



## Estimating the Real Capacity of Rain Erosion Using GIS (The Fournier Case Study for Isfahan)

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Interpolation, the generalization of point data to scatter data, and combining maps are three cases of important applications of GIS. In this study, it has been tried to make the estimation of rain erosion capacity (Fournier Method) more real through using GIS capability in interpolation and the generalization of point data to scatter data. In Fournier method, the rain erosion capacity is calculated through the use of two climatic parameters (annual precipitation and the rainfall mean in the rainiest month of year) and two physiological parameters (the height and slope of the region). The findings of this study indicated that there is significant difference between these two methods of calculating rain erosion capacity. Using the means of rain erosion potential was estimated to be almost 3.4 tones per square kilometers annually while this amount was estimated to be 4.5 tones per square kilometers annually by using GIS capabilities. [Amir Gandomkar, Estimating the Real Capacity of Rain Erosion Using GIS (The Fournier Case Study for Isfahan). International Journal of Agricultural Science, Research and Technology, 2011; 1(1):33-38].

**Keywords:** Interpolation, Point data, Scatter data, Rain erosion capacity

Abstract

Received: 15 May 2011,  
Reviewed: 19 May 2011,  
Revised: 21 May 2011,  
Accepted: 26 May 2011

### 1. Introduction

One of the problems that researchers of geomorphology-climatology and civil are met in city planning, is estimating the real amount of the rain deposition, because in some cases complex factors should be computed which their assessment is difficult, time consuming and expensive. There are more than 90 methods to estimate deposition square of an area which is different in accordance with the type of the deposition in used elements (Gandomkar, 2000).

Douglas's Method, Musgrave's Method (1947) and Fournier's Method (1960) are some common examples of estimating deposition. These models have used some limited factors which are quite simple to obtain or evaluate. In some other methods, various factors are used, such as: USLE Method (Wishmayer 1947), EMP Method (Yaroslov Serni 1952), Fao Method, Estlic Method (Zashar 1982), Psiac Method (PSIAC) and SLEMSA Method (Ramesht, 1996).

Fournier's Method (1960) estimates amount of annual deposition of an area with respect to climatic and morphologic specialties. In this method, two climatic parameters (average annual precipitation and rainfall mean in the rainiest month of year) and two physiological parameters (The height and slope of the region) are used to compute the square of the

rain erosion capacity as following (Chorley and et al, 1985).

Equation(1):

$$\text{Log } Q_s = 2.65 \text{Log} \frac{\rho^2}{P} + (0.46 \text{Log} \bar{H} \times \tan S) - 1.56$$

$\bar{H}$  : Average height of the region according to meter  
S: Average slope of the region according to degree  
P: Average annual precipitation according to mm  
Qs: Deposition according to ton in square kilometer in a year

$\rho^2$  : Rainfall mean in the rainiest month of year according to mm (Rafahi, 1999).

Fournier studied floating deposition weight for 78 arid or semi arid areas in Tunisia and Algeria which had a survey from 2460 to 1060000 square kilometer. He showed that there's a meaningful relationship between the deposition weight and

regard monthly rain to average annual ( $\rho^2/\bar{P}$ ) in areas which have different unevenness. In this relation, p is the average annually precipitation

according to mm and  $\rho^2$  is the Rainfall mean in the rainiest month of year according to mm. So it's clear that in arid and semi arid areas which most precipitation of a year happens in one or two special

months, the relation between  $\rho^2/\bar{P}$  will increase and the impression amount of this factor in Rain erosion capacity will increase, too. So the deposition capacity of region in respect with wet areas will be more (Chorley and et al, 1985).

In equation (1), average factors are used in region. This method seem correct when region is completely constant and each factor has a permanent amount in the total region, whereas the amount of each factor in different part of the region is various and it makes two principal problems in estimating amount of rain erosion. The first problem is that with Fournier's method, amount of erosion would only be a number that is used for the total region, which the amount of erosion in various points of the area is different and in some parts amount of deposition might be several time as much as other parts.

The second problem is related to different dimensions in Fournier's method. As it is observed in Fournier's method the average rain of the rainiest month of the year is squared and its minor change can change the amount of deposition strongly, while a change in average annual precipitation and height or region slope has less effect on the amount of deposition. So average amount of factors and average amount of deposition gained in equation (1), can't state the real amount of deposition in total region (Kiarsi, 2001).

To remove above problems we can use three ability of GIS software including: Interpolation, the generalization of point data to scatter data, and combining maps (Gandomkar, 2000).

Nearing and et al (2004) show that cause for concern. Rainfall erosivity levels may be on the rise across much of the United States. Where rainfall amounts increase, erosion and runoff will increase at an even greater rate: the ratio of erosion increase to annual rainfall increase is on the order of 1.7. Even in cases where annual rainfall would decrease, system feedbacks related to decreased biomass production could lead to greater susceptibility of the soil to erode. Results also show how farmers' response to climate change can potentially exacerbate, or ameliorate, the changes in erosion rates expected.

Bayramin and et al (2006) Show that ASER surfaces produced by the monthly return frequencies of rainfall events for 10 (MFI10), 20 (MFI20), and 30 (MFI30) years showed significant improvements and agreements with the erosion classes of the conventional soil survey of the study area.

Diodato and Bellocchi (2007) show that The REMDB estimates generally compared well with the USLE estimates according to different statistics. For REMDB, the relative root mean square error was, in average, 48.58% against 71.49% for MMFI and

66.55% for GJRM. The average modelling efficiency of REMDB was 0.51 against -0.02 (MMFI) and 0.13 (GJRM). REMDB was also superior in preventing biased errors in time, as quantified by the average pattern index versus months: 17.65 MJ mm h<sup>-1</sup> ha<sup>-1</sup> month<sup>-1</sup>, against 58.54 MJ mm h<sup>-1</sup> ha<sup>-1</sup> month<sup>-1</sup> (MMFI) and 57.76 MJ mm h<sup>-1</sup> ha<sup>-1</sup> month<sup>-1</sup> (GJRM). Of the two simplified models, the MMFI was the worst performer while the GJRM model performed similarly to the REMDB at two mid-altitude sites of Central Italy.

Munka and et al (2007) show that an early increase during the 1940s in the Northwest, and generally very low values during the 1970s, with the return of high values in the 1990s, especially in the Northern corner. Results pose a challenge in order to improve research on the erosion problem, since the main source of freshwater nationwide remains surface river flow, which is prone to higher turbidity problems in areas of high soil erosion.

Angolu and et al (2009) show that Two methodologies were applied: (i) daily rainfall erosivity estimated using several parametric models, and, (ii) annual rainfall erosivity estimated by regression-based techniques employing several intensity precipitation indices and the modified Fournier index. To determine the accuracy of estimates, several goodness-of-fit and error statistics were computed in addition to a spatial distribution comparison. The daily rainfall erosivity models accurately predicted annual rainfall erosivity. Parametric models with few combined parameters and a periodic function simulating intra-annual rainfall behavior provided the best results. Where daily rainfall records were not available, good estimates of annual rainfall erosivity were also obtained using regression-based techniques based on 5-day maximum precipitation events, the maximum wet spell duration, and the ratio between the lengths of average wet and dry spells. Inherent limitations remain in the use of daily weather records for estimating rainfall erosivity. Future research should focus on incorporating measures of natural rainfall properties of the particular region, including kinetic energy and intensity, and their effects on the soil

Arghius and Arghius (2011) show that The effective surface erosion map was obtained in the second stage of the mathematical modeling erosion, by integrating the effect of natural or crop vegetation. The thematic map obtained was aligned to the present Romanian legislation (order no. 223 of May 28, 2002); the superficial erosion intensity map includes five classes: insignificant erosion <3 t ha<sup>-1</sup> yr<sup>-1</sup>, low erosion: 3-10 t ha<sup>-1</sup> yr<sup>-1</sup>, moderate erosion: 10-20 t ha<sup>-1</sup> yr<sup>-1</sup>; high erosion: 20-40 t ha<sup>-1</sup> yr<sup>-1</sup>, very high erosion: >40 t ha<sup>-1</sup> yr<sup>-1</sup>. The results obtained indicate

an average annual rate of erosion of 0.575 t ha<sup>-1</sup> yr<sup>-1</sup> and a quantity of material discharged by surface erosion of 55,561 tons per year. 97.46 % of the study area has tolerable values (<3 t ha<sup>-1</sup> yr<sup>-1</sup>), revealing the low degree of human intervention, a good vegetation cover and the domination of the slopes with low inclination, less susceptible to erosion.

Mileyski (2011) shows that Implemented erosion models show a truly high average soil loss of about 1 mm/y, with significant local differences between areas subjected to a greater or lesser degree of human impact. Because of enormous sediment loads, the Kalimanci reservoir, which was built in 1969, was filled up very fast and lost more than 13 % from its storage volume of 127 million m<sup>3</sup>. As a consequence of such violent erosion, attempts to investigate and control these processes were made from the 1960s onwards, but only with partial success.

## 2. Material and Methods

Data used in this studding includes as follows:

1- Average 30 years (1971-2000) precipitation in Synoptic, climatology and rain gauge station inside and around Isfahan city that is deciphered from statistical calendars of meteorology organization.

2- Average 30 years (1971-2000) rainfall mean in the rainiest month of year in Synoptic, climatology and rain gauge station inside and around Isfahan city that is deciphered from statistical calendars of meteorology organization.

3- The topography map of Isfahan city and its suburbs.

4- The map of the region slope provided on the basis of the topography map.

When the necessary data of searching is provided by the use of Kriging method (Burrough, 1986) for the three factors, average annual precipitation, average rain of the rainiest month of a year and height of the area's points, afterwards they look for interpolation (with the same amount of pixel for three data) and later on with regard to related data of the contour map, slope of the area will be deciphered.

Using data obtained in previous step and with the average weight method, all the four factors are estimated for the region and will be placed in equation (1) and then average amount of rain erosion capacity can be computed.

Compute the real amount rain erosion capacity in different point of the region and its average in the whole region, the map of the isopleths lines of four factors are provided and the map of the average annual precipitation will be compounded

with the map of the average rain of the rainiest month

of year and as a result  $\rho^2/\bar{P}$  map is obtained that is able to describe rain erosion capacity in different point of the region.

Afterwards topography map compounded with slope map and map of the morphologic specialties of the region that shows the deposition in Fournier's relation will be obtained, and at last two gained maps are compounded on the basis of Fournier equation and final map that is rain erosion capacity in Fournier's Method will be provided. In accordance will this map rain deposition power in each part of that region can be defined and computed its average amount with average weight method for the whole region.

## 3. Results and Discussion

Rain deposition gathering in cities' places and passages is one of their biggest problems. To stop this gathering in passages and street planning and the brooks beside the passages, it should be possible to compute amount of deposition obtained from rain correctly and do necessary planning. Deposition is created by erosion of the areas that lead to cities and depend on various factors. Such as: amount and intensity of the rain, Land sloping, land use, plant covering and ets. To compute amount of erosion, different formulas and relations are represented and each one has used different factors. One of these relations is Fournier's relation that is suggested in 1960 and emphasized on climatic and morphologic specialties. The climatic specialty used in this relation is concerning between rainfall in the rainiest month of the year and average annual rain in region. That in fact emphasized the rain intensity. So the more ratio, the more the rain and the more rain erosion capacity. To compute average annual rain in Isfahan city and its suburbs, They used average 30 years annual rain of the synoptic, climatology and rain gauge station inside and around Isfahan and interpolation was done by Kriging method and then the map of the isohyets lines was sketched (Figure 1).

In accordance with this, in Isfahan city and its suburbs the average annual precipitation differs from about 111mm in eastern part of the area to about 126mm in western parts of the area and the average precipitation in the area is about 120mm.

Average 30 years rain in March (the rainiest month) is used to find the interpolation with Kriging Method and the map relation to monthly isohyets lines in March is sketched (Figure 2).

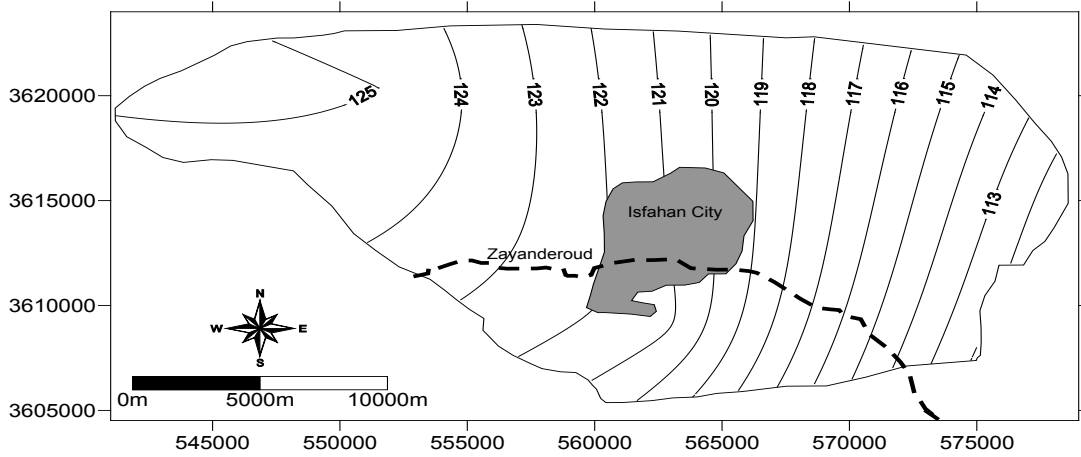


Figure 1: Annual isohyets lines map of Isfahan city and its suburbs

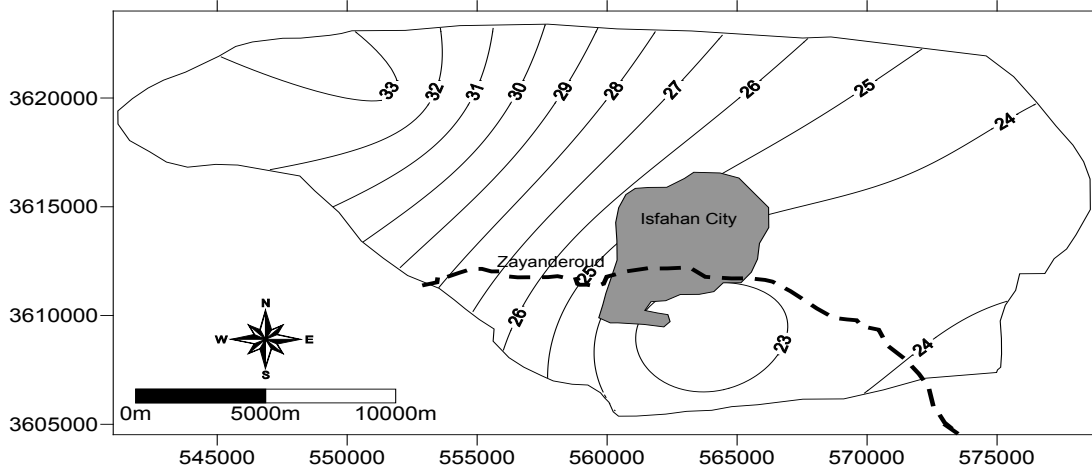


Figure 2: March isohyets lines map of Isfahan city and its suburbs

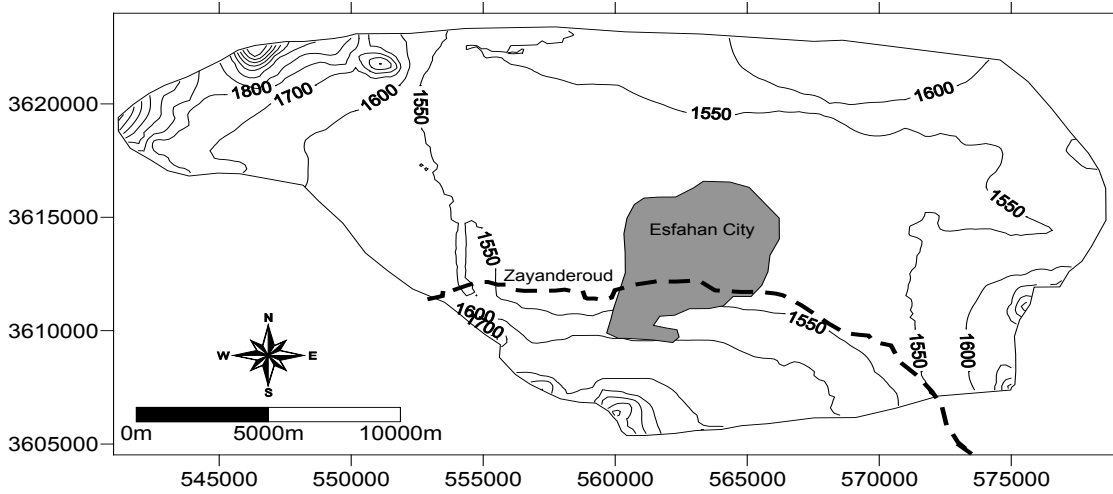


Figure3: Contour map of Isfahan city and its suburbs

According to these computations amount of the rain in the rainiest month of the year in the area differs from about 24 mm in Isfahan regions to about 34 mm in western regions and average rain in March in the whole area is about 26.5 mm.

To provide information related to contour map of the region Isfahan topography map is used, and map's data converted to the numerical data. Then with Kriging Method we found interpolation of the data and the contour map was sketched (Figure3).

In this area, the least height is about 1550 meter and the most is about 2500 meter and the area average height is about 1592 meter. To compute the slope in region, the information related to contour map was used and the map of the slop was sketched (Figure 4).

In this area the least slop is %0 (0 degree) and the most %100 (45 degree) and its average is about %3.5. After computing the average of all the four factors used in Fournier's equation and by placing their amount in equation (1) the average rain erosion in Isfahan city and its suburbs was calculated:

In this way, average amount of rain erosion in the area was estimated about 3.37 ton/square kilometer in a year. This amount is average number and in fact the whole area is supposed constant, while in some parts the amount of erosion might be several times as much as other parts.

To solve the problem, we used GIS abilities and compounded the map made in previous step in Fournier's equation and at last a map of the erosion was obtained, so that amount of the rain erosion capacity in each point was computed separately. Then by average weight, the real amount of the rain erosion power in the area was computed.

The calculation of maps compounding was used to determine the amount of the rain erosion capacity in different places in the region. With regard to this, rain erosion capacity differs from about 1.22 ton/square kilometer in a year in Isfahan regions to about 210 ton/square kilometer in a year in western regions and its average in the total area are obtained about 4.53 ton/square kilometer in a year (Figure5).

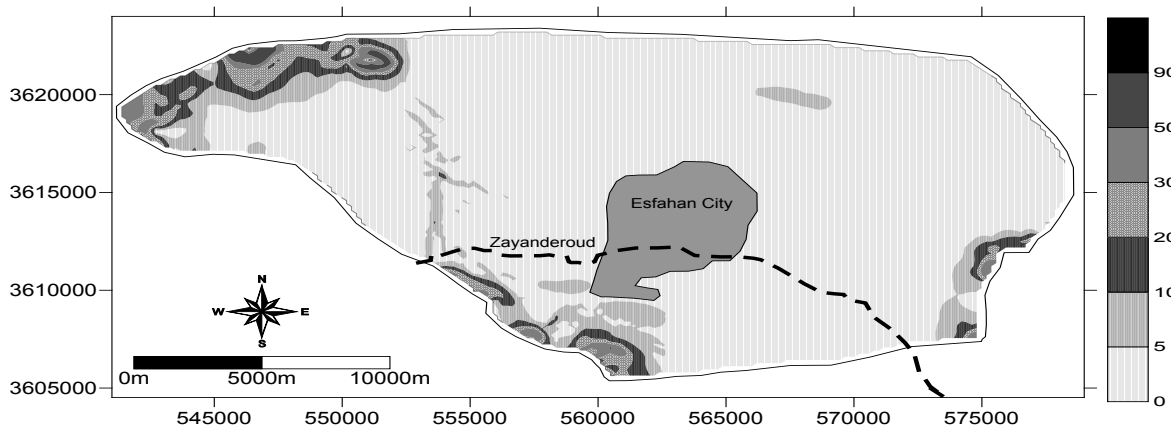


Figure 4: Slope map of Isfahan city and its suburbs

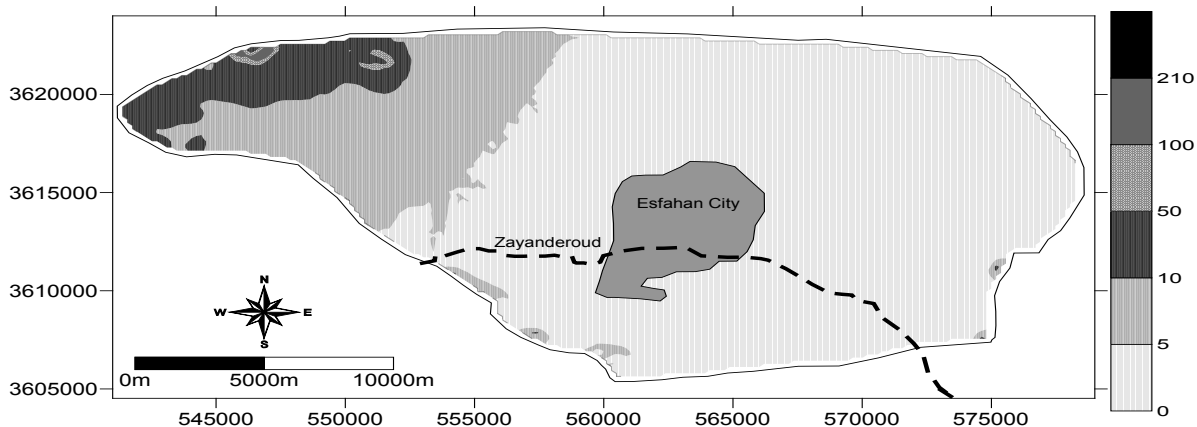


Figure 5: Rain erosion capacity map of Isfahan city and its suburbs

#### 4. Conclusion

Interpolation, generalization of point data to scatter data, and combining maps are three examples of GIS in correct estimating of rain erosion capacity has been revealed. With making the use of the average factors of Fournier's Method the amount of rain erosion capacity in region is estimated about 3.37 ton/square kilometer. This amount is an average number and obtains the some amount for total area. Whereas the factors used in the relation is so various in the area. Meanwhile we can't imagine all the area is constant and a minor change in one of the factors (average rain in the rainiest month of the year) will change the amount of erosion capacity strongly.

Will making use of the maps compounding power in GIS the amount of the rain erosion power in different places of the area was computed and not only the average amount of the rain erosion capacity in different places of the area was computed.

But also average amount of %25 more than calculated amount was obtained. (About 4.53 ton/square kilometer in a year against the 3.37 ton/square kilometer in a year) were estimated. The amount of rain erosion capacity in different places of the region was calculated too. So programmers can perform the plans regarded to the difference in the rain erosion power in different places of the area.

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