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# TIME SERIES PREDICTION OF SPECIFIC EROSION IN THE KOUDIET LEMDAOUR DAM WATERSHED BATNA REGION, ALGERIA

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## ABSTRACT

Water erosion in watersheds represents a major challenge for the management of soil and water resources, leading to degradation of agricultural land, increased sedimentation of dams and significant socio-economic impacts. This study aims to quantify the solid inputs in the form of specific erosion in the watershed of the Koudiet Lemdaouar dam, located in the Batna region (Northeastern Algeria). Fournier's empirical model was used to estimate specific erosion, followed by prediction of temporal variations using several models, including the autoregressive integrated moving average models (AR, MA, ARMA, ARIMA) and the Neural Network models (RNN, LSTM, CNN). Among these models, the ARIMA proved to be the best performing, with an RMSE of 1.66, a MAE of 1.336 and a MAPE of 1.499. These results provide a better understanding of erosion dynamics and offer valuable tools to optimize the management of natural and agricultural environments, as well as to protect the dam against siltation.

**Keywords:** Modelling, Specific Erosion, Fournier Model, Prediction, Time Series.

## INTRODUCTION

Watershed erosion is widespread in the Maghreb region, as all the conditions are in place to promote the triggering and development of this process (Remini, 2017a; Mfoutou and Diabangouaya, 2019; Riahi et al., 2020; Chabokpour and Azamathulla, 2025). The main conditions are: irregular climatic variations (Choukrani et al., 2018), low vegetation cover density, soil vulnerability to runoff, as well as flood violence (Nezzal et al., 2015; Kouadio et al., 2018; Remini, 2023). According to Berthier (1970), erosion can vary from a few tens to several thousand t/km$^2$/year.

Erosion in upstream catchment areas accelerates sediment transport, leading to excessive siltation in hydraulic structures such as dams, thereby significantly reducing their storage capacity and operational lifespan (Remini and Remini, 2003; Meguenni and Remini, 2008; Remini and al., 2009; Meddi, 2015; Remini and Bensafia, 2016; Remini and Toumi, 2017; Remini et al., 2019; Bougamouza et al., 2020; Ansari et al., 2024).

Climate variations significantly alter the availability and distribution of water resources (Nichan and Khelil, 2015; Nakou et al., 2023; Chadee et al., 2023; Remini, 2024). The prolonged droughts contribute to the degradation of agricultural landscapes and economic frameworks (Koussa, 2025). The diminished river flows and reduced groundwater recharge (Chibane and Ali-Rahmani, 2015; El Moukhayar et al., 2015; Gaaloul, 2015; Bemmoussat et al., 2017; Remini, 2019; Qureshi et al., 2024), coupled with significant evaporation from dam reservoirs and lakes (Boutoutaou et al., 2020), lead to a substantial decline in their storage capacity, thereby intensifying water scarcity especially in arid regions (Remini, 2020; Remini, 2024). In contrast to surface water, groundwater is inherently better shielded from the impacts of climate change, making it a more dependable and sustainable resource for future generations (Remini, 2025).

Intense rainfall events increase the risk of flooding and sedimentation, the assessing and the mechanism of which must absolutely be in-depth studied (Do et al., 2025; Ezz, 2025). On the other hand, effective studies have recommended tools of assessing and combating the risk of flooding (Ayari et al., 2016; Bekhira et al., 2019; Benslimane et al., 2020; Aroua, 2020; Ben Said et al., 2024; Athmani et al., 2025). In addition, attention is paid to the design and optimization of reservoirs as a means of mitigating the effects of flooding (Mezenner et al., 2022; Mehta et al., 2023; Zegait and Pizzo, 2023; Verma et al., 2023; Trivedi and Suryanarayana, 2023; Shaikh et al., 2024; Panchal and Suryanarayana, 2025).

The specific degradations of the Maghreb watersheds vary from 1000 to 5000 t/km$^2$/year (Heush and al., 1971; Demmak, 1982; Walling, 1984). In Algeria, the intensity of water erosion differs across regions, ranging from 47% in the western part to 27% in the central part and 26% in the eastern part. (Hallouz and al., 2018). In addition, land degradation disrupts the soil-plant-atmosphere continuum by impairing soil structure, reducing its water retention capacity, and hindering the upward transfer of moisture essential for plant growth (Niang et al., 2015).

The specific erosion value in North Africa reaches its highest levels, surpassing 2000 t/km$^2$/year, and affects most watersheds of the Tellian Atlas. (Rhiou, Sly, Fodda, Mazafran, Isser, Soummam,...), it reaches 4000 t.km$^{-2}$.year$^{-1}$ on the chain of Dahra coastal rivers and 5000 t.km$^{-2}$.an$^{-1}$ on the Ighil-Emda basin (Demmak, 1982). Algeria is thus one of the country's most seriously threatened by erosion on a global scale.

As has been rightly stated previously along with relevant references, the accumulation of sediment in reservoir dams leads to a decline in their storage potential. According to Remini (2017b), after 160 years of operation, Algeria's 74 dams, originally holding 8.5 billion m$^3$ of water, have lost 20% of their capacity due to silt accumulation, totalling 1.7 billion m$^3$ of sediment. Sedimentation has now reached an annual rate of 65 million m$^3$. This phenomenon can alternatively be described as reservoir alluviation or the sedimentation of fluvial-transported particles. These processes naturally result from watershed degradation caused by intense water erosion. The control of this phenomenon can only be ensured with the help of models capable of describing and quantifying the rates of soil degradation, and subsequently the consequences resulting therefrom (Remini, 2010; Remini and Ouidir, 2017; Remini, 2022).

To evaluate soil water erosion, various models are available, ranging from simple to highly complex (Mihi and al., 2020). Computer models based on empirical, physical, and conceptual approaches have been widely used by researchers, including the Water Erosion Prediction Project (WEPP) (Flanagan and Nearing, 1995), the European Soil Erosion Model (EUROSEM) (Morgan and al., 1998), the Soil and Water Assessment Tool (SWAT) (Neitsch and al., 2011), the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978), and the Revised Universal Soil Loss Equation (RUSLE) (Renard and al., 1997). However, controlling the adverse effects of water erosion requires a comprehensive understanding of the dynamic watershed behaviour and precipitation variability, achievable only through the application of efficient hydrological modelling techniques, including and adapting a preventive model for erosion risks (Koua et al., 2019; Mehta and Yadav, 2024; Atallah et al., 2024; (Kherde et al., 2024).

The selection of a model for water erosion should be based on the data requirements that can be met using the available resources (Abiot and Dwarakish, 2019). The lack of data often leads the engineer to use available empirical methods for the calculation of specific erosion (Meddi and al., 1998). The latter are linked to external parameters, such as climatic, hydrological or orographic, acting on the degree of erosion, such as Fournier (1960), Tixeront's formula (1960), Gravilevic's model (Meddi and al., 1999), ANRH formula (Algerian National Hydraulic Resources Agency) (Kassoul, 1991), Meddi's formula (Meddi and al., 1999). Machine Learning (ML), Deep Learning, and Gradient Boosting Machine (GBM), recently have emerged as a potential solution to forecast and model natural phenomena (Luça and Robustelli, 2020; Shaikh et al., 2024). With the latest progress in Machine Learning, predicting environmental behaviour, including soil erosion susceptibility, has become more innovative and accurate (Khosravi and al., 2023).

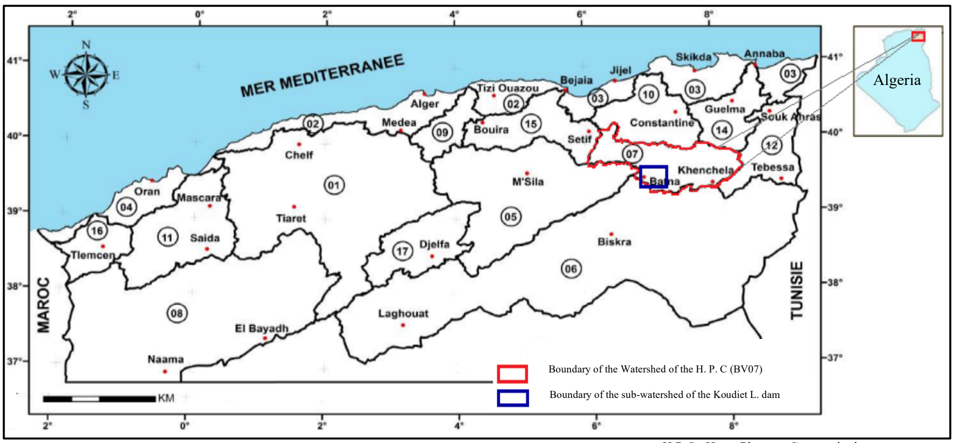
This study aims to quantify the solid inputs in the form of specific erosion in the watershed of the Koudiet Lemdaour dam, located in the Batna region (Northeastern Algeria), based on empirical model of Fournier. A prediction of the temporal variations of the specific erosion is then carried out using several Neural Network architectures including Recurrent Neural Network (RNN*),* Long Short-Term Memory (LSTM), Convolutional Neural Network (CNN) and autoregressive integrated moving average models, such as Autoregressive (AR), Moving Average (MA), Autoregressive Moving Average (ARMA) and Autoregressive Integrated Moving Average (ARIMA), in order to identify the one offering the best performance in terms of forecasting.

The time-series approach makes it possible not only to understand the past dynamics of specific erosion but also to predict future trends, which is crucial for the sustainable management of watersheds. By providing erosion predictions, planners are better equipped to manage natural and agricultural landscapes and protect the dam from siltation.

## MATERIAL AND METHODS

### Presentation and characterization of the study area

The sub-watershed of the Koudiet Lemdouar dam is situated in the Batna region, at the northeastern foothills of the Aurès, forming part of the large watershed of the "Hauts Plateaux Constantinois" (BV.07), as illustrated in Fig. 1. The climate is semi-arid Mediterranean, characterized by cold, humid winters, and hot, dry summers. Precipitation, which is very irregular in time and space, has an annual average that exceeds 300 mm. Annual temperatures vary between 0.6°C and 37°C, with an average of 18.8°C.




H.P.C : Hauts Plateaux Constantinois

**Figure 1: Geographical location of the Koudiet Lemdaouar dam watershed**

The main rivers in the Koudiet Lemdaouar dam watershed are Oued Reboa and Oued Soultez, which flow upstream to the Chemorah River. These two Oueds flow into the basin of the dam with a capacity of 74Mm$^3$, regulated since 2003, crossing the study area causing the departure of sediments following heavy rainfall.

The reliefs are made up of three large, relatively homogeneous areas:

- The mountainous area formed by the Aurès massif, bearing the forests and rising up to 2300m above sea level.
- The area of piedmont which generally corresponds to a set of ablation glacis consisting of colluvial deposits that descend in an attenuated slope towards the plain. The piedmont area is most often agricultural.
- The plain area, which is formed by a succession of plains and occupies most of the space. It extends north to the east of the piedmont; this land is used for seasonal agricultural activities.

The forest potential of the northeastern piedmont of the Aures is threatened by significant degradation, the vegetation is generally overgrazed, the plains to the north are reserved for extensive cereals, poorly protect the soil.

Under storm showers, the predominance of relatively soft rocks in the watershed (marls, marly limestones...) can lead to various erosive processes associated with these formations, sheet erosion caused by raindrop impact, diffuse runoff, and gullying can occur (Balla, 2019).

## Material and methodology

To assess the specific erosion (t/km²/year) in the study zone, using a Digital Elevation Model (DEM) obtained from the USGS (United States Geological Survey) website, we delineated and calculated the characteristics of the Koudiet Lemdaouar dam watershed using a Geographic Information System.

Table 1 summarizes some main morphometric and hydrographic characteristics of the watershed studied:

**Table 1: Main characteristics of the studied watershed**

| Designation | Unit | Value |
|---|---|---|
| Area (S) | $km^2$ | 578.51 |
| Perimeter (P) | km | 146.24 |
| Compactness Index (Kc) | / | 1.70 |
| Maximum Elevation (H max) | m | 2293 |
| Minimum Elevation (H min) | m | 975 |
| Specific Elevation Difference (Ds) | m | 287.08 |
| Main Thalweg Length – Oued Reboa (Lp) | km | 16.14 |
| Drainage Density (Dd) | $km^2$ | 2.73 |
| Concentration Time (Tc) | h | 7. 14 |

The calculated value of the Gravelius Compactness Index is 1.7, indicating that the watershed has an elongated shape, which suggests a relatively long travel time favoring linear and regressive erosion.

According to the ORSTOM classification, the specific elevation difference calculated is between: 250m< Ds < 500m, so our watershed has a fairly strong to strong relief, This is related to the massiveness of the limestone and marly limestone reliefs in this sector, which suggests that it may be exposed to water erosion.

The flow is fed by the main Oueds, which are Oued Reboa and Oued Soultez, which converges towards the outlet: the Koudiet Lemdaouar dam (Fig. 2).

Oued Reboa is a tributary of order 5 according to the Schum classification, which defines an order (X+l) any stretch of river formed by the union of two streams of order (X). Oued Soultez, classified as fourth-order, joins Oued Reboa before flowing into the dam.

It is also observed that the watershed has a dense hydrographic network, indicating intense erosive activity. Consequently, runoff finds favorable conditions for development. Additionally, the concentration time of approximately 7 hours suggests a rapid hydrological response within the watershed.

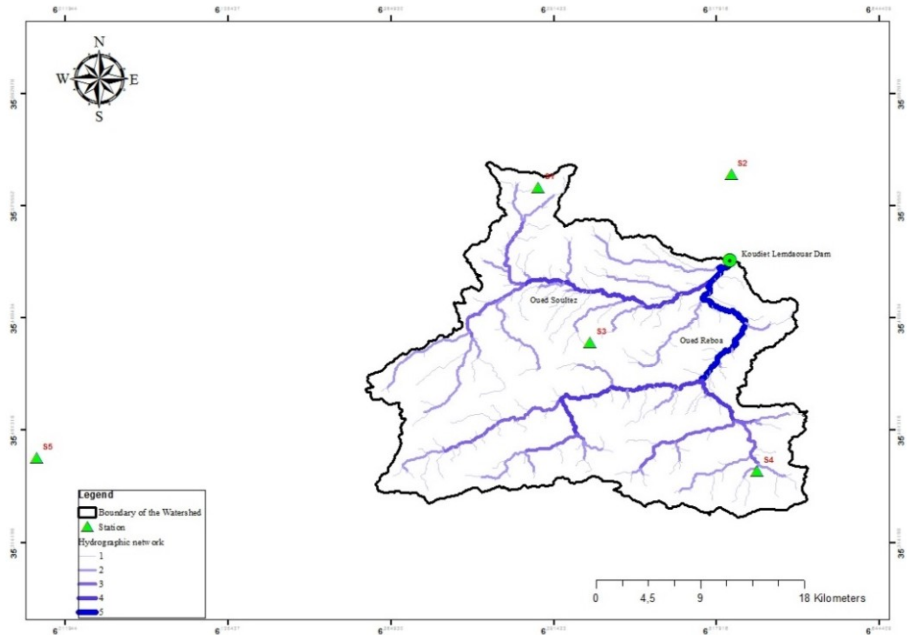



**Figure 2: Hydrographic network of the Koudiet Lemdaour Dam watershed**

The rainfall data were downloaded from the Globalclimatemonitor.org website of the University of East Anglia in England. After using the monthly average rainfall of five (05) rainfall stations (Table 2) over a period from 1901 to 2023 and calculating the corresponding annual rainfall, Table 3 presents the descriptive statistics of the latter.

**Table 2: Coordinates of rainfall stations used**

| Station Name | Coordinates of the station (WGS84) | |
|---|---|---|
| | Latitude | Longitude |
| S1 | 35.59 | 6.38 |
| S2 | 35.60 | 6.53 |
| S3 | 35.47 | 6.42 |
| S4 | 35.37 | 6.55 |
| S5 | 35.38 | 5.99 |

**Table 3: Descriptive statistics of annual rainfall Pa**

| Min. | 1st Qu. | Median | Mean | 3rd Qu. | Max. |
|---|---|---|---|---|---|
| 195.5 | 348.7 | 429.3 | 431.2 | 514.1 | 715.2 |

The estimation of the specific erosion was made using Fournier's empirical model, given the availability of data useful for its use.

Fournier (Olivry, 1991) proposed a formula (1) taking into account only the rainfall and the morphology of the watershed to estimate the annual specific erosion.

$$Es = \frac{1}{36}.(Ps^2/Pa)^{2.65}.(H^2/S)^{0.46} \quad (1)$$

With:

Es: Specific annual solid inputs ($t/km^2/year$),

Ps: Average monthly rainfall of the wettest month (mm),

H: 45% of the elevation range in watershed. (m),

Pa: Annual rainfall (mm),

S: Watershed area (578.51 $km^2$).

## RESULTS AND DISCUSSION

### Estimation of specific erosion in the Koudiet Lemdaour Dam watershed

In Fig. 3, we observe irregularity in the specific erosion rate and annual rainfall over the observation years, as well as difficulty in establishing a correlation between these two parameters. This leads us to examine other factors, such as rainfall characteristics (concentration time and intensity), seasonal influences, and interannual rainfall variability, marked by the alternation between wet and dry years.

Fig. 4 shows a correlation between the specific erosion rate and the month with the highest rainfall according to years of observation; the curves follow similar trends, suggesting a clear correlation between the increase in rainfall and specific erosion.

Very marked peaks, such as those of 1928 and 2003, indicate extreme events that can have significant consequences for the environment and agriculture.

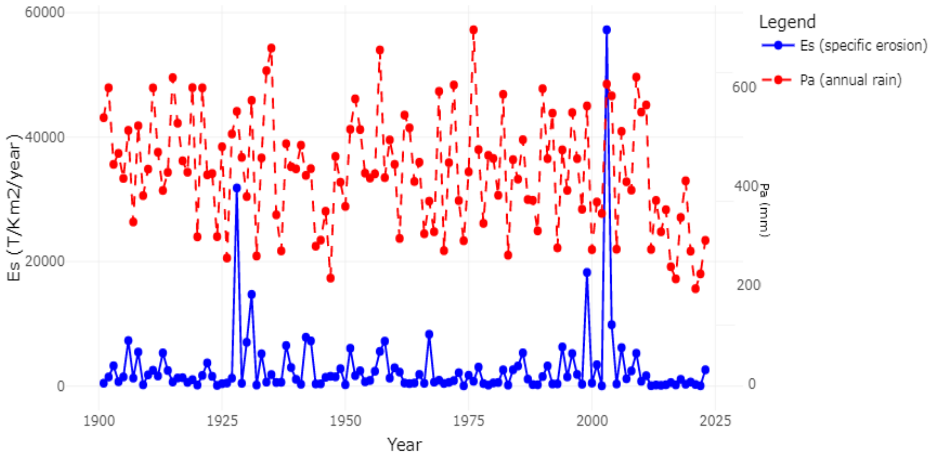



**Figure 3: Evolution of specific erosion (Es) and annual rainfall (Pa) over time**

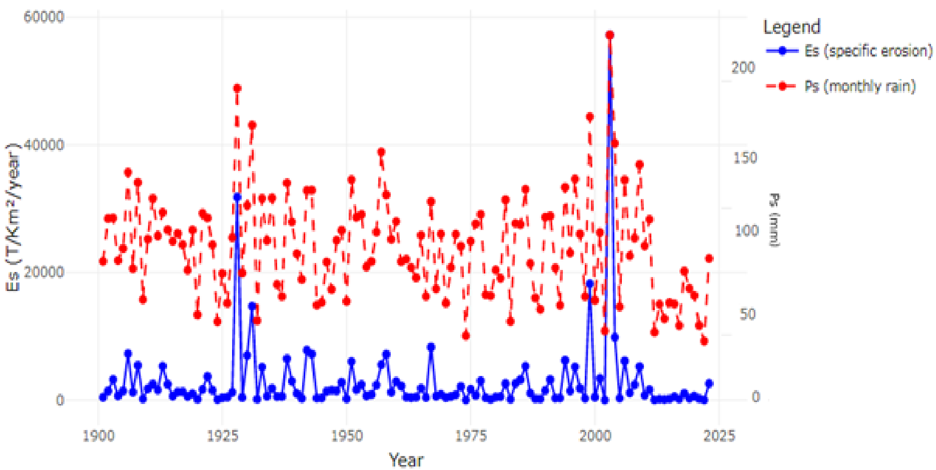



**Figure 4: Evolution of specific erosion (Es) and monthly rainfall (Ps) over time**

According to Demmak (1982), the specific erosion varies between 2000 and 4000 t/km²/year for the regions of northern Algeria, the average value calculated for the watershed studied (2887 t/km²/year) confirms that it is subject to significant water erosion.

An erosion rate of this order of magnitude has significant consequences, including:

- Accelerated sedimentation of the Koudiet Lemdaour dam, reducing its storage capacity and threatening its durability.

- Degradation of agricultural land, affecting productivity and food security.
- Increased runoff, raising the risks of floods and infrastructure damage.

The analysis of Fig. 5 clearly shows annual variations in specific erosion. We note a significant erosion value Es= 57236 t/km²/year during the year 2003, the year the Koudiet Lemdaour Dam was filled, followed by a decrease in subsequent years.

The installation of reservoirs leads to increased erosion in the upstream zones of watersheds (Van Maren and al., 2013). The filling of a dam can cause significant erosion, this results from the accumulation of sediment in the reservoir, which creates a sediment imbalance. In response, upstream streams may experience increased erosion of their beds and banks (regressive erosion) to compensate for this deficit, particularly if soils are fragile or poorly protected by vegetation.

In the years following the dam's filling, the erosion rate has decreased, the dam slows the flow of water upstream, thus reducing the speed at which the water flows. Less fast water means less energy available to move soil particles, reducing erosion. Stabilizing flows can also promote the growth of vegetation on the banks, which acts as a natural protection against erosion by stabilizing the soil.

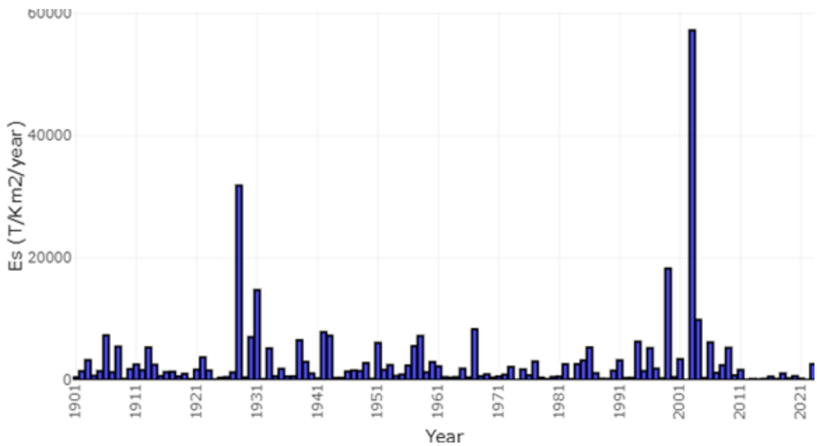



**Figure 5: Annual variation of specific erosion of the Koudiet Lemdaour Dam watershed**

According to Tixeront (1960), in his study, three distinct zones were defined:

- A zone where the annual precipitation does not exceed 300 mm, it is insufficient to cause appreciable erosion,
- A zone, the annual rainfall ranges from 300 to 700 mm, the erosion is highly active (Es> 1200 t/km²/year).
- A zone where the annual rainfall exceeds 700mm which benefits from a protective vegetation cover, specific erosion Es < 350 t/km²/year.

Tixeront admits that when the annual rainfall exceeds a certain rate, the effect of the substratum can be masked by the effect of the vegetation, which provides excellent protection regardless of the nature of the terrain.

Although the calculated average specific erosion (2887t/km²/year) respects the theoretical threshold of Zone 2 defined by Tixeront (Es>1200 t/km²/year), its amplitude 2.4 times greater than the minimum threshold, combined with extreme inter-annual variability (standard deviation = 6267), suggests that the model could underestimate the cumulative impact of extreme climatic events or local factors (substrate sensitivity, anthropogenic pressure) in the studied rainfall range (300–700 mm). This discrepancy highlights that the Tixeront framework, while valid for identifying a critical threshold, does not fully capture the complexity of erosion dynamics in contexts dominated by intense hydrological hazards or human disturbances.

**Prediction of erosion**

This section presents the results of an analysis to predict the values of specific erosion within the watershed over the historical period (1901–2023), while comparing these predictions with estimates from Fournier's classical empirical model.

The approach involved partitioning the dataset between a training set (85%), a testing set (15%) to evaluate how well various time series forecasting models perform. Specifically, we applied Long Short-Term Memory (LSTM) networks, Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN), as well as traditional statistical models including AutoRegressive (AR), Moving Average (MA), AutoRegressive Moving Average (Arma), and AutoRegressive Integrated Moving Average (ARIMA). Each model was evaluated based on its predictive accuracy using statistical precision metrics to determine its effectiveness in forecasting erosion values. This comparison aims to determine which approach delivers the most accurate and reliable predictions, thereby guiding the selection of the optimal forecasting approach for historical and future erosion data.

## *Introducing the models*

Neural Network models: Recurrent Neural Networks (RNNs) are designed for sequential data, capturing information from previous time steps via a hidden state, which is useful for time series forecasting. However, RNNs can struggle with long-term dependencies due to vanishing gradient issues, which can limit their performance on extended sequences (Rumelhart et al., 1986). In contrast, Long Short-Term Memory (LSTM) networks, a specialized type of RNN, address these limitations by incorporating gating mechanisms that manage long-term dependencies more effectively, making them particularly strong in handling complex forecasting tasks (Hochreiter and Schmidhuber, 1997). Convolutional Neural Networks (CNNs), although primarily used for image processing, can also be adapted for time series analysis. CNNs use convolutional layers to detect local patterns and features in temporal data, which can enhance the identification of significant trends and anomalies (LeCun et al., 1998). Overall, while RNNs and

LSTMs are both tailored for sequential data, LSTMs generally offer improved performance on long-term dependencies, and CNNs provide robust feature extraction capabilities for temporal data.

Autoregressive integrated moving average models: AutoRegressive (AR) models predict future values based on past values, with parameter p indicating the number of lagged observations used. In contrast, Moving Average (MA) models forecast future values by incorporating past forecast errors, characterized by parameter q, which denotes the number of lagged errors included. While Arma integrates both AR and MA components to handle stationary time series. The AutoRegressive Integrated Moving Average (ARIMA) model on the other hand extends Arma by adding differentiating to address non-stationary data, denoted as ARIMA (p, I, q), where I represent the order of differentiating needed for stationarity. For further details, see (Brockwell and Davis, 2002).

## *Models' evaluation*

To stabilize the variation between the datasets, we applied log returns, which helps to normalize the data by reducing fluctuations and making the series more stationary. Following this transformation, the pre-processing ensures a more reliable model training and evaluation process. Additionally, the dataset was split into training and testing subsets, with 85% allocated for training and 15% for testing.

For the neural network models, we used a window size of two to transform the time series data into features and targets for supervised learning. This method leverages two previous observations to predict future values, allowing the model to learn patterns and dependencies in the data. Additionally, the Adam optimizer is employed to fine-tune hyper-parameters for each model. While we ran several simulations to optimize the parameters for AR, MA, Arma, and ARIMA models, the optimal configurations are as follows: The AR model relies on 5 past observations AR(5)", MA uses 5 past errors "MA(5)", Arma combines both approaches Arma (5.5)", and ARIMA adds differencing to address non-stationarity ARIMA (5.1.5)".

After applying the seven models to the training datasets, we generated predictions for the subsequent 19 years. These predicted values were then compared to the actual values using statistical measures to evaluate each model's performance. The results are summarized in Table 4. The measures used were calculated as follows:

- Root Mean Squared Error (RMSE): This measure is derived by computing the square root of the average squared differences between the actual values $y_i$ and the predicted values $\hat{y_i}$ The formula is:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y_i})^2}. \quad (2)$$

- Mean Absolute Error (Mae): The MAE is the average of the absolute differences between the actual values and the predicted values. It is given as follows :

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|y_i - \hat{y_i}|. \tag{3}$$

- Mean Absolute Percentage Error (MAPE): The MAPE measures the average absolute percentage difference between the actual values and the predicted values. It is calculated follows :

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{y_i - \hat{y_i}}{y_i}\right| \tag{4}$$

Where $n$ represents the number of observations.

**Table 4: RMSE, MAE and MAPE values of the models studied**

| Model | RMSE | MAE | MAPE |
|---|---|---|---|
| RNN | 1.795 | 1,494 | 1 696 |
| LSTM | 1,818 | 1.459 | 2,420 |
| CNN | 2.131 | 1.640 | 2,380 |
| AR | 1 638 | 1,384 | 1 656 |
| MA | 1,694 | 1,443 | 1 858 |
| ARMA | 1762 | 1 464 | 1,771 |
| ARIMA | 1,660 | 1 336 | 1,499 |

The comparative analysis of forecasting models, presented in the table, highlights the superiority of the ARIMA model, which exhibits the lowest RMSE (1.660), MAE (1.336), and MAPE (1.499), making it the most accurate for forecasting erosion time series. RNN shows strong performance with low RMSE (1.795) and MAE (1.494) but has a higher MAPE (1.696) compared to ARIMA, indicating some larger relative errors. LSTM, while competitive with an RMSE of 1.818 and MAE of 1.459, falls short with the highest MAPE (2.420), suggesting less consistency in error proportions. CNN underperforms overall with the highest RMSE (2.131), MAE (1.640), and MAPE (2.380), indicating it is the least effective. AR and ARMA perform moderately well, with AR (RMSE: 1.638, MAE: 1.384, MAPE: 1.656) being a close second to ARIMA, and Arma (RMSE: 1.762, MAE: 1.464, MAPE: 1.771) also showing reasonable accuracy, but neither matches the ultimate precision of ARIMA.

The Arma model, although statistically inferior to ARIMA, seems to offer a better visual match with historical data with some time lag certainly, but the overall shape of the curve of predicted values looks very similar to that of current values (with two peaks at the beginning of the series and a third towards the end). This duality is explained by ARIMA's ability to correct non-stationarities (trends, seasonality) via its integrated component, thus optimizing error metrics, whereas Arma, designed for stationary series, preserves the temporal consistency of historical patterns. So the choice of the model converges towards ARIMA for accurate forecasts incorporating extremes.

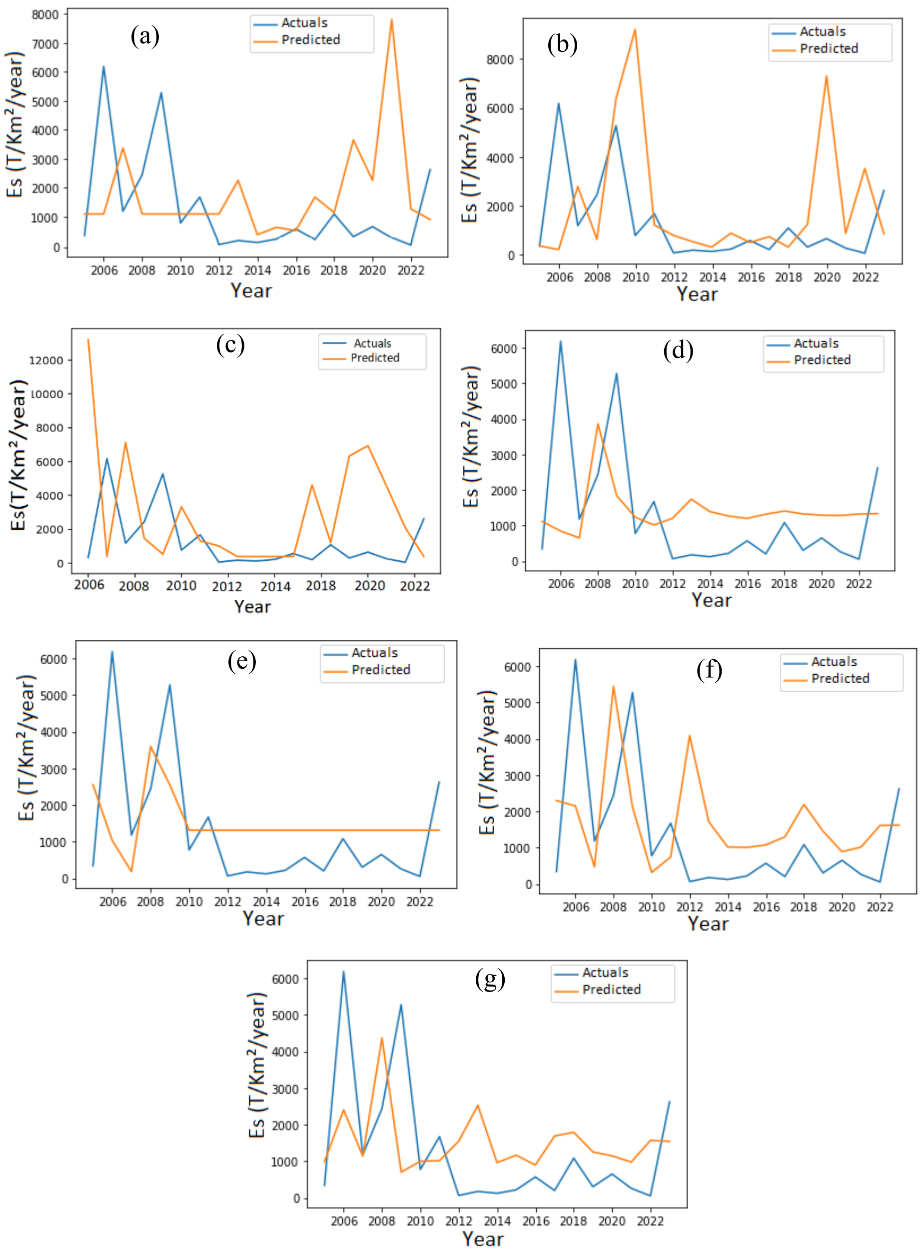



**Figure 6: Variation of specific erosion during validation phase using the models: (a) RNN, (b) LSTM, (c) CNN, (d) AR, (e) MA, (f) ARMA, and (g) ARIMA**

## CONCLUSION

The estimation of the specific erosion in the watershed of the Koudiet Lemdaour dam, confirmed the great irregularity of the erosion. This region with a semi-arid climate is marked by active and irregular erosion, closely linked to annual and monthly rainfall fluctuations. Other elements such as the nature of the rain (concentration time, intensity), the soil characteristics and the density of the vegetation cover must be taken into consideration.

The mean specific erosion rate of 2887 t/km²/year in watershed confirms the need for integrated and proactive management to prevent negative impacts on the dam and thus to propose sustainable solutions for resource management in the watershed.

Among the time series prediction models tested (RNN, LSTM, CNN, AR, MA, ARMA, ARIMA), the ARIMA model showed the best performance in predicting annual specific erosion, with an RMSE of 1.66, an MAE of 1.336 and an MAPE of 1.499. These results demonstrate a strong correlation between the predicted and observed values calculated from Fournier's empirical model, confirming the effectiveness of ARIMA in modelling erosion in the Koudiet Lemdaouar dam watershed.

This study highlights the usefulness of time series models for predicting erosion dynamics, particularly in semi-arid regions. ARIMA's performance suggests that classical, well-calibrated methods can compete with more complex models, providing an effective alternative for studies where data is limited. These results open up prospects for the integration of these tools into real-time management and forecasting systems, contributing to better planning of soil and water conservation measures.

### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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