

# LOAD SEDIMENTS QUANTIFICATION IN ALGERIAN NORTH-WEST BASINS BY ARTIFICIAL NEURONS NETWORK METHOD

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## ABSTRACT

Due to the complexity of basins morphometric parameters and the hydroclimatic irregularity of the semi-arid regions of North Africa, solid transport has been still far from being clearly assessed. This study attempts to shed light on this problem; in order to conceive a global model for the suspended sediment load quantification, taking into account all stream waters of the North-West area of Algerian. The calculation is based on the use of the ANN artificial neurons network method, which has proven its success and its reliability in several fields of research. The collected data are measured in hydrometric stations of several basins, such as Cheliff, Tafna, Macta, and Oran's basins. The results obtained using the ANN method are sufficiently reliable, the best correlations were obtained for each studied stream water exceeding 97% (specific model to each station), and 90% in the case of a global model characterizing for all studied stations, which allows the extracted model to give better estimation of the suspended solid flow rates for any measured liquid flow rate of the north-west Algerian basins.

**Keywords:** Solid transport, ANN method, Watersheds, North-West Algeria, Siltation dam

## 1 INTRODUCTION

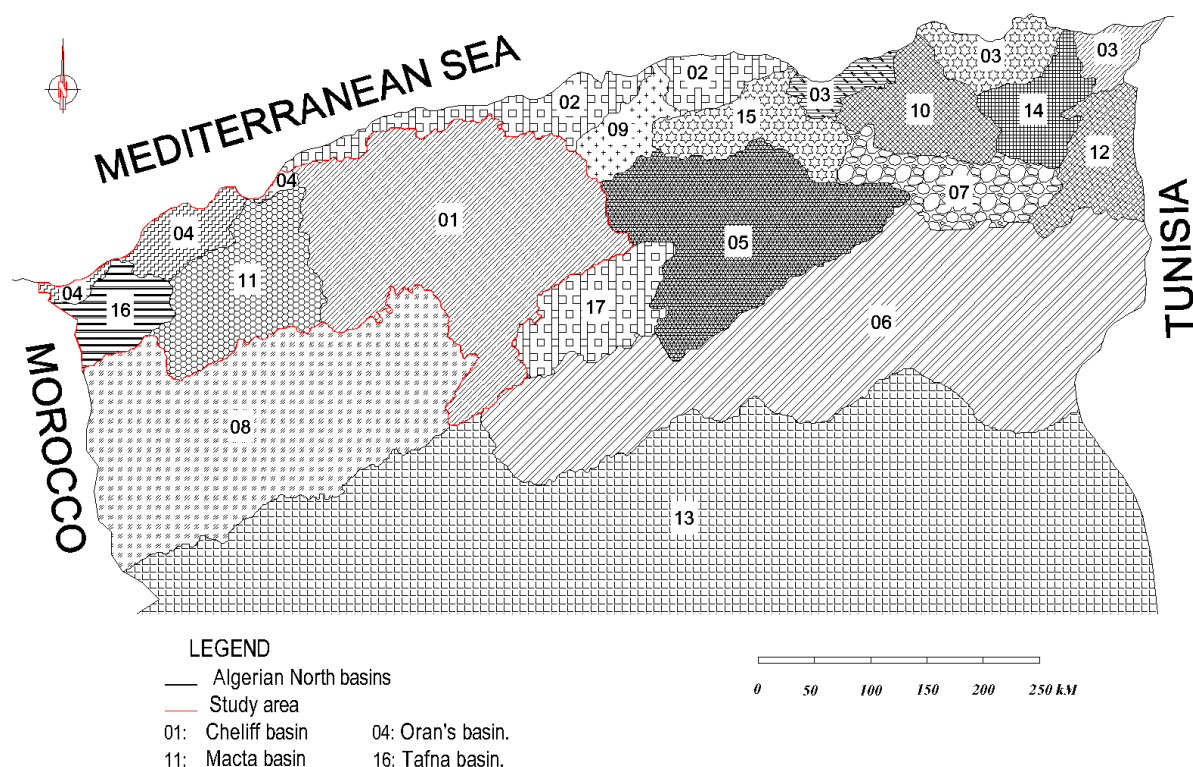
Water resources development in the north of Algeria requires water reservoirs construction for various purposes; however, the design and successful exploitation of water reservoirs can only be made through an accurate and proper sedimentary volume prediction. This volume estimation will have a big economic impact, knowing that an underestimation or overestimation decreases or increases the dead-volume. Underestimation can affect dam's life time by contrast, overestimation can lead to a huge increase in dam's cost.

Because of its semi-arid climate, relief irregularities and precipitations volume, the northwest side of Algeria is one of the most vulnerable regions in soil erosion. The phenomenon of sediments reaching the dams every year has prompted many researchers who have tried to solve this problem with several methods. In this context, we mention the works of Tixeront [1], Capolini [2], Ghorbel and Claude [3], Heusch [4], Milliman and Meade [5], Sogreah [6], Demmak [7], Colombani [8], Walling [9], Probst and Suchet [10], Lahlou [11], Rais and Abidi [12], Albergel [13], Snoussi et al. [14], Merzouki [15], Moukhchane et al. [16], Meddi [17], Bouraba [18], Remini and Avenard [19], Remini [20], Terfous et al. [21], Ghenim et al. [22], Megnounif et al. [23], Bouanani [24], Dechemi et al. [25], Achite and Touaibia [26], Touaibia et al. [27], Marouf and Remini [28], Marouf [29], who have studied some Algerian, Tunisian, and Moroccan basins. In reality, the problem is very difficult, complex and far from being solved with the current theoretical formulas. A considerable gap between the empirical formulas used, the siltation quantities in dam's measured by bathymetric surveys and the estimation during the design. Consequently, we were obliged to choose ANN method to solve this problem in a concrete way. The method has been known for its power, efficiency and also proves its success in several areas of research [30, 31].

This study is based on historical data "liquid flow rates-solid flow rates" of the North-West Algerian basins namely Cheliff, Tafna, Macta, and Oran, in order to provide the most appropriate global sedimentary load estimation model.

## 2 PRESENTATION OF THE STUDY AREAS

The study focuses on the basins located in the north-west of Algeria, i.e. Cheliff, Tafna, Macta, and Oran basins (Figure 1). Seven (07) measurement stations were selected in this area, on the large amount of data stored, to have reliable and concrete models for the suspended sediment load quantification. The choice of these hydrometric stations is aroused by the availability and richness of historic measurement data, in our case, liquid flow rates, solid flow rates. The data were provided by National Agency of Water Resources 'Agence Nationale des Ressources Hydriques' (ANRH) in 2016 [32] - see Table 1.



**Figure 1. Representation of the studied basins [32]**

**Table 1: Characteristics of the studied hydrometric stations [32]**

| Basin   | Stream waters | Station        | Code     | Period    | Measurement data Number |
|---------|---------------|----------------|----------|-----------|-------------------------|
| Cheliff | Djidiouia     | Djidiouia RN4  | 01-27-01 | 1974-2000 | 4 995                   |
| Cheliff | Cheliff       | Sidi Belatter  | 01-36-02 | 1969-2001 | 432                     |
| Tafna   | Mouilah       | Mouilah RN7    | 16-02-02 | 1973-2001 | 5 943                   |
| Tafna   | Tafna         | Pierre du chat | 16-08-01 | 1971-2005 | 537                     |
| Macta   | Mekerra       | El Hacaiba     | 11-01-01 | 1989-2003 | 1905                    |
| Macta   | Froha         | Griss          | 11-14-12 | 1976-2003 | 652                     |
| Oran's  | Mellah        | Turgo Nord     | 04-02-20 | 1978-2003 | 5083                    |

## 2.1 BASINS CHARACTERISTICS

The characteristics of the studied watersheds are given in Table 2.

**Table 2: Characteristics of the studied watersheds [32]**

| Basin  | Stream waters | Surface area (km <sup>2</sup> ) | Perimeter(km) | CI Compactness index | Equivalent length(Km) | Talweg length (Km) | Hmin (m) | Hmax (m) |
|--------|---------------|---------------------------------|---------------|----------------------|-----------------------|--------------------|----------|----------|
| Chélif | Djidiouia     | 835                             | 135           | 1.31                 | 51.20                 | 51                 | 70       | 925      |
|        | Cheliff       | 43700                           | 1383          | 1.85                 | 619                   | 759                | 20       | 1983     |
| Tafna  | Mouilah       | 1 820                           | 187           | 1.23                 | 65.90                 | 124                | 410      | 1824     |

|        |         |       |     |      |     |        |     |      |
|--------|---------|-------|-----|------|-----|--------|-----|------|
|        | Tafna   | 6 900 | 350 | 1.18 | 115 | 160.00 | 50  | 1824 |
| Macta  | Mekerra | 955   | 127 | 1.15 | 39  | 54     | 925 | 1440 |
|        | Froha   | 132   | 56  | 1.36 | 22  | /      | 499 | 1201 |
| Oran's | Mellah  | 697   | 135 | 1.43 | /   | 60     | 36  | 824  |

### CHELIFF BASIN

It is located in the North-West region of Algeria, bordered at North by Algiers coastal basin; South by Sahara basin, West by Oran costal basin, Macta and Oran highlands and East by Chott-Melghir, Zahrez, Chott-Hodna and Isser. The main watercourse in this Basin is Chélif-stream water.

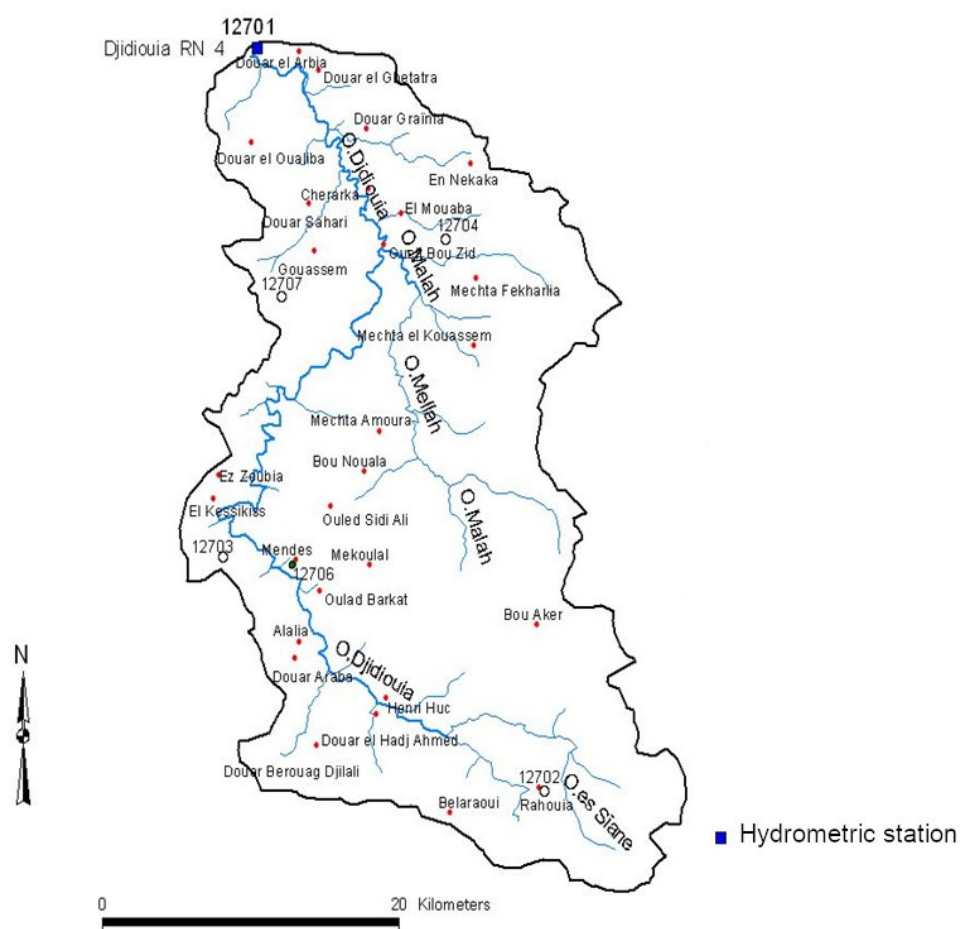


Figure 2. Djidiouia stream water watershed [32]

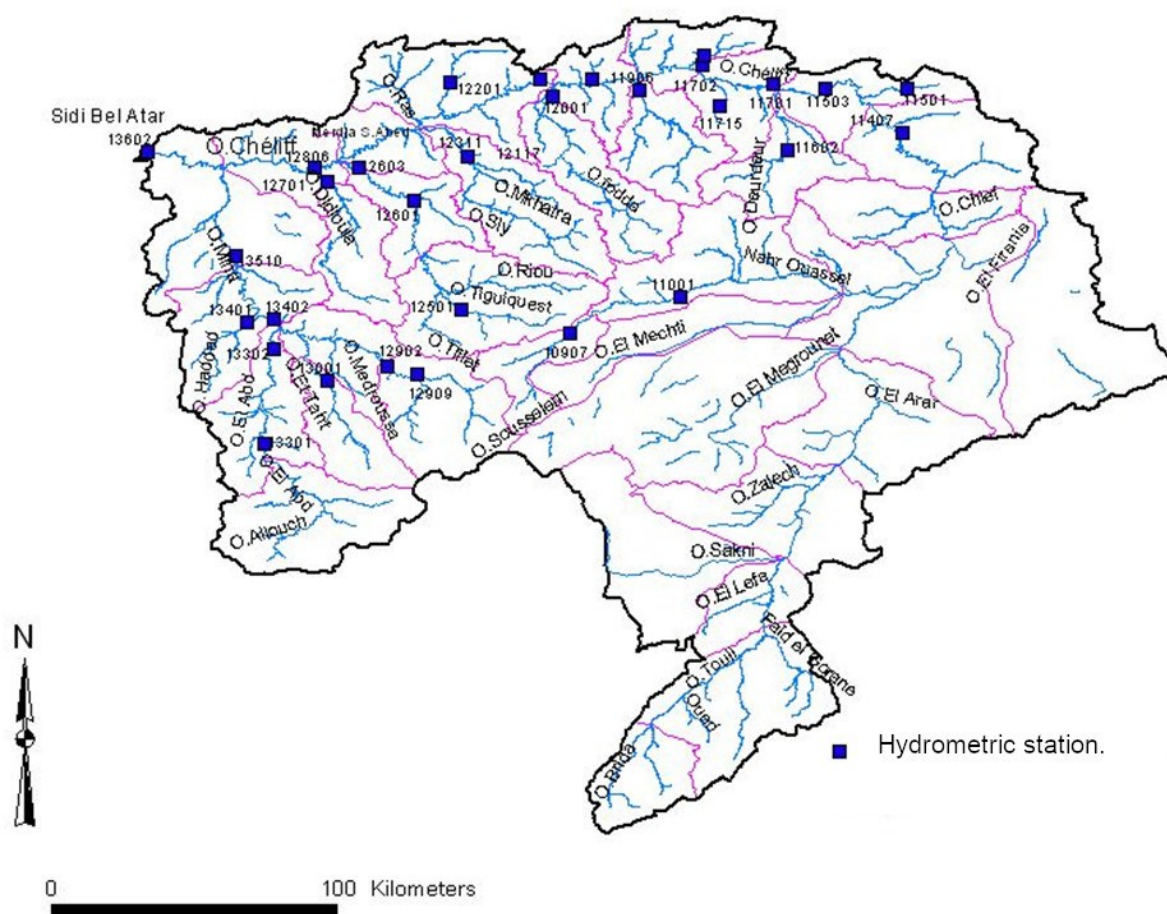


Figure 3. Cheliff stream water watershed [32]

- Djidiouia stream water is a stream located east of the wilaya of Relizane, north-western Algeria which flows from the Rahouia Mountains and runs into Cheliff stream water (Figure 2).
- Cheliff stream water is a river of 725 km long, located in the north-west of Algeria which is fed from the Tellian Atlas, more precisely in the Djebel AMOUR and flows into the Mediterranean Sea. The Cheliff is characterized by a very fertile valley and it is the most important river in Algeria (Figure 3).

### TAFNA BASIN

The Tafna Basin is located in the extreme north-west of Algeria while a part of it is immersed in Morocco, bordered to the north by the Oran Basin Coastal, east by Macta Basin, and west by Moroccan borders. Its main watercourse is the Tafna River.



- Tafna stream water is a stream of 170 km long, stretching in the wilaya of Tlemcen (Figure 4) and after having crossed sinuous gorges, enters the wilaya of Ain Témouchent, crosses the ancient city of Siga, and flows into the Mediterranean Sea. The Tafna watershed is fed from mountains of Djebel Merchiche near Sebdouand extending partially to Morocco.
- Mouillah stream water is located in the left bank tributary of Tafna stream water that starts in the region of El Abed in Algeria at 550 m altitude, then enters Morocco and takes the name of Stream water Isly, and follows in intermittent flow (Figure 5). It becomes a permanent downstream of the city of Oujda (Morocco) to 490 m of altitude to take the name of the Stream water Bounaïm and enters in Algeria near Maghnia, under the name of Mouillah stream water. It sits down on its right bank, the Effou its tributaries, Abbas, Aounia and Méhaguène stream waters.

### MACTA BASIN

It is located in the north-western region of Algeria, bordered to the north by the Oran's coastal basin. One part of it extends to the Mediterranean Sea; south is bounded by the Oran's Highlands Basin; east by the Cheliff basin and west by the Tafna Basin. It is drained by two main watercourses, the Mebtouh stream water to the west and El-Hammam stream water to the east.

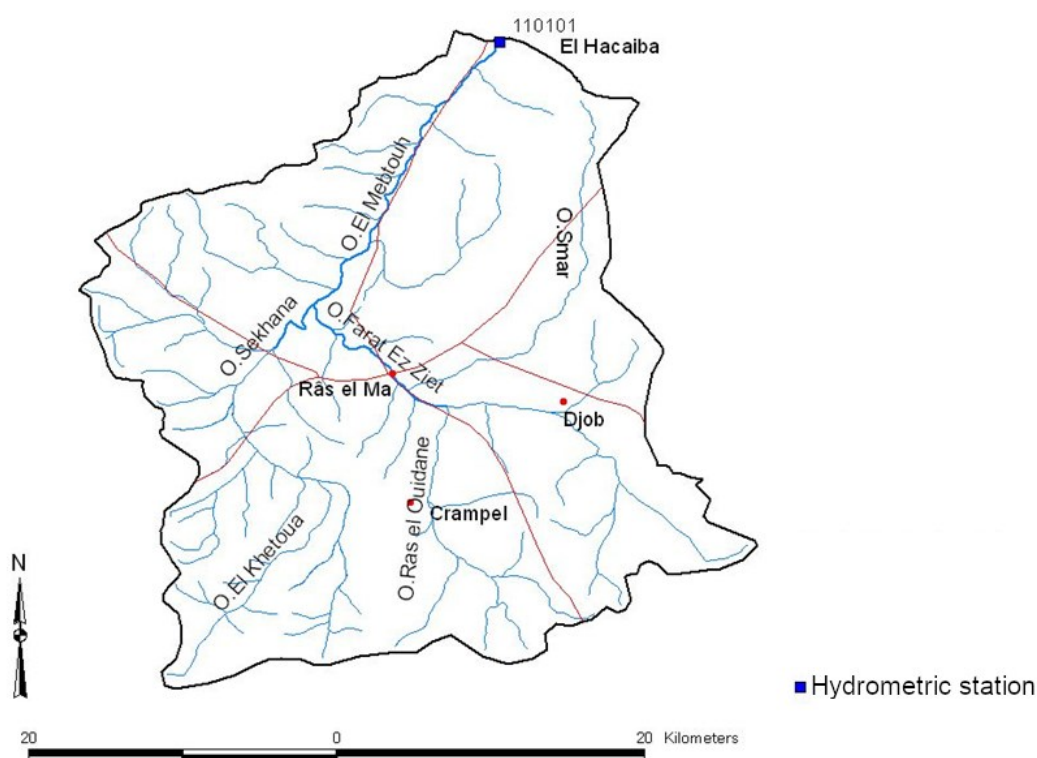
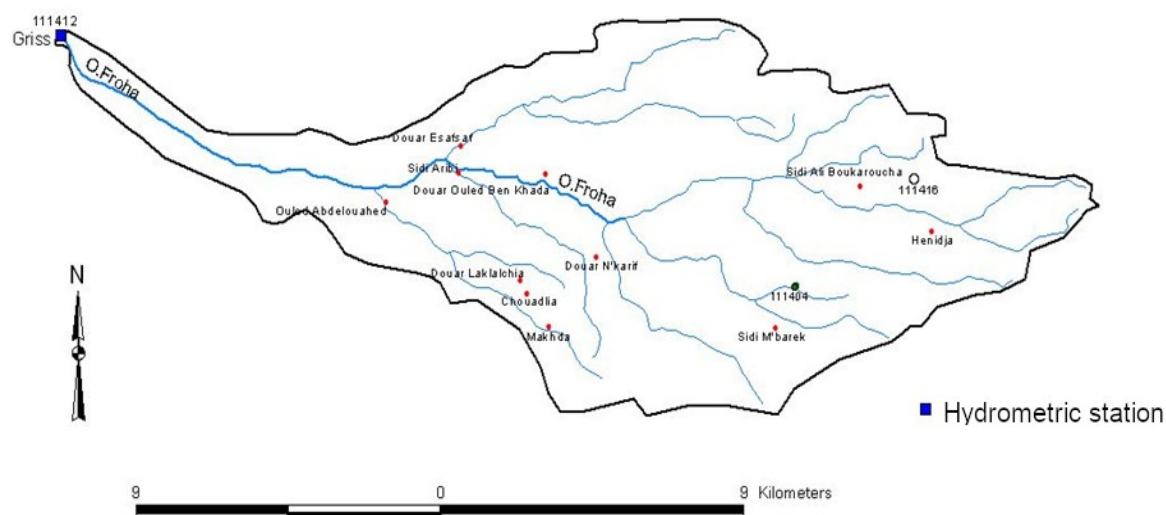


Figure 6. Mekerra stream water watershed [32]

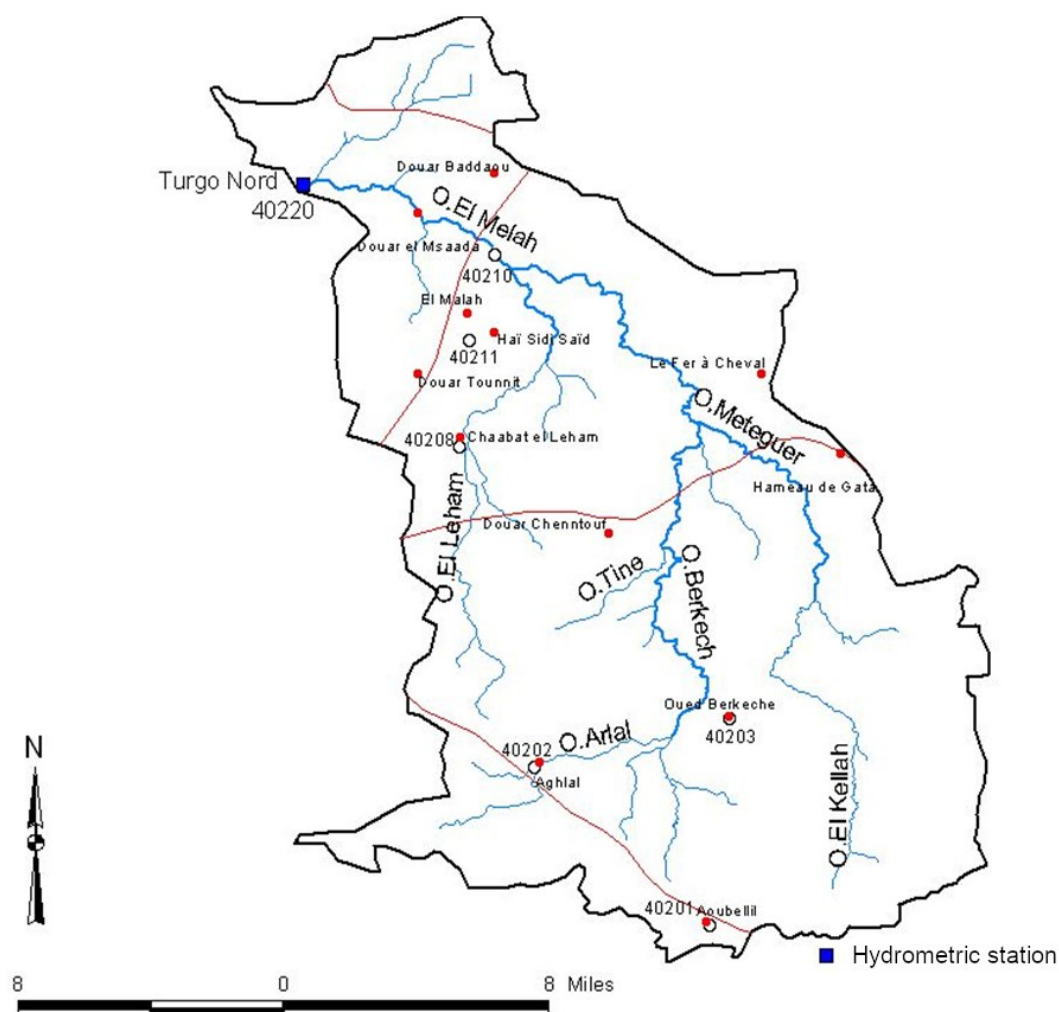


**Figure 7. Froha stream water watershed [32]**

- Mekerra stream water is a watercourse originating in the mountains of Djebel El-Marhoum in the south of the wilaya of Sidi-Bel-Abbes. It divides the city centre in two parts, and then it runs into the Medtough stream water (Figure 6).
- Froha stream water is a watercourse that originates in the mountains of Djebel Bezita in the south-east of the wilaya of Mascara and flows into the Ain-Fekan stream water (Figure 7).

### ORAN'S BASIN

It is located in the north-west of Algeria, bounded in the north by the Mediterranean Sea; east by the Algiers coastal basin; south by the three Basins: Chélif, Macta and Tafna; west by Moroccan borders. Among the main streams of this Basin, we can mention El-Mellah stream water.



**Figure 8. Mellah stream water watershed [32]**

- Mellah stream water is a watercourse that begins in the south of Hammam-Bouhadjar and flows into the Mediterranean Sea (Figure 8).

### 3 RESULTS AND DISCUSSIONS

#### 3.1 Distribution of Solid flow rate depending on liquid flow rate.

The representation of the measured solid flow rates in relation with the measured liquid flow rate of each studied hydrometric station is illustrated in the graphs mentioned in Figure 9.

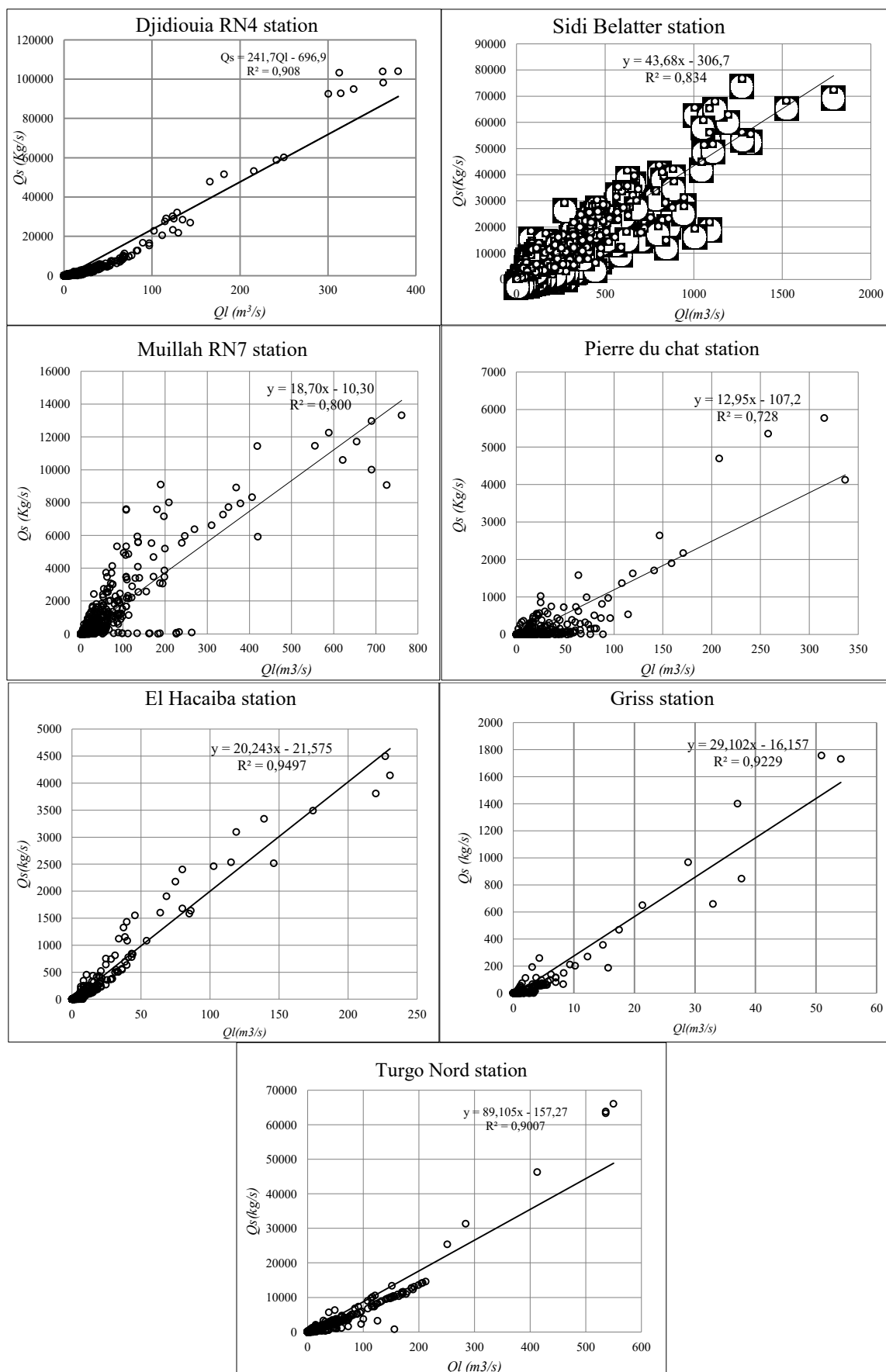


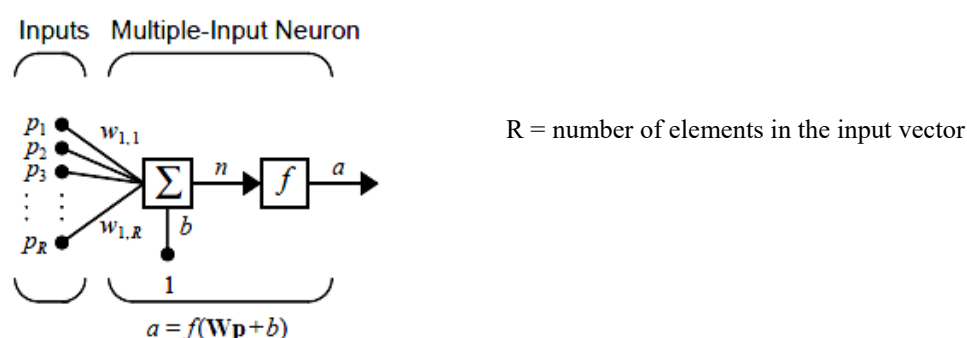
Figure 9. Relationship between solid-liquid flowrate in each hydrometric station

Graphical representations of solid-liquid flow rates of all the studied stations (Fig. 9) show a good linear trend. This was interpreted by the correlation coefficients closer to (1). Furthermore, the highest solid flowrates were recorded during the floods that come after drought periods (June to October). In this case, the greatest contribution of the sediments comes from the valley of the basin due to the climatic conditions (high temperature during the summer season and the first rain drops of heavy rains [28]). It is hardly possible that a solid flowrate is important because of degraded soil being ravaged by the first floods; therefore, the predictive power of the chosen model is strong and the function that links the solid flowrates to the liquid flowrates is in linear form.

### 3.2 Application of ANN method

The ANN method is a harmonized calculation model whose design is very schematically inspired from the functioning of human biological neurons. The formal neuron is designed as a PLC (programmable logic controller) with a transfer function that transforms its input to output according to specific rules. Neurons are also associated in networks whose topology of connections is variable; the efficiency of signal transmission from one neuron to another can vary: we speak about "synaptic weight", and these weights can be modulated by training rules (which presents the synaptic plasticity of biological networks). There are several methods of ANN calculations. We opted for the method of '*feedforward backprop*' because it is the most appropriate [30].

An elementary neuron with  $R$  inputs is shown in Diagram 1. Each entry is weighted with  $w$ . The sum of weighted inputs and bias ( $b$ ) is the input to the transfer function ( $f$ ). Neurons can use any differentiable transfer function  $f$  to generate their output.



**Diagram 1. Elementary Neuron**

For multi-layer networks, the number of layers determines the index on the weight matrix. This network can be used as a general function approximator. It can approximate any function with a finite number of discontinuities arbitrarily well, if enough neurons are given in the hidden layer [30].

### Preparation of liquid-solid flowrate (Ql-Qs) data for multilayer neural networks

Before starting the network design process, we must first collect and prepare data (Ql-Qs). It is important that the data (Ql-Qs) cover the range of inputs for which the network will be used. After collecting the data, there are two steps that must be performed before using the data (Ql-Qs) for network learning: the data shall be pre-processed and divided into sub-sets.

### Neural Network Input-Output functions

Training the neural network can be more efficient if we perform certain pre-treatment steps on the inputs and targets of the network. The normalization step is applied to both the input and the target vectors in the data set (Ql-Qs). Hence, the network output always falls within a normalized range. The network output can then be transformed back into the original target data units when the network is put in use in the field.

### (Ql-Qs) Data Division for optimal training on neural networks

The general practice is to divide the data into three subsets. The first subset is the training set which is used to calculate the gradient and update the weights ( $w$ ) and the network bends. The second subset is the validation set. The error on the validation set is monitored during the training process. Normally, the validation error decreases during the initial phase of training, as does the error of the training set. However, when the network begins to overload the data, the error on the validation set usually begins to increase. Weights and network biases are recorded as a minimum of the validation error. The test error is not used during training, but it is used to compare different models. The chosen ratios for training, testing and validation are 0.6, 0.2 and 0.2, respectively.

### Running and application of a multilayer neuron network

The fastest training function is usually the *trainlm*. We are now launching our ANN network for each measurement station with  $Ql$  as input and  $Qs$  as target, based on the calculation steps mentioned earlier.

## Improvement of results

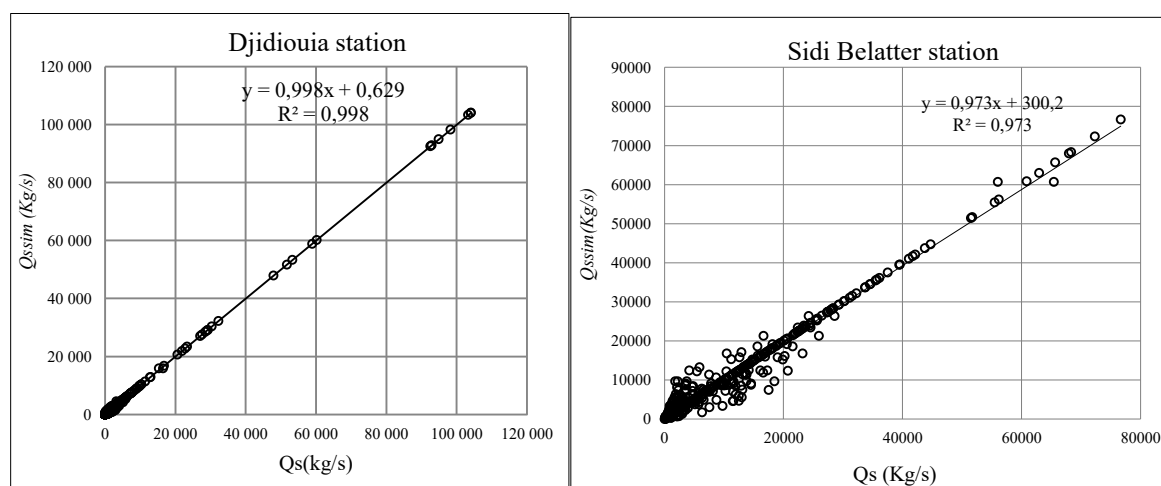
If the formed network is not precise enough (does not give accurate results), we try to reset the network and run it again. Each time a *feedforward* network is initialized; the network settings are different and can produce different solutions. As a second approach, one can increase the number of neurons hidden above 10. A larger number of neurons in the hidden layer provides more flexibility to the network. A third option is to try different training functions. Table 3 shows the calculation parameters that we have achieved after several attempts, in order to have better results.

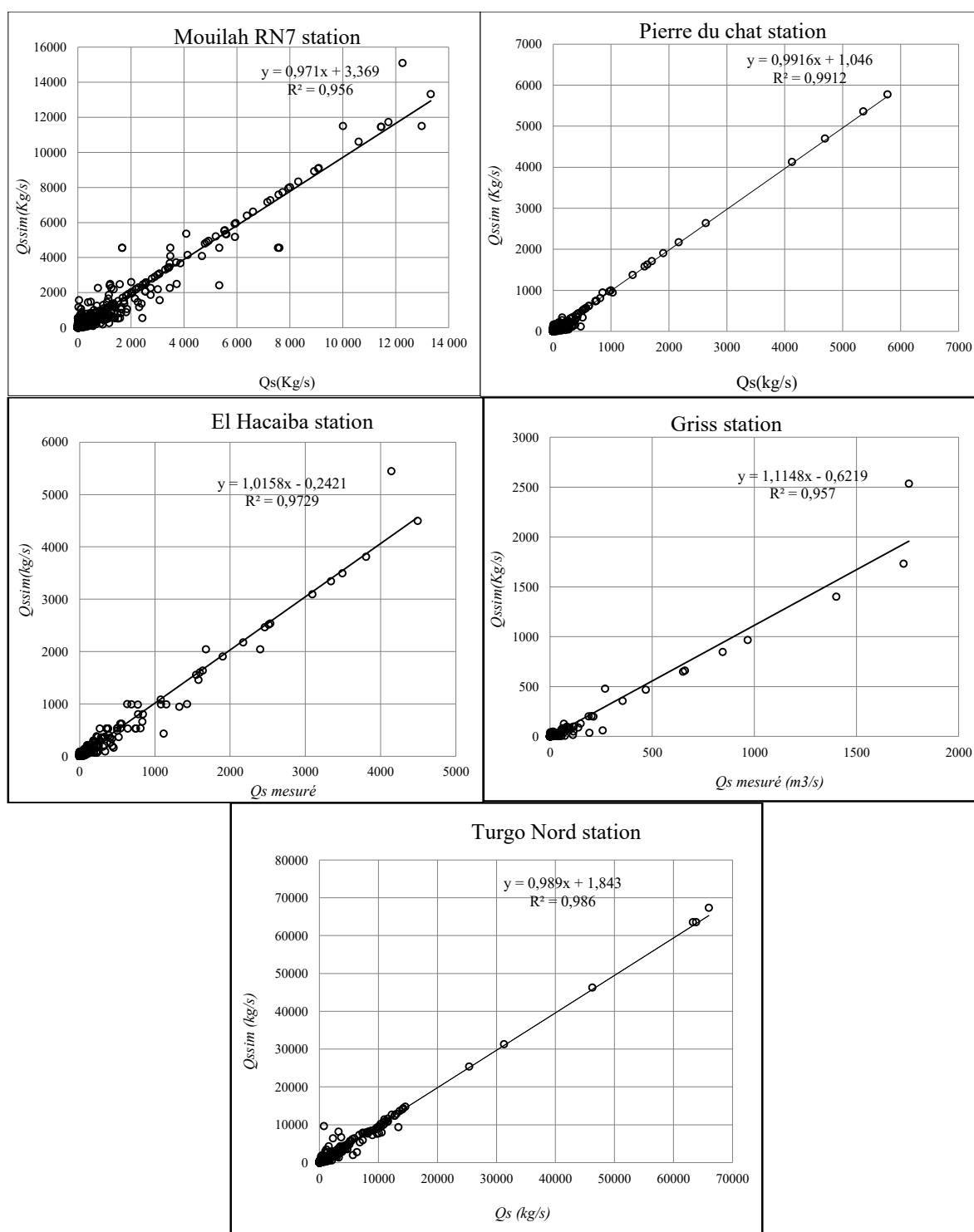
**Table 3. Station's parameters.**

| Station        | Year      | No of measurements | ANN Method           | Training Function | Layers No | Transfer function | Iteration No | Neurons No |
|----------------|-----------|--------------------|----------------------|-------------------|-----------|-------------------|--------------|------------|
| Djidiouia RN4  | 1974-2000 | 4 995              | Feedforward backprop | Trainlm           | 2         | Tansig-Purelin    | 100          | 800        |
| Sidi Belatter  | 1969-2001 | 432                | Feedforward backprop | Trainlm           | 2         | Tansig-Purelin    | 100          | 800        |
| Mouilah RN7    | 1973-2001 | 5 943              | Feedforward backprop | Trainlm           | 2         | Tansig-Purelin    | 100          | 800        |
| Pierre du chat | 1971-2005 | 537                | Feedforward backprop | Trainlm           | 2         | Tansig-Purelin    | 100          | 1000       |
| El Hacaiba     | 1989-2003 | 1905               | Feedforward backprop | Trainlm           | 2         | Tansig-Purelin    | 100          | 50         |
| Griss          | 1976-2003 | 652                | Feedforward backprop | Trainlm           | 2         | Tansig-Purelin    | 100          | 30         |
| Turgo Nord     | 1978-2003 | 5083               | Feedforward backprop | Trainlm           | 2         | Tansig-Purelin    | 100          | 10         |

## ANN method results

We describe the variation of simulated solid flow rate simulated ( $Q_{ssim}$ ) by ANN model depending on solid flowrate that was measured in each hydrometric station. The attached graphs illustrate the ( $Q_{ssim}$ - $Q_s$ ) variation obtained at each measuring station (Figure 10).





**Figure 10. Relationship between solid flow rates simulated by ANN method and measured in each station**

The graphical representations shown in Figure 10 represent ( $Q_{sim}$ - $Q_s$ ) variations. The  $Q_{sim}$  are the output data of the ANN neuron network model built according to  $Q_s$  measured in each hydrometric station. We can see an almost linear regression between ( $Q_{sim}$ - $Q_s$ ). The training data indicate a good fit. The validation and test results also show correlation values greater than 0.9. The scatter plot is useful for showing that some data points have poor adjustments. In the seven (07) studied hydrometric measurement stations, the correlation coefficients reach values in the interval ( $R = 0.98$ - $0.99$ ). The result obtained by ANN shows an excellent approach. The measured values of each measurement station are almost the same and the variables aggregate on a better fit by increasing linear lines.

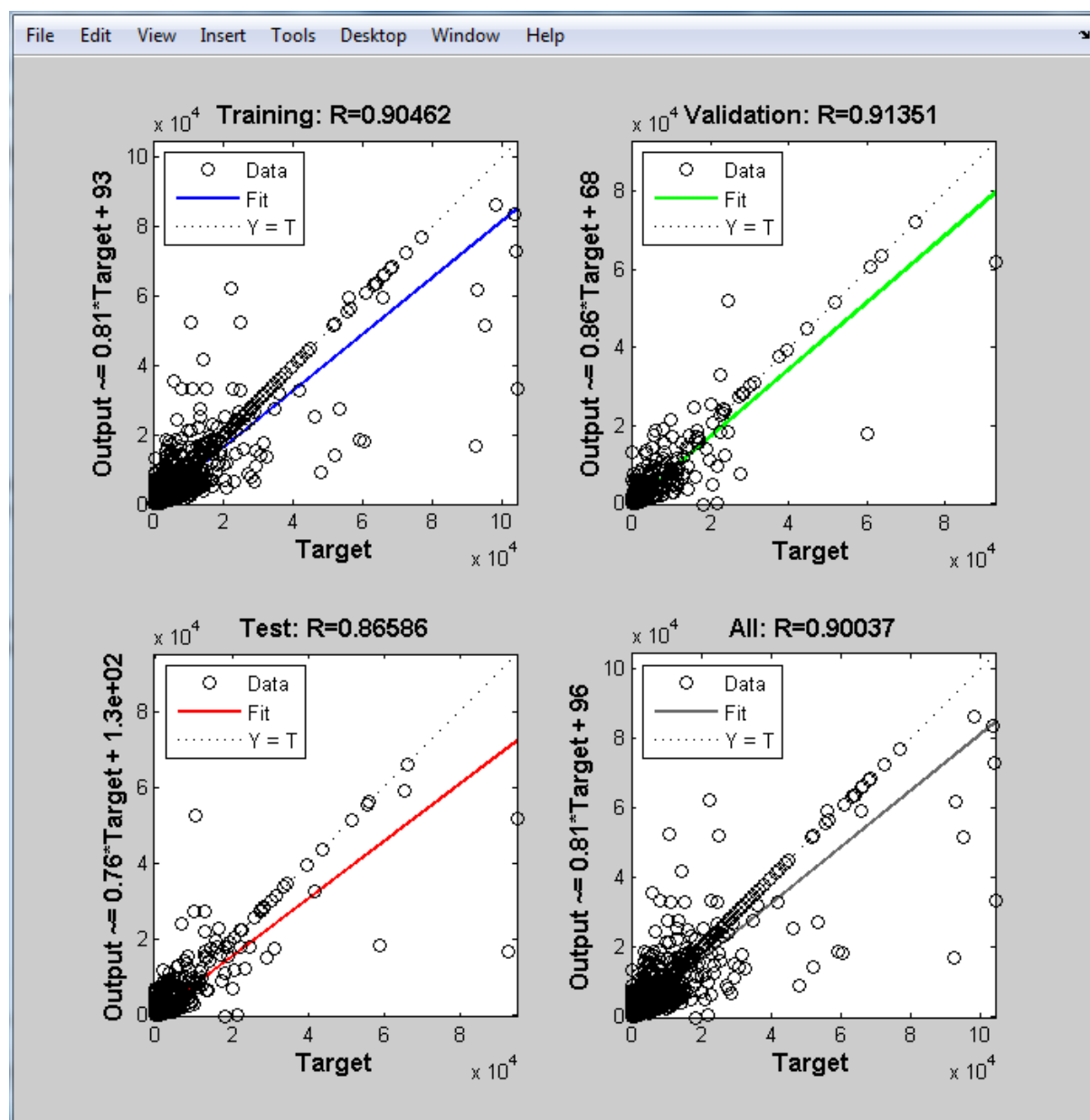
### 3.3 Comparison of the unique and the general model of ANN method

All collected measures of the liquid/solid flowrate data ( $Ql-Qs$ ) from all the hydrometric stations are used to form one single block in order to build up one ANN model of all the studied watersheds. We have set 70% for data training, validation 15%, and 15% for testing the result (Table 4).

**Table 4. Global station parameters**

| Global station | Years     | Measurement No | AN N method          | Training Function | Layers No | Transfer function | Iteration No | Neurons No |
|----------------|-----------|----------------|----------------------|-------------------|-----------|-------------------|--------------|------------|
| Global         | 1974-2000 | 19 547         | Feedforward backprop | Trainlm           | 2         | Tansig-Purelin    | 100          | 400        |

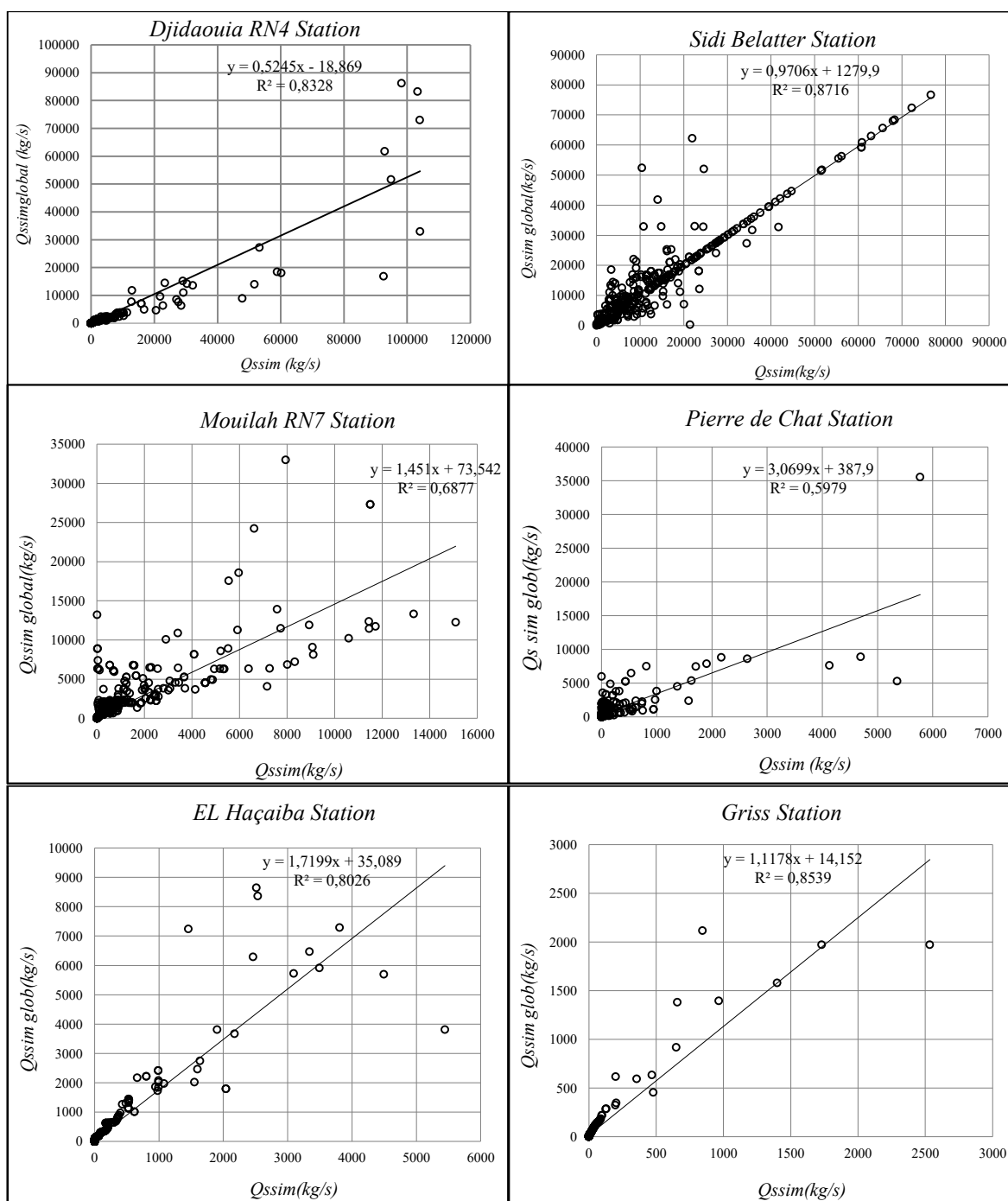
The obtained results are shown in Figure 11.

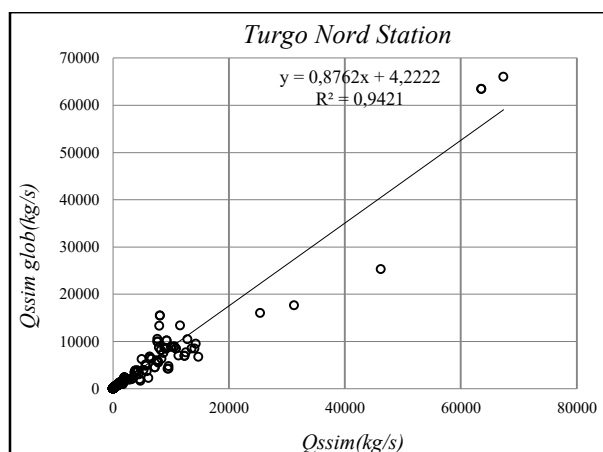


**Figure 11. Solid flow rates simulated by global ANN model (Training, validation, test and All)**

As shown in the graphs obtained by the global ANN model, we can observe quasi-linear fit in the three execution blocks (training, validation and test). The correlation coefficient approaches to 1 and has the lowest correlation of about 86.6% in the test graph. Therefore, it can be deduced that the general model performed is reliable and prevailing.

To prove the efficiency of the general simulation model, we tested it for each studied measuring station. The simulations results are shown in Figure 12.





**Figure 12. Solid flow rates simulated by the global model according to solid flow rates simulated by each model ( $Q_{ssim\ glob}$ - $Q_{ssim}$ ) in each station**

The representations of solid flowrate simulated of global model ( $Q_{ssimglob}$ ) depending on each individual model show a good linear trend. The correlation exceeds 77% in all the measuring stations. It reaches a maximum correlation of (97%) at the Turgo Nord station in the Oran's basin (Figure 12) and a minimum trend of (77%) at the Pierre du Chat station in the Tafna basin. These adequate results obtained approve the general simulation model found and confirm its reliability of estimation in all the hydrometric measurement stations despite the training sample did not exceed 70%.

#### 4 CONCLUSION

The quantification of the suspended sediment load by the *ANN* method has been applied in the North-West Algerian basins including Cheliff, Tafna, Macta and Oran's. This method has proved its computing efficiency. The obtained results are almost perfect and show ideal correlations. This model has been tested on several historical data of liquid flowrates of each hydrometric station to guarantee its reliability over time. The extracted global model is valid for estimating suspended solid transport in all studied watersheds. The other established individual models are designed for each studied basin and specific to each measuring station. So, this approach allowed calculation of the solid flowrate in a concrete, precise or even eloquent way. Consequently, it makes it easier for engineers and managers of hydraulic structures to have better estimate solid transport volumes and to predict their protection. In the same way, it also allowed to gain time and means by properly estimating the sediment load and minimizing the project cost. The final global model only needs liquid flowrates as data at the program input to predict the amount of sediment transported in stream waters. We can also make measurements on site directly using the introduction of software (global model) in hardware (flow meter) something that allows reading the solid flowrate directly on the meter.

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