al., 2010). Furthermore, the shift from extensive to intensive agriculture during the 20th century has further exacerbated flood and erosion phenomena in some places (Patault, 2018). All these natural and anthropogenic factors explain that measurements of erosion exports in watercourses are ranked among the highest in the world (Woodward, 1995; Vanmaercke et al., 2011), generating sedimentation in water bodies, reducing dam capacity, safety and cost effectiveness (Palmieri et al., 2001) and impacting long-term water availability (de Araújo et al., 2014).

The global changes taking place in the Mediterranean region are likely to amplify the threat to water and soil resources (Raclot et al., 2018). In a recent study, Vicente-Serrano et al. (2025) showed that the Mediterranean region is undergoing a process of increasing climatic aridity due to a stationary of annual precipitation and a significant increase in atmospheric evaporative demand. If precipitation has largely remained stationary from 1871 to 2020, these authors identified significant multi-decadal and interannual variability. Moreover, Diodato and Bellocchi (2014) identified a significant increase in extreme precipitation. Long-term data sets from observatories are one of the most effective means of understanding the impact of climate change on the hydrological response and anticipating and adapting to future conditions (Vallebona et al., 2015, Cid et al., 2017, Folton et al., 2020).

Long-term hydrological monitoring infrastructures have been developed to document the hydrological response and the key factors and processes involved. They aim to provide a solid basis for anticipating the hydro-erosive risk and defining mitigation strategies to reduce these negative impacts. Among them, we may cite the "Critical Zone Collaborative Network" (CZNet, https://criticalzone.org/), which is the next phase of NSF's Critical Zone research initiative, or the "Critical Zone Observatories: Research and Application (OZCAR, https://www.ozcar-ri.org/), which is a French distributed research infrastructure dedicated to the observation and monitoring of the Critical Zone.

In small Mediterranean catchments, interest in hydro-sedimentary observations stems from the complex interaction between climate, geological composition, agricultural practices, and hydrological dynamics in a context of intermittent regime. By analyzing the response of eight small Mediterranean catchments across different environments, Smetanová et al. (2018) showed that the runoff and erosive response occurs generally in a very limited number of days by year (i.e., high time compression). These authors also demonstrated that the extent and seasonality of the hydro-erosive response can differ significantly between catchments, and that this information is crucial for selecting and sizing flood and erosion risk mitigation measures adapted to local conditions.

OMERE observatory (https://www.obs-omere.org/) is a long-term observatory of soil and water resources, in interaction with agricultural and land management in Mediterranean hilly catchments. It was created in 2002 to fill the lack of long-term environmental observatories in the Mediterranean region (Molenat et al., 2018). It is part of the

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French network of critical zone observatories OZCAR (Gaillardet et al., 2018) and the European eLTER (European Long-Term Ecosystem, critical zone and socio-ecological Research) network. The OMERE observatory is composed of two Mediterranean agricultural catchments, the Roujan catchment located in France and the Kamech catchment located in Tunisia. Molenat et al. (2018) detailed the specificities and complementarities of these two catchments. A significant feature of the Kamech catchment is the high proportion of vertisols, which exhibit shrinkage cracks for much of the year as a result of swelling and shrinkage processes (Inoubli et al. 2016).

As continuous hydro-sedimentary measurements covering almost thirty years are extremely rare in small southern Mediterranean catchments, it is important to make these observations publicly available. Indeed, it will provide the international scientific community, where comparable datasets are scarce, with a valuable reference for comparative studies, model calibration and designing management and adaptation strategies.

In this paper, we present the data related to hydrological and suspended-sediment fluxes at four nested hydrometrics stations in the Kamech catchment, as well as the precipitation and evaporation data related to climatic forcing. The paper first describes the study site and the monitoring system. It then details the monitoring and data-processing procedures. A first exploration of the database then provides some key elements on the hydro-erosive response observed in the Kamech catchment, and investigates trends in the rainfall, runoff and erosion time series. In the final section, the interest of the data presented is highlighted by a selection of previous studies and open questions.

2. Presentation of the Kamech catchment and the monitoring infrastructure

The Kamech catchment area (36.877° N, 10.878° E) is located on the Cap Bon peninsula in northern Tunisia (Fig. 1).

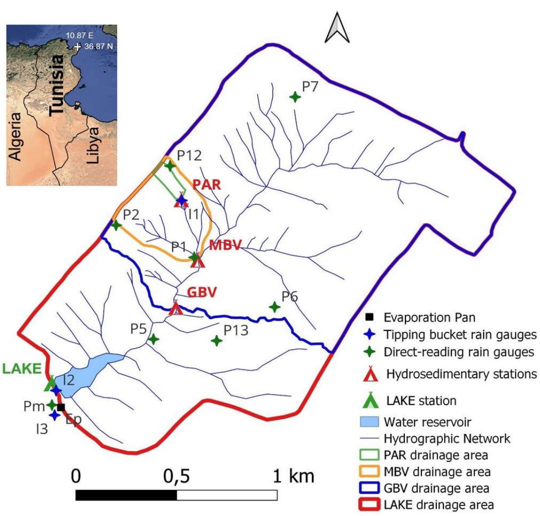

Figure 1. Long-term monitoring infrastructure related to rainfall, discharge and suspended sediment in the Kamech catchment (OMERE observatory).

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The Kamech catchment area is a hilly landscape, with altitudes ranging from 95 to 203 m and with a moderate to fairly steep relief including slopes that locally exceed 100%. The main parent material in the region is a slightly calcareous laminated mudstone inherited from Miocene marine deposits. The top of the slopes is made up of sandstone outcrops inherited from intercalations of hard sandstone in the parent material. The soils along the hillslopes are directly developed mainly with colluvial processes over and from the Miocene deposits. In descending order of importance, soils can be classified as Vertisols, Calcisols, Cambisols and Leptosols (IUSS Working Group WRB, 2022). According to Khairallah (2025), "soils in the study site area are very clayey (mean and median value to 49 and 53 %, respectively), with a very low fraction of coarse elements (mean and median value to 1.7 and 0.6 %, respectively), with pH ranging from 8 to 9, and very low to moderate soil inorganic carbon content varying from 1 to 30 g kg^{-1}. Approximately two-thirds of the soils in the catchment show significant active shrink-swell processes that significantly impact water and sediment delivery (Inoubli et al., 2016). This high proportion of soils dominated by shrink-swell processes makes Kamech an original observatory among existing Mediterranean agro-hydrological observatories. Land use is dominated by annually tilled farmland, including cereal crops and, to a lesser extent, leguminous crops. The remaining area consists of more or less degraded rangelands, housing, tracks and a water reservoir at the catchment outlet. The climate is Mediterranean, predominantly semi-arid, and characterised by pronounced seasonal variations. Summer is very dry, with daily temperatures often exceeding 30 °C and winter is rainy with temperatures averaging around 15 °C. Mean annual rainfall is 620 mm. More details on the rainfall dataset are given in Section 3.2.

The strategy for observing water and sediment flows involves high-frequency acquisition of water levels and concentrations of suspended matter in runoff water. This is achieved using four spatially nested hydrometric stations monitoring areas ranging from a single cultivated plot to the entire catchment area as shown in Fig. 1. The four hydrometric stations are illustrated in Fig. 2 and the main morphometric characteristics and soil properties of their impluvium are summarised in Table 1.

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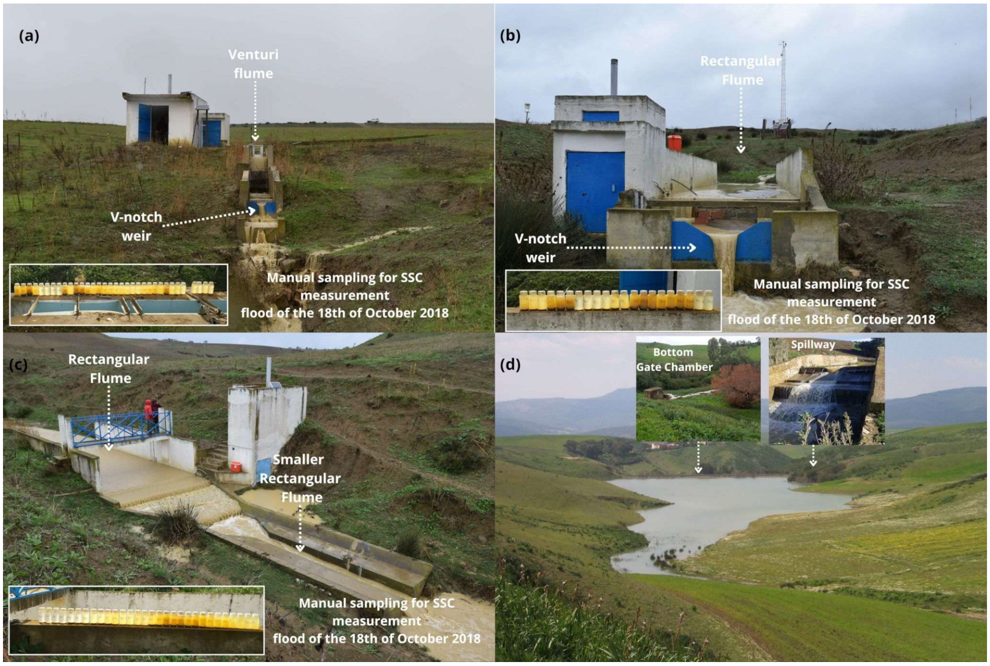

Figure 2. Series of photos illustrating the four hydrometric stations in the Kamech catchment observatory : (a) PAR station , (b) MBV station, (c) GBV station, (d) LAKE station. Photo copyright: © Damien Raclot for the main four photos and © Radhouane Hamdi for the additional small photos.

Table 1. Main characteristics of the impluvium for the four hydrometric stations.

		Impluvium			
Main characteristics		**LAKE**	**GBV**	**MBV**	**PAR**
Surface km²		2.60	1.75	0.15	0.013
slope, %	Mean	13.7	13.3	11.4	9.8
	Median	10.5	10.3	10.4	9.3
	Max	120.4	120.4	49.9	25.0
Soil types (% of area)	Vertisols	53.5	54.3	66.3	81.6
	Calcisols	21.3	23.0	11.5	14.1
	Cambisols	15.9	13.4	20.7	0
	Leptosols	9.3	9.3	1.5	4.3
Land Use (% of area)	Cultivated area	71.6	74.6	72.3	100
	Rangelands	21.4	18.4	27.4	0
	Other (housing area + tracks +...)	7	7	0.3	0

3. Data

This section describes the data relating to precipitation, evaporation and water and suspended-sediment fluxes measured on a nested observation system in the Kamech catchment. The summary of the whole measured variables with acquisition periods is presented in Fig. 3. All the automatic devices are equipped with solar panels and batteries. They are all connected to a data logger (Campbell Scientific) which controls the acquisition of the sensors, stores the data and, since 2018, uploads them remotely to a server.

This paper details how the data is collected and processed, the types of instruments used, the acquisition protocol, the pre-processing procedures (e.g., using height-discharge rating curve or a water balance model, when applicable) and the assessment of data quality.

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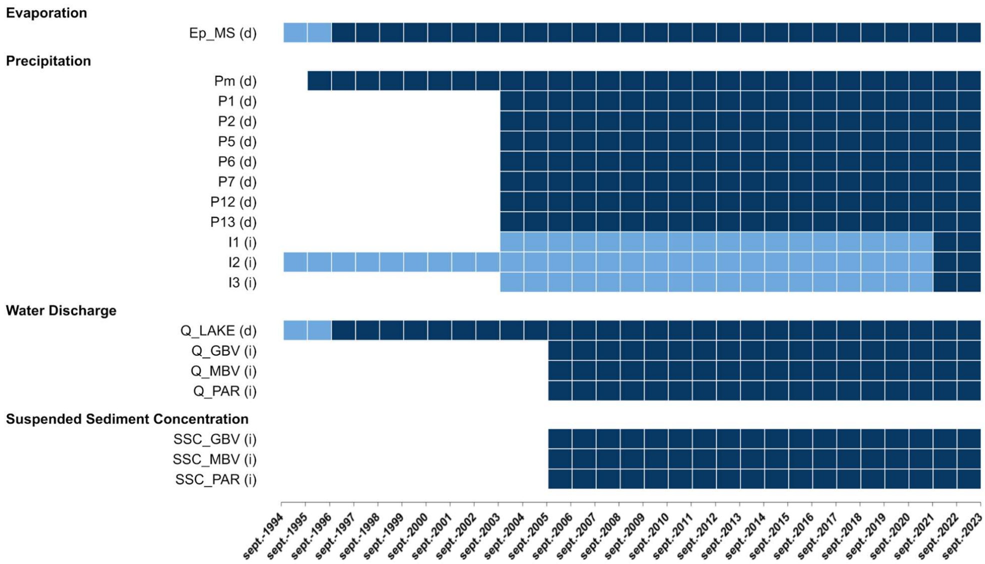

Figure 3. Acquisition period for each station and variable (1994-2023). Blue indicates qualified data in the database, light blue indicates data not yet in the database. See Fig. 1 for the location of each acquisition device.The text '(d)' is specified for daily time series and '(i)' for instantaneous time series, typically with a resolution time step of 5 minutes or less.

Codes for sources and quality qualification are presented in Table 2. Most of the data are qualified with a MB source, meaning that the data are from raw measurement. For data that have undergone corrections, a distinction is made between low- and high-magnitude corrections (i.e. MFAC and MFOC respectively). Data that are calculated from raw data, such as discharge which is derived from water level measurement, are qualified with the 'CALC' source code. Five quality codes have been distinguished to provide qualitative information on the level of data reliability as described in Table 2. When the distinction between the degree of reliability according to codes F1, F2 and F3 is not relevant, a single "F" code has been used to designate reliable data.

To facilitate future analysis of the dataset, this paper also proposed additional synthetic precipitation and discharge time series, which are developed from a combination of several individual variables or derived from gap-filled procedures.

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Table 2. Codes to qualify quality and source of each dataset.

Source code	MB	MFAC	MFOC	IND	CALC
Meaning	Raw measurements	Weakly corrected measurements	Highly corrected measurements	Indeterminate (unknown)	Calculated values
Quality code	F3	F2	F1	IND	NF
Meaning	Highly reliable	Moderately reliable	Lowly reliable	Indeterminate (unknown)	Non-reliable

3.1. Evaporation

3.1.1. Measurement

Daily evaporation is manually measured using a 1 m² Colorado-type evaporation pan located at the Meteorological Station, abbreviated as MS. Every day around 8 a.m. UTC, an operator measures the volume of water that needs to be added or removed to return to a reference level in the tank of the evaporation pan.

3.1.2. Data processing and qualification

Daily evaporation amount (in mm) is then evaluated as the difference between the volume of water measured each day in the evaporation pan and the daily rainfall measured locally in the MS. Measurement accuracy is estimated at 0.5 mm.
By default, measurements are qualified with a MB source code and a F quality code. On the infrequent days when the operator has been unable to take the measurement, a value of 'NA' is indicated with a 'IND' source code and a 'IND' quality code. The daily evaporation value for the day following a period with 'NA' is indicated with a 'MB' source code and a 'NF' quality code, and a comment indicating that it is a cumulative value is added.

3.2. Precipitation

3.2.1. Measurement

The measurement of rainfall began in 1994 with a tipping bucket rain gauge (0.5 mm), and a standard direct-reading rain gauge located at the Meteorological Station. The measuring equipment was subsequently supplemented in 2003 by a series of 2 additional tipping bucket rain gauges (0.2 mm or 0.5 mm) and a series of 7 additional standard direct-reading rain gauges within the catchment area. All the rain gauges have a receiving cone surface of 400 cm². Data for

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tipping bucket rain gauges are stored in a logger system that records tipping times. Standard direct-reading rain gauges are taken daily at around 9 a.m. local time (i.e. 8 a.m. UTC) by an operator, providing a daily rainfall measurement with an accuracy of 0.25 mm up to 10 mm and 0.5 mm for larger daily amounts. All tipping bucket rain gauges are checked frequently and cleaned if necessary to prevent clogging.

3.2.2. Data processing and qualification

By default, all daily rainfall amounts recorded by the operator are qualified with a ‘MB’ source code and considered as reliable (‘F’ quality code). A control procedure consisting of comparing the amount of daily rainfall between all the other rain gauges enables anomalies such as reading or data entry errors to be identified. Data detected as anomalous is given an ‘NF’ quality code. The daily rainfall value for the periods when a direct-reading rain gauge is not operational due to vandalism, for example, is indicated as Na, with an ‘IND’ quality code. On the infrequent days when the operator has been unable to take the measurement, a value of ‘NA’ is indicated with a ‘IND’ quality code. The daily rainfall amount for the day following a period with ‘NA’ is indicated with a ‘MB’ source code and a ‘NF’ quality code, and a comment indicating that the value corresponds to a cumulative value is added.
By default, all instantaneous rainfall recordings are qualified with a ‘MB’ source code and a ‘F’ quality code. The measurements corresponding to the calibration tests are first removed from the time series. They are easily identifiable because each calibration test is recorded in a field notebook. A two-step control procedure is then applied to identify periods of failure. The first step consists in comparing the daily accumulated values derived from the rain gauge tipping buckets with the daily rainfall amounts derived from all rain gauges. The second step consists in comparing the 5-minute rainfall intensities between the tipping bucket rain gauges to identify failures such as partial or complete clogging. For periods of complete failure, 2 consecutive lines with ‘NA’ as values and ‘IND’ as source and quality codes are entered in the measurement file to the start and end of the failure. For periods of malfunction, the raw recordings are kept and the NF quality code is assigned. Note that every malfunction identified by the operator during his recurring visits is also recorded in the field notebook, enabling particular attention to be paid to the quality of the data concerned.

3.2.3. Additional synthetic rainfall time series

An instantaneous synthetic time series and a daily synthetic time series of rainfall measurements over the entire 1994-2023 period are provided in addition to the previous individual daily or instantaneous rainfall time series.
The synthetic daily rainfall time series (from 8 a.m. to 8 a.m. UTC the following day) is produced using the average of all reliable daily rainfall records provided from the eight direct-reading rain gauges and calculated from the three tipping-bucket rain gauges. On the rare days when the operator was unable to take the measurement, the cumulative daily rainfall recorded on the direct-reading rain gauge on the day following the NA period was first distributed over the days without recording using the daily rainfall distribution derived from tipping bucket rain gauges. The daily synthetic time series is qualified with a source code ‘CALC’ and a quality code ‘F’, except for the period prior to 1/9/2004 for which a quality code ‘IND’ is assigned because there were not enough rain gauges to guarantee reliable daily rainfall value.

The instantaneous synthetic rainfall time series is compiled from the three rainfall tipping bucket rain gauges, retaining only reliable values, and applying the following order of priority from 2003 onwards: I1 > I2 > I3. This choice is based on the fact that the I1 rain gauge is slightly more centrally located in the catchment area than the two others. The instantaneous synthetic time series is qualified with a source code 'MB' and a quality code 'F', except for the period prior to 1/9/2004 for which a quality code 'IND' is assigned because there was only one operational tipping bucket rain gauge in the catchment.

3.3. Water discharges at hydrosedimentary stations

3.3.1. Measurement

Each hydrosedimentary station has been designed to measure water levels at two points, one suitable for low flows (LQ) and the other for high flows (HQ), as illustrated in Fig. 2. For the PAR station, the gauging system is a Venturi flume for HQ and a V-notch weir for LQ. For the MBV station, the gauging system is a rectangular flume for HQ and a V-notch weir for LQ. For the GBV station, the gauging system is a rectangular flume for HQ and a smaller rectangular flume for LQ. Water levels for each station are recorded using digital sensors (e.g. pressure probe) at these two measurement points. Measurements are taken with a time step of 1 minute and recorded when height variations exceed 5 mm or systematically every 30 minutes. Water level sensors are accurate to within a few millimetres. Each measuring point is equipped with a limnimetric scale, i.e. a metal ruler, so that an operator can manually read the water level on a daily basis, or even more frequently in the event of flooding.

3.3.2. Data processing and qualification

The time series of raw water levels are first compared with the scales readings in order to identify any biases. Biases are mainly induced by changes in the vertical position of the digital sensors during cleaning operations, for example. A piecewise bias-correction is then made to the raw water levels to bring them into line with the scale readings. When necessary, corrections are generally less than one or two centimetres.

Flow discharges are then derived from bias-corrected water levels using a rating curve specifically elaborated for each monitoring point. The rating curves were all based on information supplied by the manufacturer (e.g. for the Venturi flume) or theoretical laws (e.g. for the V-notch weir), then adjusted locally by flow control measurements. The water discharge time series for each hydrosedimentary station was compiled from a combination of the LQ and HQ discharge time series, using the most accurate measurement source at each instant.

By default, the origin and quality of the water discharge time series for each hydrosedimentary station are set to MFAC and F3. If there are gaps at the measurement point suitable for low discharges (LQ), it may be necessary to use the HQ discharge values, but in this case the quality code has been changed from F3 to F2 for the PAR station (because the Venturi flume provides an accurate discharge rate even for low values); and from F3 to F1 for the MBV or GBV stations. If there are gaps at the HQ measurement point, a gap period is inserted (NA value at the start and end) for the corresponding periods. In some cases, discharge values exist for the appropriate discharge range but they are derived

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from water levels of altered quality. This happens, for example, when there are heavy deposits of sediment at the point where the water level is measured. If this is the case for LQ discharges, either the code source was changed from F3 to F2 or from F3 to F1 depending on the estimated level of distortion, or the HQ discharge values were used and the quality code was modified according to the rule mentioned above. If this is the case for HQ discharges, either the code source was changed from F3 to F2 or from F3 to F1 depending on the estimated level of distortion. Where distortions were considered too great, a gap period has been introduced.

3.4. Runoff rates at the LAKE station

3.4.1. Measurement

The water level in the outlet reservoir, i.e. at the LAKE station, is monitored using a pressure probe. Raw measurements are made every 5 minutes and they are recorded when height variations exceed 10 mm or systematically every 60 minutes. The outlet reservoir is equipped with a limnimetric scale so that an operator can manually read the water level on a daily basis, or even more frequently in the event of flooding. The spillway has been designed so that the overflow discharge can be accurately estimated from the water level using a theoretical curve adjusted locally by flow control measurements. The periods during which the bottom gate is open are recorded manually, enabling the flow rate discharged to be estimated from the water level using a theoretical curve adjusted locally by flow control measurements. Lastly, the depth/volume and depth/surface curves of the reservoir are established on the basis of topo-bathymetric surveys carried out every 2 to 5 years.

3.4.2. Data processing and qualification

As with the hydrosedimentary stations, the time series of raw water levels are first compared with the scale readings and a piecewise bias correction is then applied to the raw water levels to bring them into line with the scale readings. Then daily runoff entering into the reservoir (Q_LAKE) could be derived using an hydrologic budget as described in Albergel et al. (1998). Basically, the flow into the lake is evaluated as the variation in the stock of water in the reservoir, to which is added the volume of water leaving through overflow, the bottom gate and evaporation, and from which is subtracted the volume of rainwater falling directly onto the water body. The hydrological balance was established on a daily time step, with the value for day D corresponding to the daily runoff entering the reservoir between day D at 8 a.m. UTC and day D+1 at 8 a.m. UTC, in order to be in line with the operator's field surveys.

By default, Q_LAKE is qualified with a source code ‘CALC’ and a quality code ‘F3’, except for the period with overflow or bottom discharge for which a quality code ‘F2’ is assigned because the corresponding terms in the hydrological budget are estimated less accurately. When there are gaps in the time series of water levels (e.g. sensor failure) and overflow or bottom discharge occurs, the daily runoff entering the reservoir is set to NA, with a code source ‘IND’ and a quality code ‘IND’.

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3.4.3. Additional synthetic time series of daily runoff

A synthetic gap-filled time series of daily runoff is proposed for the lake station over the entire 1994-2023 period. Gap-filling was realized using the GR5J model and the procedure available in the baseflow R package (Coron et al., 2017, Pelletier and Andréassian, 2020). The daily synthetic time series is qualified with the same source code and quality code as the water discharge values for the day in question. The gap-filled values are qualified with a source code 'CALC' and a quality code 'IND'. A specific comment is also added to indicate the values derived from the GR5J gap-filling procedure.

3.5. Suspended sediment concentration

3.5.1. Measurement

Manual and automatic water samples are used to evaluate suspended sediment concentrations (SSC) in runoff water at each hydrosedimentary station. Automatic samples are taken using a 24-vial sequential sampler, the sampling of which is controlled by the flow rate. They are supplemented by manual sampling when an operator is present at the site during flooding. Samples were transported after each flood to the laboratory for oven drying (48 h at 105 °C) and weighing.

3.5.2. Data processing and qualification

SSC is calculated as the ratio of the dry weight to the sample volume. The measurement uncertainty associated with the SSC is estimated at 5 % maximum.

The SSC values are all qualified by default with a source code 'MB' and a quality code 'F'. The quality code was modified in NF for a few values deemed unreliable, in particular very high concentrations at the end of major floods when it is suspected that the sample taken is affected by the deposit of sediment at the strainer. An additional comment indicates for each SSC value whether the value comes from a manual or automatic sample.

4. Preliminary explorations of the database

In this section, we propose characterising the key elements of the hydro-sedimentary regime and investigating trends in rainfall, runoff and erosion time series using the database presented in this paper. In addition, we also combined the time series of discharge and suspended sediment concentration at the GBV station to evaluate the daily sediment yield (in t ha^{-1}) over an 18-year period (from 2005 to 2023) to be used for the time compression and trends analysis for erosion. This required the development of a specific gap-filling procedure, the description of which is beyond the scope of this paper.

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4.1. Streamflow discharge at the four nested stations

Figure 4 presents the matrix of pair plots with the runoff measured at the four hydrometric stations. The upper part of the matrix corresponds to pair plots computed from daily data, while the lower part shows those obtained at the monthly scale. Overall, the flows recorded at the four stations are strongly correlated, which suggests that the main driving factors of runoff generation are likely very similar from field to catchment outlets.

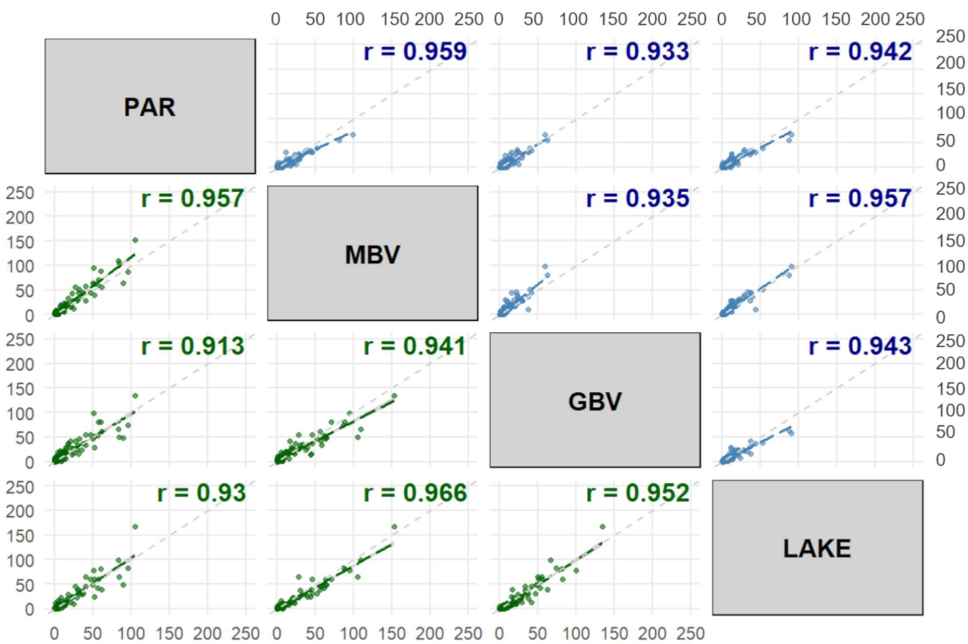

Figure 4. Correlation matrix of discharge for the four stations: upper triangle for daily values, lower triangle for monthly values. The red dashed line indicates y = x.

4.2. Hydro-sedimentary regime

4.2.1. Interannual and intrannual variability

Figure 5a depicts the interannual variability of the rainfall regime in the Kamech catchment. Annual rainfall amounts range from a minimum of 395 mm yr^{-1} to a maximum of 1036 mm yr^{-1}, resulting in an amplitude of 642 mm. The standard deviation is approximately 150 mm around an interannual mean of 618 mm. The annual runoff response is as variable as precipitation. Annual runoff rates range from 2.2 mm to 275.5 mm, with a standard deviation of 84.5

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mm around a mean close to 108 mm yr^{-1} at the LAKE Station. The annual runoff coefficient, defined as the ratio of annual discharge to annual precipitation, exhibits considerable variability, with a standard deviation of 10.8 %, an interannual mean around 16 %, and a range from 0.5 % to 38 %.

Figure 5b shows the intra-annual variations of runoff discharge and suspended sediment concentration (SSC) at GBV hydrometric station. For runoff, maximum rates are observed from December to March, with intermediate values in November. For SSC, maximum values are observed in September and October, and then quickly decrease, with intermediate values in November. As a result, there is a significant seasonal lag between runoff rates and suspended sediment concentrations, which greatly affects sediment yield dynamics in the catchment area.

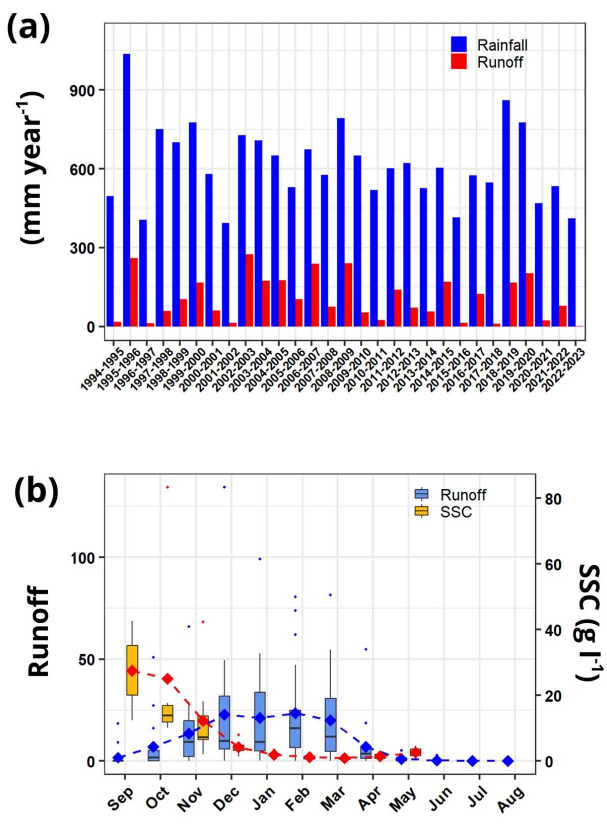

Figure 5. (a) Interannual variability of rainfall and runoff at the LAKE Station between 1994 and 2023; (b) Monthly variability of runoff and SSC at the GBV station between 2005 and 2023.

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4.2.2. No flow occurrence

The analysis of the daily discharge time series at the catchment outlet (i.e., Q_LAKE) shows a mean of 258 days with zero-flow per year over the period 1994-2023 (Fig. 6). In other worlds, discharge from the catchment is highly intermittent as it only occurs 30 % of the time. Figure 4 also indicates the number of dry periods, a dry period being defined as consecutive days without flow discharge at the catchment outlet. The number of dry periods per year ranged from 15 to over 50, highlighting the very frequent changes between periods of flow and no flow.

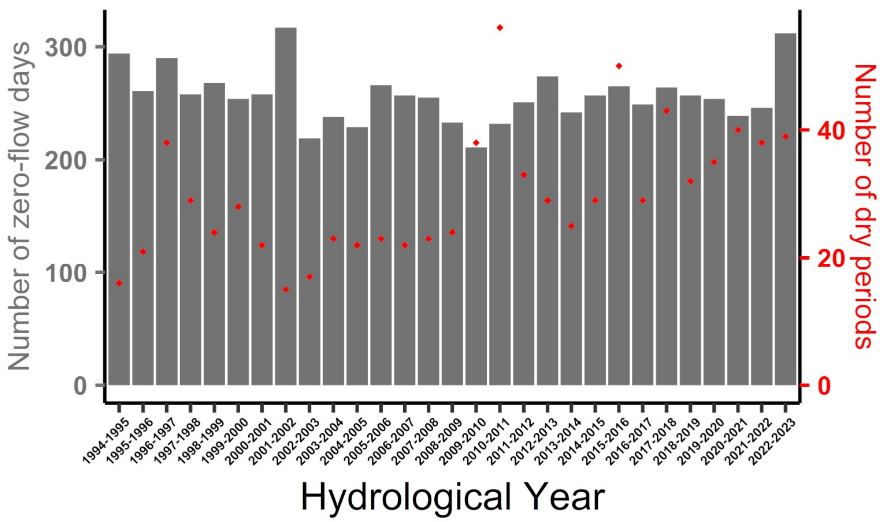

Figure 6. Number of periods with zero flow and dry periods per year (1994–2023)

Analysis of the cross-correlation between precipitation and discharge enables a rapid estimate of the lag time (t_{lag}), which is a measure of how quickly a stream responds to runoff-producing rainfall (Sultan et al., 2022). According to these authors, the lag time corresponds to about two-thirds of the time of concentration. Figure 7 shows the cross-correlogram drawn up for the 2005-2023 period using the precipitation and discharge time series at the GBV station at 5-minute time steps. It highlights narrow peaks with very low time lag ranging from 15 minutes in autumn to 50 minutes in spring. These results show that the Kamech catchment is highly reactive, with sub-hourly lag time. This means that flash floods highly dominate in this catchment.

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Open Access Earth System Science Data Discussions

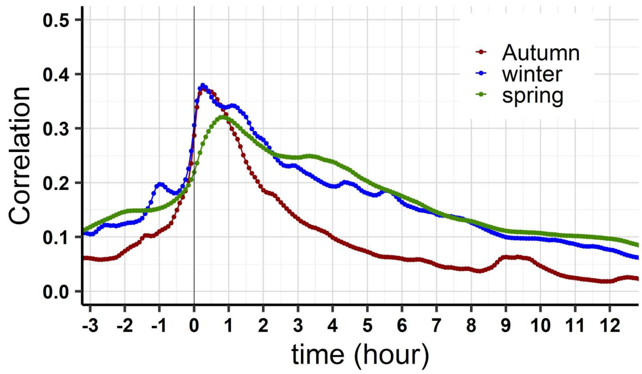

Figure 7. Seasonal cross-correlation between precipitation and discharge at the GBV station elaborated with time series at 5-minute time steps.

4.2.3. Baseflow contribution

A series of base flow separation methods (Table 3) was applied to the daily discharge entering the outlet reservoir (Q-LAKE time series) to derive the baseflow index, which represents the percentage of slow or delayed components to the streamflow. Five hydrograph separation methods come from the R "grwat" package (Rets et al., 2022). They were applied with the default parameters proposed in the package. A sixth one comes from the baseflow package (Pelletier and Andréassian, 2020), and is considered more impartial as it integrates a way to estimate the parameters entering in the flow separation procedure. As shown in Table 3 below, the contribution of baseflow varies depending on the algorithm applied from 3 to 14 %, confirming the very high reactivity of the Kamech catchment, and therefore a presumed very low contribution of groundwater to the streamflow.

Table 3. Estimation of the slow or delayed flow contribution to streamflow at the Kamech outlet.

algorithm	Boughton (1993)	Jakeman and Hornberger (1979)	Lyne and Hollick (1979)	Chapman (1991)	Chapman and Maxwell (1996)	Pelletier and Andréassian (2020)
% of slow or delayed flow to streamflow	14	11	7	3	5	9

4.2.4. Time compression

The concept of time compression in hydrology and erosion refers to the phenomenon whereby significant geomorphological changes occur within a short time frame, often as a result of extreme events. The level of time

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compression in a catchment may have direct implications for land management practices (Molina et al., 2020; Smetanová et al., 2018; Cheng et al., 2017).

In this paper we characterized time compression in the Kamech catchment during the 18-year period between 2005 and 2023 using the synthetic daily precipitation time series and the gap-filled daily discharge and sediment yield at the GBV station. Results show a very significant time compression, with 75 % of precipitation, flow, and sediment yield occurring during only 427 days, 302 days, and 28 days, respectively, representing 6.5 %, 4.6 %, and 0.4 % of the period considered. Figure 8a shows the number of days during which daily discharge exceeds various thresholds ranging from 10 to 100 mm. Only 42 days with a specific streamflow discharge over 10 mm/day were observed, i.e. an average of 2.3 days per year. The average number of annual days decreases to less than 1 when considering a threshold of 20 mm d^{-1}, whereas one day exceeded 60 mm during the considered period. The contribution of extreme events to total fluxes is even more important for sediment yield than for runoff, as seen in Fig. 8b. During the 18-year period, only 44 days exceeded 0.5 t ha^{-1}, 12 days exceeded 2 t ha^{-1} and one day exceeded 16 t ha^{-1}.

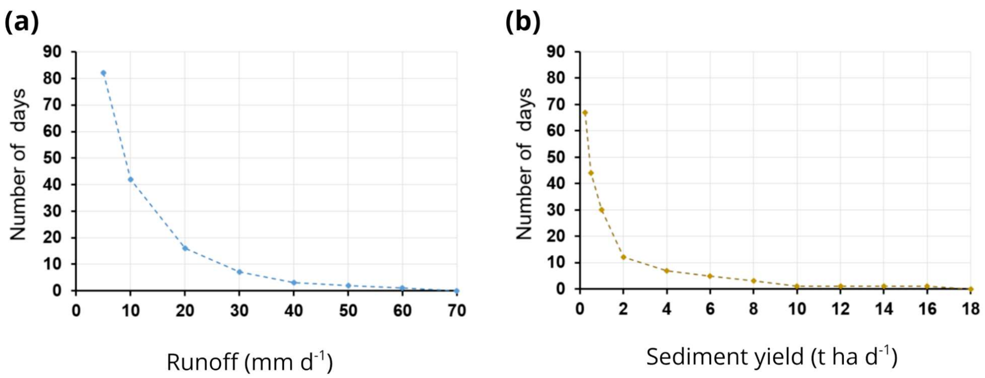

Figure 8. Number of days exceeding a daily runoff threshold (a) and a daily sediment yield threshold (b) at the GBV station during the 18-year period between 2005 and 2023.

4.2.5. Key points about the hydro-sedimentary regime

The hydro-erosive regime in Kamech catchment is clearly non-perennial, it can be classified as ephemeral according to the classification proposed by Busch et al. (2020). Indeed, our preliminary analysis shows that streamflow occurs during a very short percentage of time and almost exclusively in response to precipitation events. The very significant time compression observed in the catchment emphasised the importance of accurately and comprehensively documenting the response of extreme events, which are rare but account for most of the runoff and sediment fluxes in a Mediterranean context as already shown by Gonzalez-Hidalgo et al. (2007).

4.3. Trends in the rainfall, runoff and erosion time series

The dataset acquired within the framework of the OMERE observatory over a period of approximately 30 years provides an opportunity to explore if trends can be detected in the rainfall, runoff and erosion time series. The analysis

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was made for annual, seasonal and monthly values derived from the synthetic daily rainfall time series (1994-2023), the synthetic gap-filled time series of daily runoff for the lake station (1994-2023), and the gap-filled time series of daily sediment yield established at the GBV station (2005-2023). Trend analysis for rainfall maximum precipitation from 5-minutes to 12-hours was based on the synthetic instantaneous rainfall time series (1994-2023). The annual timestep corresponds to the hydrological year, running from September 1st to August 31st. Autumn covers the period from September 1st to November 30th; winter spans from December 1st to February 28th (or 29th in leap years); and spring extends from March 1st to May 31st.

The presence of trends was tested using the Sen's slope technique, and their statistical significance achieved using the Mann-Kindall test. Only trends with a significant p-value under 0.1 were shown in Table 3 and discussed below.

Table 4. Sen slope estimates for time series trend analysis of precipitation, maximum rainfall intensity, runoff and erosion rate at different time steps. The time series for precipitation and runoff cover 29 years, while those for erosion cover 18 years. Values underlined in bold refer to Sen' slope values with a Mann-Kindall test p-value of less than 0.05; other values refer to slope values with a Mann-Kindall test p-value between 0.05 and 0.1; and "-" indicates no trend considering a p-value threshold of 0.1.

		Annual	Season				Month											
			Aut	Win	Spr	Sum	9	10	11	12	1	2	3	4	5	6	7	8
Rainfall (sum)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rainfall (max. intensity)	05min	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	15min	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	30min	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	01h	-	-	-	-	-	-	-	0.27	-	-	-	-	-	-	-	-	-
	02h	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-0.02	-	-
	03h	-	-	-0.09	-	-	-	-	-	-	-	-	-	-	-	-0.004	-	-
	06h	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12h	-	-	-	-	-	-	-	0.04	-	-	-	-	-	-	-0.01	-	-
	24h	-	-	**-0.78**	-	-	-	-	0.57	-0.40	-0.60	-	-	-	-	-	-	-
Runoff (sum)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Number of days with zero-flow		-	-	-	-	-	-	-	**-0.33**	-	**0.42**	-	-	-	**-0.08**	-	-	-
Erosion (sum)		-	-	-	-	-	-	-	**0.05**	-	-	-	-	-	-	-	-	-

Annual and monthly precipitation in the Kamech catchment has remained largely unchanged over the last thirty years. This result is in line with the study by Vicente-Serrano et al. (2025), who found that precipitation in the Mediterranean

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region is highly variable over time but does not show a consistent trend. However, certain seasonal or monthly trends have been detected in terms of maximum precipitation intensity, indicating certain changes in the intra-annual rainfall regime and, more specifically, in the timing and intensity of maximum rainfall events.

No significant trends were observed in the annual and monthly runoff, consistent with the lack of significant trends in the corresponding precipitation time series. Similarly, no trend was found in the annual number of days without runoff. However, significant trends emerged for the number of days without runoff during specific months, likely reflecting shifts in the timing and intensity of maximum rainfall events.

Regarding erosion, the only significant trend identified is an increase in total sediment yield in November. A possible explanation could be the observed upward trend in maximum rainfall intensities over 1-hour, 12-hour, and 24-hour durations during November.

Finally, this analysis reveals no significant trends in annual rainfall, runoff, or erosion. However, it detects minor shifts in the timing of days without runoff and erosion events, likely attributable to subtle changes in the temporal distribution and intensity of peak rainfall throughout the year. These subtle changes have an obvious impact on the annual number of dry periods between 1994 and 2023 (see Fig. 4), with a significant upward trend (Sen slope = +0.7; p-value = 2×10^{-4}). Longer time series are required to determine whether these trends are persistent or if they are associated with multi-decadal variability.

5. Examples of previous studies and open questions

The dataset presented in this paper has multiple applications for addressing questions related to hydrological risks, including flood events and severe erosion, as well as risks to agricultural production associated with the frequency of drought episodes. As briefly described below, several studies already used them for these purposes.

For example, Ben Slimane et al. (2013) combined the dataset from the LAKE station with sediment archives extracted from the sediment trapped into the reservoir to identify the main erosive processes in the catchment. Using a fingerprinting method based on several tracers, including radionuclides, they showed that sediment trapped in the reservoir mainly originated from agricultural topsoils, indicating that interill and rill erosion was more involved than gully erosion in the silting up of the reservoir since its construction in 1994. Combining the OMERE monitoring and morphometric analysis of gullies from photographic imagery, Ben Slimane et al. (2018) confirmed the predominance of interrill and rill erosion processes. They estimated that 70 to 80% of the sediments reaching the reservoir came from surface soils (diffuse erosion), while only 20 to 30 % came from banks and ravines. Thus, this dataset, combined with other data, has enabled a better understanding of the sediment sources contributing to the reservoir siltation, which is highly valuable for more effectively targeting recommended soil and water conservation measures.

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Inoubli et al. (2016) investigated the impact of shrinking-swell soils dynamics on the dynamics of water and sediment exports at the PAR station. They first observed that the cracks remained open for over six months of the year. This finding is consistent with the conclusion of Mekki et al. (2006) that a threshold of approximately 200 mm of cumulative precipitation since the beginning of the hydrological year is necessary to induce significant runoff in the Kamech catchment. Inoubli et al. (2016) concluded that crack dynamics are likely the main drivers explaining the time lag between runoff flows and suspended matter concentrations observed at the experimental plot outlet. Inoubli at al (2017) also showed that a seasonal time lag between runoff and erosive response existed at the MBV station, with shrink–swell processes as the most likely driver of this time lag. In this study, we showed that a similar shift is also observed at the GBV station (Fig. 5b), suggesting that crack dynamics can strongly influence runoff response across the entire catchment.

The proposed dataset has also been analyzed in the framework of environmental research catchment networks. For example, Smetanová et al. (2018) analyzed a comprehensive dataset comprising 104 years of continuous sediment yield records from eight small catchments, including Kamech. The study reported a wide range of sediment yield variability (0–271 t ha^{-1} yr^{-1} and 0–116 t ha^{-1} $month^{-1}$). Considering the eight catchments, they identified that intense time compression was observed in catchments with low sediment yield during spring and summer, whereas low time compression was linked to very high soil loss, low runoff and sediment production thresholds, and high connectivity. These authors also demonstrated that identifying periods of high sediment production is essential for defining management strategies, and that these periods can be predicted by analysing intra-annual variability, seasonality and time compression. Another study conducted by Peña-Angulo et al. (2019) enabled a detailed examination of the spatial variability in hydro-sedimentary variables throughout the Mediterranean basin. This study involved data from 68 research sites (including Kamech) in nine Mediterranean countries, totaling 22,458 events. The study revealed that a small subset of weather types could be responsible for a large proportion of total precipitation, runoff, and sediment yield, suggesting that variations in the frequency of these weather types in the context of climate change could have a significant impact on hydrological responses and sediment transport in the Mediterranean basin.

However, the high temporal variability observed in the study catchment, which is strongly influenced by a few rare events, is likely to alter the previous conclusions. It is therefore important to continue collecting monitoring data and to pursue studies by analyzing longer time series. An ongoing study involves comparing sediment data from core sampling in the reservoir with sediment flows derived from in situ monitoring in order to assess the ability of sediment deposits to estimate the intensity of past floods. Future studies may lie on a variety of questions concerning critical zone processes and the interactions between chemical, physical and biotic components in headwater Mediterranean catchments. A major step forward would be to better understand and prioritize the factors that control water and sediment flows in the Kamech catchment area. Among the main challenges are the need to (i) distinguish the effects of climate variability or climate change from those related to land use and management, (ii) study the interactions between vegetation, carbon, and erosion or between flows and crack dynamics, (iii) better understanding the impact of intermittency on the response of watersheds in terms of water and sediments, etc. Future studies could also focus on exploring modelling strategies aimed at improving water and sediment export from the event scale to longer time

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scales, and helping to identify land management practices that preserve water and soil resources in changing and uncertain environmental conditions.

6. Data availability

All datasets referenced in this work are openly accessible via the repository: https://doi.org/10.23708/PPPPDL (Raclot and Hamdi, 2025). We also encourage users to visit https://www.obs-omere.org/fr/donnees (currently in French, but available in English in the future), which also provides access to this dataset and additional information. It will host future data, as monitoring will continue as long as our institutions can fund it.

7. Conclusion

This paper presents a comprehensive database of rainfall measurements and hydro-erosive fluxes collected over nearly 30 years in an agricultural catchment under a Mediterranean climate and vertic soils. These data were acquired as part of the Mediterranean Observatory for Environmental Research (OMERE). In addition to providing a detailed description of the data acquisition protocols, we implemented rigorous quality control and validation procedures to ensure the usability of the data.

The paper also included a characterization of the hydro-erosive regime in the Kamech catchment, indicating an ephemeral regime with high temporal variability and time compression. The data analysis shows a strong correlation between the runoff rates measured at the different stations. It also highlights the complexity of the hydrological and erosive response, with a significant time lag between runoff flows and suspended matter concentrations throughout the year. The analysis of the rainfall records reveals an overall stationarity in annual precipitation and runoff throughout the study period, although a notable increase in the frequency of dry periods was observed. Regarding erosive fluxes, a slight but significant increase in specific erosion was detected in November, consistent with the observed rise in maximum rainfall intensities at both hourly and daily scales during that month.

Beyond the detailed description of the monitoring protocols and the initial analyses presented, this work highlights the irreplaceable value of maintaining long-term observations in small Mediterranean agricultural catchments subject to intense climatic variability. Only continuous datasets extending over several decades make it possible to disentangle short-term fluctuations from multi-decadal trends, to detect subtle changes in hydro-sedimentary regimes, and to attribute them to climate variability, climate change, or land management practices.

In regions such as the southern Mediterranean, where extreme events dominate water and sediment fluxes, such sustained monitoring is essential for understanding the frequency, magnitude, and timing of rare but high-impact events. The exceptional temporal depth, spatial resolution, and data quality of this dataset thus provide a unique empirical basis for scientific research, the calibration and validation of predictive models, and the design of effective adaptation and conservation strategies. This long-term commitment also ensures that policy-makers and stakeholders can rely on robust evidence to guide decision-making in increasingly uncertain environmental conditions.

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Author contribution

RH, DR, IM and JA conceptualized the paper. RH and DR criticized and validated the data. RH and DR analyzed the data. The original draft was prepared by RH and DR, while IM, MG and JA contributed to review and editing.

Competing interests

The authors declare that they have no conflict of interest.

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