Assessment of Raindrops Size Distribution to Natural Precipitation In Kurdistan Province, Iran

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Abstract

Using two methods, stain and flour-pellet, the effect of natural raindrops was assessed in seven Synoptic meteorology stations in Kurdistan province. Calibration equations of the above methods were determined by dropping raindrops from a certain height at terminal velocity and using them in turn and diameter of raindrops was calculated. Then the correlation between the diameter of the drops and the rainfall intensity was investigated. The mean and median (d₅₀) of raindrops diameter were maximum in Marivan station and minimum in Zarineh station. The statistical analysis of the data using Gtm distribution which is appropriate for unequal data was used. It was determined that the different between the two methods was significant and also the Duncan test was used to compare the means. It showed that the stain method is more appropriate than flour pellet method.

Key words: Raindrop size distribution, Rainfall, Soil Erosion, Stain method, Flour pellet method.

Introduction

According to the studies conducted in past decades, it is proven that rain drops are the main factor in soil erosion (Roswell 1988). The blow of raindrops on soil surface causes decomposition and dispersion of soil particles. Although in the studies on erosion and soil protection, the yearly rainfall has been investigated, other factors such as the size and the number of raindrops causing rainfall erosivity play are more important role in soil erosion than the amount of rainfall. For example in two different areas with the same amount of rainfall and keeping other variables ineffective different reactions of different intensity of rainfall were observed. For example in Sanandaj and Lali plain the amount of rainfall is about 450 mm yearly but because of the intensity of rainfall in lali plain, the amount of rainfall is about 450 mm yearly but because of the intensity of rainfall in Lali plain more than Sanandaj, the index of rainfall erosivity in Sanandaj is 25, but in Lali is 200 metric units [3]. therefore the methods of measuring erosion that use the intensity of rainfall bring about better results than other methods because there is a direct relationship between the intensity of rainfall and the size and number of raindrops. Since the bigger and the more the raindrops, the more it would have kinetic energy, the rate of soil erosion increases.

This study was conducted to investigate the characteristics of rain including the diameter of drops and evaluating different methods like stain method and flour pellet in normal conditions for different meteorology stations of Kurdistan province. The literatures of previous studies show that studies conducted in this field are lab-bound under controlled conditions and no studies have been conducted on natural rainfall. Among specific characteristics of this study
to achieve the objectives not only case rainfalls but also the rainfall during rain season, i.e., from the beginning of autumn to the end of spring were sampled.

**The literature of the study**

There are different methods for measuring the diameter of raindrops and their volume distribution in the world. Here are some of them:

1. Stain method [8]
2. Flour pellet [8]
3. Radar reflectivity [7 & 13]
5. Stroboscope [5]
6. Optical disdrometer [9]

Rafahi (1993) stated that the first research was conducted on the size of raindrops by Laws in 1892. In his research he measured the stains of raindrops on the rock plates and produced the following relation [2]:

\[ D = a S^b \]  

(1)

\( D \) = diameter of the drop (mm),
\( S \) = the diameter of the stain (mm)

And \( a \) and \( b \) are their coefficients.

Hudson (1975) based on Blanchard's studies mentioned that the drops with diameter less that 4.6 mm are stable and more than 5.4 mm are unstable. Drops with diameter between 4.6 to 5.4 mm, based on the intensity of collision, are either shattered or changed. What is concluded from Blanchard's studies is that there aren't natural raindrops with 5.4 mm and by themselves they change in to smaller drops [5].

The stain method was first used by Laws. Laws and parsons (1948) used this method and found out that in rain fall intensity of 75mm/hr no increase in the diameter of the drops is observed [3]. Van Dijk and his colleagues in their studies conducted in the south of Australia discovered a relation for measuring the middle diameter of the drops [14].

\[ D_{50} = a R^b \]  

(2)

\( a \) and \( b \) are coefficients that their values change from 0.8 to 1.28 for \( a \) and from 0.123 to 0.292 for \( b \). \( R \) is the intensity of rainfall based on mm/h. Horton and Chapman (1948) and Elliot and lat produced the relation 3 to describe the relationship between rain fall intensity and average diameter of drops [8]

\[ D_{50} = a + bi + ci^2 + di^3 + \ldots \]  

In which
\( D_{50} \) = the middle diameter of drops based on mm a, b, c and d are coefficients and is rainfall intensity based on mm/h.

Sheklabadi (1379) using rain simulator device, made the water drops float in oil and measured the size of drops of artificial rain. He concluded that the drops lie in the range of 6.13 to 7.13 mm but diameters like these do not exist in natural rains and don't exceed 5.4 mm [4].

Orsham (1374) quoted that the first project to make rain with the intensity and size similar to those of natural rain was geyser type F which was developed by Wilm in 1943. Hudson (1975) quoted that Laws and Kinzer (1941) have discovered the relationship between the diameter of drops and speed limit of drops from 0.2 to 6mm. Laws used stroboscope and Kinzer used lab conditions and both concluded that the height of 10 meters based on the diameter of the drops...
to reach the speed limit is necessary [5]. Hudson (1975) presented the relation introduced by Best to describe the relation ship between the middle diameter and rainfall intensity \(D_{50}=aI^b\) in which \(a\) and \(b\) are fixed coefficients [5].

Using radar to study different characteristics of rain such as the diameter of drops has a lot of applications today and because of its features like accuracy, speed and convenience has replaced other methods. Joss and Waldvogel (1967) used this method for the first time [11]. Christian Salles and colleagues (1999) in Mar say, France using radar reflectivity measured the diameter of raindrops and using optical spectrum and formula \(z-r\) measured the size of raindrops of Mediterranean climates 0.2 – 4.8 and the intensity of rainfall is at most 60 mm/hr \((r=\text{rainfall intensity})\) and \(z\) is radar reflectivity [7]. The main function in this system is sending long waves and receiving and recording these waves after contacting the rain drops and through the interpretation of the results the characteristics of drops are measured.

This method has also the ability of measuring the amount of rainfall Chandrasekhar and colleagues (2001) investigated a shower in Colorado and the findings showed that the recorded rainfall is 15 percent different from that of metrology station [6]. Moayeri and Zhang (1999) in their studies used law and parson's model based on the existing data to investigate drops distribution using radar reflectivity. They suggested Gama distribution to analyze the data of latitudes and log distribution for tropical regions [15]. Masayuki and his colleagues (2001) in Australia used radar reflectivity to investigate raindrops and the diameter of drops changed from 0.3 to 5 mm [12].

Marshal and Palmer (1948) using a lot of measurement methods in different conditions showed that about the diameters smaller than 1mm, the average of size distribution of particles at ground level can be expressed through

\[
N(D) = N_0 e^{41r^{0.21}} \times D
\]  

(2)

In which \(N(D)\) is the frequency distribution of diameter of drops and \(D\) is the drops diameter and \(R\) is the amount of rainfall. This formula can be expressed in another way \(f(r) = \lambda e^{-2r}\) [11]. Lee and his colleagues (2004) used formula 4, Gama distribution and different kinds of clouds to identify the characteristics of rain in Bussan, South Korea in different months of the year. The comparison of results of April, July, and September is shown on a diagram in this article [10].

**Materials and Methods**

To carry out this project, natural rainfall was used and synoptic meteorology stations of the province that have rain-gauge and their specifications are in table 1 were selected in which the project was carried out and the data were recorded. First through using drop-makers the drops with given diameter according to formulae 5 and 6 in different sizes were made and to reach the speed limit, they were dropped from the height of 9 m/s and then the obtained stains made by the contact between the drops and Faberyano paper and also the weight of flour pellet made in flour plates were measured and calibrated equation were obtained, the diameter of rain stains and the weight of flour pellets in different intensity rain fall at these stations according to table 2 were measured.
Table 1: the specifications of meteorology stations
(where the project was carried out)

<table>
<thead>
<tr>
<th>Name of station</th>
<th>Height from sea level(m)</th>
<th>Geographical coordinates</th>
<th>Mean of rainfall(mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Longitude</td>
<td>Latitude</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Degree</td>
<td>Minute</td>
</tr>
<tr>
<td>Baneh</td>
<td>1600</td>
<td>48</td>
<td>32</td>
</tr>
<tr>
<td>Saghez</td>
<td>1522</td>
<td>46</td>
<td>16</td>
</tr>
<tr>
<td>Zarineh Obatoo</td>
<td>2142</td>
<td>46</td>
<td>12</td>
</tr>
<tr>
<td>Marivan</td>
<td>1287</td>
<td>46</td>
<td>12</td>
</tr>
<tr>
<td>Airport of Sanandaj</td>
<td>1373</td>
<td>47</td>
<td>00</td>
</tr>
<tr>
<td>Bijar</td>
<td>1883</td>
<td>47</td>
<td>37</td>
</tr>
<tr>
<td>Ghorveh</td>
<td>1906</td>
<td>47</td>
<td>48</td>
</tr>
</tbody>
</table>

Measuring the diameter of raindrops using special paper
In this method, first different kinds of paper having the ability to absorb raindrops and changed color after being in contact with raindrops were tested such as lab strainer, papers used in botany and papers having Faberyano trade mark, water-color and Eshtenbakh. Based on the findings of studies, Faberyano paper is more appropriate than the rest. While raining in the given place, the paper was exposed to rain (depending on the amount and intensity it varies from 3 to 10 seconds) to be hit by some raindrops. Then the touch point of the drops made some stains and they were measured by ruler and recorded in the appropriate tables. Another important piece of information that should be recorded is the exact time of sampling which relates to the time of exposing the paper to drops (in the form of year-month-day-hour-minute) to determine the rain fall intensity. The frequency depends on the period of rainfall and changes in intensity. The longer the rainfall, the more the number of samples would be and if there are great changes in rainfall intensity the number of samples increases. About short showers the time was 15 minutes and three samples, about long-term rainfall the time was every half or an hour, a sample and about rainfall events the time was several days and 10 samples were recorded. Then the related calculations of each sample such as drop diameter and median ($d_{50}$) were done.

Measuring the diameter of raindrops using flour
In this method, first different samples of flour that has public consumption were investigated and tested, and then the type of flour having ting texture in which the pellet after getting the drops is easily formed was selected. Some flours were poured in a plat and was exposed to raindrops to make some pellets (make sure each pellet should be formed by only one drop because a pellet formed by more than a one drop decreases the accuracy of measurement). The following stop was recording the information including the exact time of sampling (like the previous methods and adding it to the table). After that the pellets were dried in a certain room or 1 ab. The pellets were weighted on a digital scale with the accuracy of 1 mg and the average weight of flour pellets of each sample was calculated and added to the table.

Investigating the relationship between drop diameter and rainfall intensity
The rain fall intensity was extracted from rain-gauge graphs and the relationship between the drop diameter and rainfall intensity was calculated using formulae (5) and (6). Then using the regression of two variables the relationship between them for each station was obtained.
Results

The equations for stain and pellet diameters are as follows:

The obtained equation for the stain diameter:

\[ d = 0.2419D^{0.8799} \quad (r=0.81, \quad \alpha = 0.01, \quad \text{standard error}=0.06) \quad (5) \]

\(d=\) the diameter of raindrop (mm)
\(D=\) the diameter of stain (mm)

The equation obtained for flour pellets:

\[ d = 11.154W^{0.3495} \quad (r=0.80, \quad \alpha = 0.01, \quad \text{standard error}=0.065) \quad (6) \]

\(W=\) average weight of flour pellet (g)

These equations were obtained by dropping the drops from the height of 9 m (figures 1 and 2 show their calibrated curves).

![Figure 1: The calibrated equation for the stains diameter and raindrops](image1)

![Figure 2: The calibrated equation for the flour pellets and raindrops](image2)

The summary of the results of measuring the diameter of raindrops using the measurement of stain diameter and average weight of flour pellets at meteorology stations of the province are shown in table 2.
Table 2: summary of the results of measuring the diameter of raindrops using the measurement of stain diameter and average weight of flour pellets at meteorology stations of Kurdistan

<table>
<thead>
<tr>
<th>Name of station</th>
<th>Marivan</th>
<th>Sanandaj</th>
<th>Baneh</th>
<th>Zarineh</th>
<th>Ghorveh</th>
<th>Saghez</th>
<th>Bijar</th>
</tr>
</thead>
<tbody>
<tr>
<td>The number of samples in stain diameter method</td>
<td>138</td>
<td>24</td>
<td>230</td>
<td>62</td>
<td>33</td>
<td>118</td>
<td>163</td>
</tr>
<tr>
<td>The number of samples in flour pellet method</td>
<td>59</td>
<td>24</td>
<td>216</td>
<td>56</td>
<td>22</td>
<td>111</td>
<td>174</td>
</tr>
<tr>
<td>The average diameter of drops in stain diameter method(mm)</td>
<td>2.4</td>
<td>1.8</td>
<td>2</td>
<td>1.4</td>
<td>1.7</td>
<td>2.1</td>
<td>1.9</td>
</tr>
<tr>
<td>The average diameter of drops in flour pellet method(mm)</td>
<td>2.7</td>
<td>2.7</td>
<td>2.7</td>
<td>2.7</td>
<td>2.7</td>
<td>2.7</td>
<td>2.7</td>
</tr>
<tr>
<td>The average of methods (mm)</td>
<td>2.5</td>
<td>2.0</td>
<td>2.2</td>
<td>1.8</td>
<td>2.0</td>
<td>2.3</td>
<td>2.2</td>
</tr>
<tr>
<td>The median diameter of drops(d_{50})(mm)</td>
<td>2.4</td>
<td>1.6</td>
<td>1.9</td>
<td>1.3</td>
<td>1.6</td>
<td>2.0</td>
<td>1.9</td>
</tr>
<tr>
<td>The height of station from sea level(m)</td>
<td>1287</td>
<td>1373</td>
<td>1600</td>
<td>2142</td>
<td>1906</td>
<td>1522</td>
<td>1883</td>
</tr>
</tbody>
</table>

The relationship between the diameter of raindrops and different rainfall intensity the correlation between rainfall intensity and drop diameter using two-variable regression for each station was obtained. Since the rain-gauges in some stations had problems and their graphs were not readable (such as Baneh and Bijar stations). Therefore, the correlation between rainfall intensity and drop diameter was not obtained for these stations.  
And at Sanandaj station, because of the rain-gauges, graphs weren’t available (accessible) no correlation was obtained for stain diameter method. In this relation d is drop diameter, I is rainfall intensity based on mm/h an r is the correlation coefficient. This relation has been presented in table (3).
Table 3: the correlation between diameter of drops and rainfall intensity at meteorology stations

<table>
<thead>
<tr>
<th>Name of station</th>
<th>Diameter of stain</th>
<th>Flour pellet</th>
<th>Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marivan</td>
<td>( d=2.064e^{0.139} )( (r=0.67 &amp; \alpha=0.01) )</td>
<td>( d=2.6819e^{0.0268} )( (r=0.65 &amp; \alpha=0.01) )</td>
<td></td>
</tr>
<tr>
<td>Zarineh</td>
<td>( d=1.4342e^{0.041} )( (r=0.7 &amp; \alpha=0.01) )</td>
<td>( d=2.6575e^{0.0058} )( (r=0.65 &amp; \alpha=0.01) )</td>
<td></td>
</tr>
<tr>
<td>Saghez</td>
<td>( d=1.790^{0.0578} )( (r=0.63 &amp; \alpha=0.01) )</td>
<td>( d=2.7083e^{0.204} )( (r=0.63 &amp; \alpha=0.01) )</td>
<td></td>
</tr>
<tr>
<td>Sanandaj</td>
<td>-</td>
<td>( d=0.09231+2.6417 )( (r=0.68 &amp; \alpha=0.01) )</td>
<td>Information about rainfall intensity for stain diameter was not enough, so no formula was given.</td>
</tr>
<tr>
<td>Ghorveh</td>
<td>( d=1.7539e^{0.1401} )( (r=0.6 &amp; \alpha=0.01) )</td>
<td>( d=0.09231+6776 )( (r=0.635 &amp; \alpha=0.01) )</td>
<td></td>
</tr>
</tbody>
</table>

The results of correlations between diameter of drops and rainfall intensity of the measured data in the province show that the amount of correlation in stain diameter method is more appropriate and correlation coefficient is more. The results also show that the rainfall intensity of the recorded data is average and low (about 10 mm per hour). Therefore this relation is used for a certain range of intensity and it is necessary to use it for intensity above 20 mm per hour cautiously. The diagram related the relationship between changes in drop diameter and rainfall intensity for Marivan station is shown in figures 3.

![Figure 3](image)

Figure 3: The diagram related the relationship between changes in drop diameter and rainfall intensity for Marivan station

**Changes in rainfall intensity and diameter of raindrops**

In order to investigate the relations presented in this study, the diagram of changes in rainfall intensity and the diameter of drops observed for Saghez station using the method of stain diameter(Table 3) is drawn(figure 4). Diagram a shows the changes in rainfall intensity and the measured diameter of drops and diagram b shows the rainfall intensity and the measured diameter of drops for Saghez station using stain diameter method (Table 3) As it is understood the two curves of changes in rainfall intensity goes parallel with x axis and its function in higher intensity gets closer to each other. Therefore the diameter of drops increases as the intensity of rainfall increases. But as it can be observed from the literature of the study, the increase in the diameter of raindrops cannot be limitless physically (5).
Discussion and conclusion
Physical characteristic of rain are among the main factors of soil erosion, so investigating these factors seems necessary. The relationship and correlation between the data of the diameter of raindrops and rainfall intensity in the measuring method of stains on paper is more appropriate. The obtained results are true about the rainfall with the intensity of less than 10 mm/hr that took place in this project. The mean diameter and the median volume of raindrops are higher at Marivan station because the rainfall intensity is higher and there is a positive relationship between the mean diameter of drops and median volume of drops and rainfall intensity [table2].

Also, the mean diameter and median volume of drops at Zarineh station is less than those of other stations due to size and intensity of rainfall. The obtained results for these two factors shown in table (2) show a positive relationship between the intensity and amount of rainfall. The correlation between intensity of rainfall and the diameter of drops, according to best’s studies, is more significant for median volume of data (d50).

In this study, d50 and mean were investigated and they didn’t have any significant difference. Therefore, it can be concluded that in applied researches both indicators (d50 and mean) are reliable and can be used. The correlation between rainfall intensity and the diameter of drops at Marivan station shows higher correlation coefficient. Of course the difference is not noticeable and it is attributed to factors such as accuracy in sampling and the quality of rain-gauges graphs. Since the time base used in this study is 15 minutes, the charges in rainfall intensity during 15 minutes caused an error that decreased the correlation coefficients of those formulas. As it is seen in table (4) the frequency percentage of the diameter of drops in natural rainfall follows normal distribution. There is a short distance between mean and d50. While in more intensive, Rainfalls, frequency distribution of at high levels is more and at low levels is less. So, the negative frequency distribution of size of drops tends to ward the right side of the avis and for light rainfall this condition changes. Although measuring the diameter of drops in flour pellet method brought about sat are factory results and showed high correlation between the weight of flour pellets and the diameter of drops. But the comparison of correlation coefficient between the diameter of drops and rainfall intensity and Duncan and Glm tests show the relative advantage of the method of stain diameter. Speed and convenience are the other advantages of stain diameter method.
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