Discussion on the Method of Measuring Sand Content

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Abstract. The determination of sand content is related to the accuracy of soil and water loss measurement. With the development of science and technology, there are many advanced sediment content measurement technologies. However, due to the differences and complexity of soil conditions in various regions, the applicability of this method for sand content measurement needs to be verified. This article explores the method for measuring sand content in red soil on the conditions of simulated rainfall and runoff experiments, and verifies the measurement accuracy of water samples with different sediment contents using the gravimetric method. The results show that when the sediment content is small, the error of the specific gravity method is large, and its accuracy increases with the increase of the sediment content, and the accuracy is the highest when the sediment content is about 40g/L. In addition, the fitting curve is used in this paper. The sediment content is measured and compared with the drying method. The experimental results show that the measurement accuracy is higher than the specific gravity method, but the results are different from the drying method.

1. Introduction
Soil erosion in China is serious, leading to the deterioration of the ecological environment and frequent occurrence of natural disasters. In soil and water conservation monitoring, the measurement of soil erosion is one of the most basic items. To study soil erosion in nature, a scale model is usually used. The slope and artificial rainfall system are used to simulate the rainfall erosion experiment, in which the accuracy of the runoff sediment concentration measurement is directly related to the reliability of the experimental results. The "Soil and Water Conservation Test Regulations" proposed that the method of sand content measurement commonly used in the Loess Plateau of China is to stir the sediment in the runoff bucket, and then take a certain amount of representative samples for drying and weighing to obtain the overall runoff sediment content. However, this method is only applicable to the Loess Plateau, and the operation is more complicated. Samples are required to be more representative. Based on this, scholars have conducted a lot of research and proposed many methods for measuring sand content. Dongsheng Yu et al [1], established a model for predicting sand content in the Yangtze River Estuary based on the bp algorithm. Direct processing of the original detection
data, to obtain a higher fitting accuracy. Suhua Fu, etc [2], for stratified sampling of coarse particles, the use of stratified sampling. The method used to determine the sand content, the results obtained are closer to the actual value than the traditional measurement methods. Dongbing Cheng [3] and other based on long-term experimental observation experience and a series of experiments, discussed the accuracy of the determination of the sand content by the gravimetric method and hydrometer method. Due to the large differences in soil characteristics in various regions, the existing sand content measurement methods are generally poorly applicable. In the study, it is necessary to choose a measurement method that is more suitable for this experiment according to the situation, and to ensure a certain measurement accuracy. The method that is easier to operate is selected below. Based on the actual artificial simulated rainfall and runoff data, this article discusses different methods of measuring sediment content based on the drying and weighing method.

2. Sand content measurement method
According to the different measurement principles, the commonly used methods for measuring sediment content can be divided into direct measurement methods and indirect measurement methods. Direct measurement methods include drying and weighing method, specific gravity method and density bottle method, etc., and indirect measurement methods include infrared method, vibration Method, capacitance method, ultrasonic method, γ-ray method, etc [4]-[6]. In the current research, direct measurement methods are usually used.

2.1. Drying method
The principle of the drying and weighing method is to measure the weight of the sample before and after drying, so as to obtain the sand content. The drying and weighing method is the most basic method for measuring the sediment content, which has higher accuracy and reliability, and is generally available. As a standard for evaluating the accuracy of other measurement methods. Because the general runoff sediment samples are large and difficult to operate, a certain amount of representative samples are generally taken and dried and weighed after pretreatment, which results in the determination of The accuracy of the sand content depends on the representativeness of the sample taken. In addition, the time required for drying generally requires more than 10 hours, plus the time for standing the sediment, making the entire measurement process longer, and the results cannot be obtained quickly.

2.2. Specific gravity method
The principle of the specific gravity method is to determine the sand content based on the effect of the sediment on the specific gravity of the water body. Generally, a hydrometer or a balance and a measuring cylinder can be used for measurement. The calculation formula is as follows [7, Peiling Gao]:

$$\rho = \frac{G}{V - \rho_w} \frac{\rho_s}{\rho_s - \rho_w}$$  \hspace{1cm} (1)

Where: $\rho_s = 2.65 \times 10^3$ kg/m$^3$, which is the standard sediment density;
$\rho_w = 1.0 \times 10^3$ kg/m$^3$, the density of clear water;
$G$ is the total weight of the sample (kg);
$V$ is the volume of the sample (m$^3$);
$\rho$ is the sand content of the sample (kg/m$^3$).
The method of determining the sand content by the hydrometer method is to gently put the hydrometer into the muddy water that is stirred uniformly, and then read the specific gravity \( r_m \) immediately after the plateau.

\[
R_m = \frac{\rho_m}{\rho_{yw}}
\]  

(2)

\[
\frac{V_s}{V_w} = \frac{\rho_m - \rho_{yw}}{\rho_s - \rho_m}
\]  

(3)

In the formula: \( r_m \) is a hydrometer reading, dimensionless; \( \rho_m \) is the density of muddy water (g/cm\(^3\)); \( \rho_{yw} \) is the density of clear water (g/cm\(^3\)); \( \rho_s \) is the sediment density, generally 2.5 ~ 2.8 (g/cm\(^3\)); \( V_s \) is the volume of sediment (cm\(^3\)) in muddy water; \( V_w \) is the volume of fresh water (cm\(^3\)) in muddy water;

The volume ratio of water and sand can be calculated by formula (3). After measuring the total volume of the water sample, the sediment content in the water sample can be calculated.

3. Materials and methods

The test soil used in this test is red soil developed from the parent material of the Quaternary red clay, which belongs to silty clay. The soil texture is heavy, and iron and aluminum oxides are rich and acidic. The particle composition is shown in Table 1.

| Particle size (mm) | <0.002 | 0.002~0.02 | 0.02~2 |
|-------------------|--------|------------|--------|
| Content (%)       | 21.67  | 63.55      | 14.78  |

The length, width, and height of the test soil trough are 400cm, 120cm, and 70cm, respectively. The bottom of the soil trough is filled with 10cm thick sand, which makes the water permeability of the test soil trough close to the natural slope. The rainfall system uses QYJY-501 (502) portable and fully automatic Stainless steel simulated rainfall device, the rainfall height is 6m, and the range of rainfall intensity is 10 ~ 200mm / h. After the experimental rainfall starts, take a sample of less than 1000ml from the collecting port at a certain time with a measuring cylinder with a range of 1000ml, and record the sample Collect the length of time, read the volume of the water sample in the graduated cylinder after weighing with a precision of 0.01g balance, transfer the water sample to the beaker, leave it to stand for precipitation, skim off the supernatant, and put it in an oven at a constant temperature of 105 °C. After drying for more than 24 hours, the balance used after taking out weighs the weight of the sediment. Divided by the volume of the sample, the sand content of the sample can be obtained. The sand content obtained by this measurement method is used as a standard value for other measurements. The sand content obtained by the methods is compared.

In order to easily measure the sand content and save the drying time, this study uses the fitted curve method to measure the sediment content based on the original experiments. First, the sediment collected from the experimental soil trough is placed through a 2mm sieve and placed. Dry it in the oven, put it in a drying dish and cool it for later use. When experimenting, weigh a certain amount of sediment with a balance, pour the sediment into a 1000ml volumetric flask, add water to the scale and mix thoroughly to obtain The volume of the water sample contains the sand content, and then the temperature of the water sample is measured and the total weight is measured. The weight of the water and sand mixed sample can be obtained after subtracting the weight of the volumetric flask itself, and then divided by the volume of the volumetric flask to obtain the water sample. According to the
corresponding relationship between the sediment content and the density of the water sample, a standard curve is drawn to predict the sediment content of the experimental sample. In addition, according to the mass and volume of the sample, the specific gravity method is used for verification, and the accuracy and applicable conditions of each sand content measurement method are compared.

4. Results analysis

4.1. Accuracy determination by specific gravity method

In order to verify the accuracy of the specific gravity method, 15 different sand contents in the sand content range of 0.1 to 80 g/L were designed. When the water temperature was 15 °C, a certain amount of dry sediment was weighed with a balance with an accuracy of 0.01, and then use a 1000ml volumetric flask to make a constant volume and measure its mass. Use formula (1) to calculate and get the results shown in Table 2.

| Actual sand content (g/L) | Density (g/ml) | Calculate sand content (g/L) | Absolute error (%) |
|---------------------------|---------------|-----------------------------|-------------------|
| 0.10                      | 0.9963        | 0.26                        | 156.38            |
| 0.50                      | 0.9966        | 0.66                        | 31.39             |
| 1.00                      | 0.9970        | 1.33                        | 33.00             |
| 3.00                      | 0.9983        | 3.41                        | 13.77             |
| 5.00                      | 0.9989        | 4.39                        | 12.19             |
| 10.00                     | 1.0019        | 9.13                        | 8.67              |
| 15.00                     | 1.0051        | 14.29                       | 4.71              |
| 20.00                     | 1.0084        | 19.56                       | 2.18              |
| 25.00                     | 1.0115        | 24.61                       | 1.55              |
| 30.00                     | 1.0148        | 29.80                       | 0.65              |
| 40.00                     | 1.0211        | 39.98                       | 0.05              |
| 50.00                     | 1.0277        | 50.44                       | 0.88              |
| 60.00                     | 1.0338        | 60.31                       | 0.52              |
| 70.00                     | 1.0400        | 70.25                       | 0.35              |
| 80.00                     | 1.0466        | 80.76                       | 0.95              |

It can be known from Table 1 that when the sand content is measured by the specific gravity method, the accuracy increases with the increase of the sand content. When the sand content is 0.1 g/L, the absolute error reaches 156.38%. When the amount is 40g/L, the accuracy is the highest, and the absolute error is only 0.05%. Therefore, when the sand content is small, the measurement of the sand content using the specific gravity method may have a large error.

4.2. Comparison of different sand content measurement methods

According to the data of previous rainfall experiments, the maximum sand content of the collected water samples does not exceed 10 g/L. Therefore, the sand content of water samples prepared in the laboratory ranges from 0 to 10 g/L. The standard curve drawn is shown in Figure 1. As shown.
It can be seen from Figure 1 that the sand content has a good linear relationship with the density, the regression coefficient can reach 0.999, and the fit is good. The fitted curve is reliable for the determination of the sand content.

Select part of the sample data collected in the rainfall experiment, calculate the sand content using the specific gravity method and the formula obtained from the fitting curve, and compare it with the sand content obtained from the drying experiment method (Table 3). The absolute error range of the calculation results is 4.56% ~ 67.53, and the average value is 47.99%. The absolute error range of the calculation results of the specific gravity method is 1.29% ~ 107.50%, and the average value is 68.95%. The amount of sand is close to the drying method, and the accuracy is higher. The sand content calculated by the specific gravity method is greater than the drying method, and the calculation results of the fitted curve method are mostly large, and only a small part is smaller than the drying method.

Table 3. Comparison of results of different methods for measuring sand content.

| Sand content in drying method (g / L) | Fitted curve method | Specific gravity method |
|--------------------------------------|---------------------|------------------------|
|                                      | Calculated value (g / L) | Relative error (%) | Calculated value (g / L) | Relative error (%) |
| 0.34                                 | 0.40                 | 16.68                  | 0.59                     | 73.12                |
| 1.40                                 | 1.14                 | -18.47                 | 1.38                     | 1.29                  |
| 0.77                                 | 0.81                 | 4.56                   | 1.03                     | 32.94                 |
| 2.04                                 | 0.73                 | -64.13                 | 0.95                     | 53.62                 |
| 0.47                                 | 0.72                 | 53.46                  | 0.93                     | 99.15                 |
| 0.90                                 | 1.23                 | 36.51                  | 1.47                     | 63.80                 |
| 1.68                                 | 2.56                 | 52.45                  | 2.88                     | 72.08                 |
| 0.57                                 | 0.96                 | 67.53                  | 1.19                     | 107.50                |
| 1.72                                 | 2.07                 | 20.51                  | 2.37                     | 37.88                 |
| 0.84                                 | 1.29                 | 53.44                  | 1.54                     | 83.13                 |
| 0.99                                 | 1.39                 | 40.85                  | 1.65                     | 66.71                 |
| 0.80                                 | 0.41                 | 48.17                  | 0.61                     | 23.89                 |

The error of measuring the sand content with the fitted curve mainly comes from the drawing of the standard curve. Drying sand will absorb moisture during operation and cannot be kept absolutely dry. Therefore, there will be errors in the measured dry sand quality. There is also an error when the bottle is fixed. The result of measuring the sand content using the fitted curve as a whole is larger than that of the drying method, which may be due to the following reasons: First, some particles are lost during
the pretreatment operation of the drying method. Smaller sediments and water-soluble substances in the soil make the results smaller. Secondly, the water samples collected at the header will have eroded soil aggregates, and there are more pores in the soil aggregates. The measured volume of the water sample is larger than the actual volume, and the soil particles remaining after passing through the 2mm sieve used to draw the fitted curve are smaller and can be completely dissolved in water. Finally, during the experiment, it is considered that the result has the biggest impact on the measurement of the volume of the water sample. Because the measurement accuracy of the 1000ml graduated cylinder is 5ml, there will inevitably be errors in measuring the volume. When the sand content is calculated by the fitted curve method and the specific gravity method, the volume directly affects the calculation. Results while drying the effect of measuring sand content on volume is relatively small, so volume measurement is the most critical factor affecting the accuracy of the calculation. In the sampling process of rainfall experiments, it is difficult to accurately measure the volume of the sample. Increasing the accuracy of the volumetric accuracy of the specific gravity method and the fitted curve method will also be higher.

5. Conclusion
As a traditional measurement method, the measurement results of the drying and weighing method are more accurate and reliable, but the operation process is more complicated and the experimental conditions are more demanding. It requires a lot of time and effort, and the measurement results cannot be obtained quickly and easily. The measurement of sand content is relatively simple. It only requires a graduated cylinder and a balance to measure. However, when the sand content is small, the measurement error is large. When the sediment content is less than 1 g/L, the absolute error is more than 30%. For water samples with higher sediment content, the measurement accuracy is higher. When the sediment content is greater than 10 g/L, the absolute error is within 10%, which can be used for direct measurement. The accuracy of the fitted curve method is higher than that of the specific gravity method, but due to the differences in soil conditions in various regions, a standard curve needs to be drawn first. Compared to the drying method, the measurement results of the specific gravity method and the fitted curve method are relatively large, and the average absolute errors are 68.95% and 47.99%, respectively. The errors are large, mainly because the volume measurement error of the collected sample has a large impact on the measurement result. Therefore, for the specific gravity method and the fitted curve method, the volume measurement accuracy is directly related to the sediment content measurement result. Precision, such as it can improve the measurement accuracy of sample volume, and the fitted curve method will provide a simpler, more accurate and more applicable method for measuring sediment content.

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References
[1] Dongsheng Yu, Yixin Yan, Chun Tian. Research on sediment content prediction based on bp algorithm [J]. Journal of China Three Gorges University (Journal of Natural Science), 2003, 25 (1): 47-51.
[2] Suhua Fu, Jinsheng Fu, Xiaolan Wang, et al. Research on the method for measuring the sand content of the collecting buckets in runoff communities [J]. Bulletin of Soil and Water Conservation, 2003, 23 (6): 40-41.
[3] Dongbing Cheng, Pingcang Zhang, Changwei Zhang, et al. Discussion on simple method for calculating sediment content [J]. Journal of Soil and Water Conservation, 2014, 28 (1): 193-197.
[4] Xiangzhou Xu, Hongwu Zhang, Zhang Li, et al. Study on the method of measuring sediment yield in soil and water conservation model tests [J]. China Soil and Water Conservation, 2007, (1): 35-37.

[5] Yanhong Fu, Tiebin Shi, Yan Xu. Methods and comparative analysis of sand content measurement [J]. Northeast Water Resources and Hydropower, 2010, (9): 35-45.

[6] Minjie Chen, Weicong Wang. Analysis of Sand Content Measurement [J]. Value Engineering, 2010, (3): 37.

[7] Peiling Gao, Tingwu Lei, Jun Zhao, et al. Research and Prospect of Runoff Sediment Measurement Methods in Slope Erosion [J]. Sediment Research, 2004, (5): 28-33.