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# Using of Close Range Photogrammetry for Interrill Soil Erosion Quantification

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**Abstract:** The needs for evaluation of interrill soil erosion spatially and validation of spatial explicit erosion model were behind the initiation of this study. The interrill soil erosion quantification using multi-temporal digital elevation model (DEM) generated by close range photogrammetry system was assessed. The DEM accuracy was evaluated using the root mean square error (RMSE) on the check points (CP). The average of the RMSE for the four trays was 7.52, 9.69, and 7.61 mm for the x, y, and z directions, respectively. The soil erosion was calculated from the soil surface DEM generated before and after the rainfall simulation and then compared with the sediment amount collected at the outlet.

**Keywords:** Digital elevation model, Interrill soil erosion, Rainfall simulator

## 1. Introduction

Soil erosion by water is a complex phenomenon, which involves surface flow detachment and transport of the top fertile soil materials and nutrients as a result of rainfall. Interrill soil erosion can be defined as an erosion process that results from mechanical forces such as rainfall impact and water film transport, and that occurs in region between two rills (Meyer, 1981). The notion of spatial demarcation of rill and interrill erosion started with the necessity to model the process of erosion by mass balance equation (Meyer, 1981). Such processes that work in an interrill area are soil detachment by raindrop impact and surface flow, transport by raindrop impact and surface flow, and deposition of soil particles (Meyer, 1981). Generally, the upland and farmland interrill erosion is the main source of sediment, and related nutrients and pollutants discharged to water bodies and streams. The most common models used to evaluate the interrill soil erosion are empirical equation, even under the physically based erosion models .

The new generation of erosion models are capable of simulating the event and annual sediment budget in a whole watershed of farmland although, these models fail to describe the spatial distribution of soil erosion (Favis-Mortlock, 1998). Recently, some models have used spatial data in order to simulate the erosion distribution rather than lumped quantitative sediment production at the outlet of the watershed. In order, to validate the capability of these models to simulate the spatial distribution of soil erosion, the quantification methodology of these models and the achievement of actual spatial distributed data for model results must be validated.

Soil topography represents the main input for spatial explicit models. There are different methods to monitor the soil topography in a macro- and micro-scale, which can be divided to contact and non-contact methods. The widely used non-contact methods are laser scanner and digital photogrammetry. The digital photogrammetry is a modified version of analog and analytical photogrammetry, which is an efficient, rapid and inexpensive tool compared with laser scanning and other methods (Chandler, 1999; Rieke-Zapp and Nearing, 2005). This study was attempted to assess the use of an inexpensive close range photogrammetry system for interrill soil erosion quantification using temporal DEM differences.

## 2. Methodology

### 2.1 Rainfall Simulator Experiments

A laboratory dripper-type rainfall simulator (**Fig. 1**) at the Arid Land Research Center, Tottori University, Japan was used to generate artificial rainfall on a 0.5m × 1.0m × 0.16m steel tray (**Fig. 2**). Two rainfall intensities (35 and 50 mm $h^{-1}$) were used under two slope angles (15 and 20 degrees). The soil was packed in the steel tray over a 0.04 m gravel filter up to 0.09 m depth with approximately 1.1 g $cm^{-3}$ bulk density for all experiments. The soil trays were saturated from the bottom for 24 h and left for 12 h

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to remove the excess water. The saturation was preformed for two reasons, first to decrease the soil air transport (splash loss); second, to reduce the impact on soil surface elevations due to raindrop impact energy (soil compaction or consolidation). The runoff was collected at the soil tray's outlet (Fig. 2) using plastic bottle, and then the water was evaporated to determine the sediment mass.

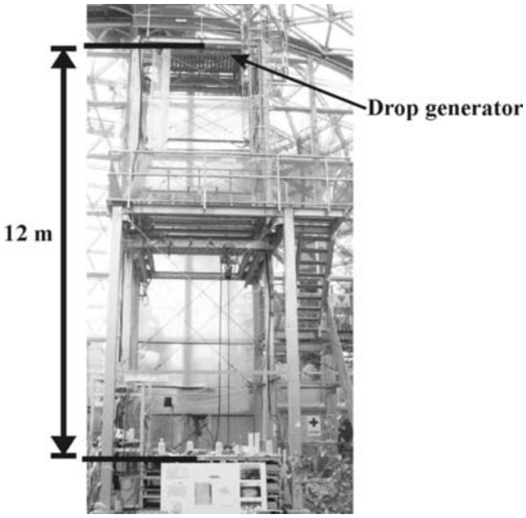


**Fig. 1. Rainfall simulator.**

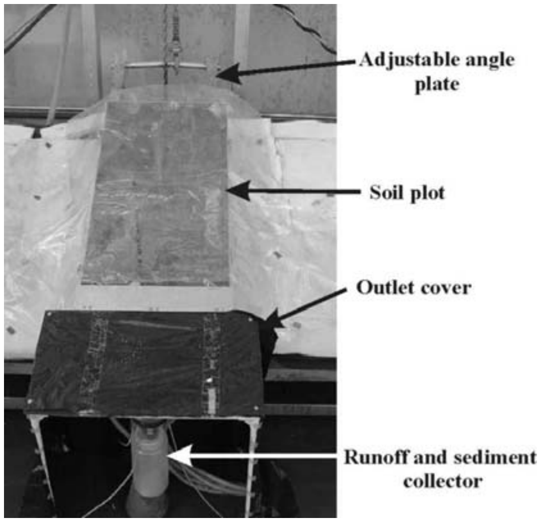


**Fig. 2. View of soil tray with runoff and sediment collector before rainfall simulation.**

## 2.2 Photogrammetry System

Eleven adhesive tape marks were fixed on the edges of the soil trays as ground control points (GCP) (**Fig. 3**) and check points (CP). Two images for each experiment were acquired from left and right for the soil tray before and after the rainfall simulation (Fig. 3). A Canon® Power-Shot50 digital camera (Consumer-grade) was used for imaging the soil trays. The images were imported into a photogrammetry system developed by Asia Air Survey Co. The photogrammetry system follows the standard methods to generate the three dimension data of the soil surface from a pair of images. There are two steps of the photogrammetric processing for each stereo-pair: photogrammetric triangulation involved matching the image by fixing the GCPs for the left and right images, and automated DEM generation. The DEM was extracted as a distributed x, y, and z coordinates for surface before and after rainfall simulation.

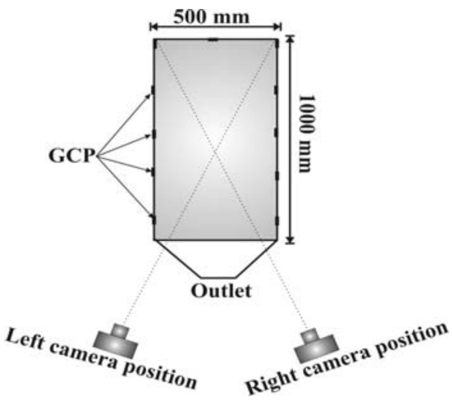


**Fig. 3. Soil tray and photogrammetry system.**

## 2.3 The DEM Analysis

The DEMs were first manipulated to detect and remove the error points before and after the interpolation. The error points were detected and removed before interpolation using simple method. In this method, depending on the differences between the raw DEM and simulated smooth surface (reference surface) has a same slope angle of the soil tray and must not exceed certain value (threshold) (Abd Elbasit *et al*., 2008). The DEMs were then interpolated to different grid size using inverse difference weight method (IDW). The interpolated DEMs were manipulated for error rectification using parametric statistical method (Flicísmo, 1994) using simple FORTRAN code. The center area (200 × 700 mm) of the soil tray's DEM was selected for the erosion quantification analysis to avoid the effect of the soil tray borders.

The interrill soil water erosion was estimated using the elevation difference between the DEM generated before the rainfall event and the DEM after the rainfall event using equation (1) as follow:

$$\begin{aligned}
&\Delta Z_{i,j} = Z_{i,j}^{final} - Z_{i,j}^{initial} \\
&case: \\
&\Delta Z_{i,j} < 0 \Rightarrow Erosion \quad grid \\
&\Delta Z_{i,j} > 0 \Rightarrow Deposition \quad grid \\
&\Delta Z_{i,j} = 0 \Rightarrow No-change \quad grid
\end{aligned} \tag{1}$$

where $\Delta Z_{i,j}$ is the elevation difference at the i,j point, $Z_{i,j}^{initial}$ is the elevation at point i,j before the rainfall, and $Z_{i,j}^{final}$ is the elevation difference after the rainfall simulation. This code is simply tried to quantify and classify the erosion and deposition from the elevation difference and draw a general figure about the spatial distribution of the interrill soil erosion.

## 3. Results and Discussion

### 3.1 The DEM Accuracy

The DEM accuracy was assessed by comparing the measured and photogrammetrically estimated CP coordinates for each soil tray. The root mean square error (RMSE) was used to calculate the accuracy of the DEM at x, y, and z direction (**Table 1**). The average RMSE for the four experiments was 7.52, 9.69 and 7.61 mm for the x, y and z directions, respectively. There is no standard procedure available to evaluate the accuracy of the DEM at the micro-scale. The optimum accuracy depends, mainly, on the desired accuracy in which the DEM will be applied (Chandler, 1999). Generally, the accuracy has many integrated factors, such as the size of the object, camera proficiency, number of images, method of image acquisition, and software flexibility.

**Table 1. Root mean square error for the DEM of soil trays.**

| Surface source | Root Mean Square Error (mm) | | |
|---|---|---|---|
| | x | y | z |
| **35/15*** | 6.18 | 11.76 | 10.07 |
| **35/20** | 6.23 | 9.61 | 8.74 |
| **50/15** | 10.27 | 8.55 | 4.88 |
| **50/20** | 7.38 | 8.84 | 6.73 |

*The first two digits stand for rainfall intensity (mm $h^{-1}$) and last two digits stand for slope angle (degree)

### 3.2 Quantification of Soil Erosion

Based on equation (1), the amount of eroded soil was calculated and compared to the observed sediment at the outlet (**Fig. 4**). There were noticeable differences between observed and calculated erosion which could be attributed to the DEM accuracy, optimum grid size, quantification method, errors related to soil splashing, and soil erosion and deposition occurring outside the selected area. The erosion calculated from the DEM usually over-estimated the soil erosion compared to the observed outlet sediment. On the other hand, the sediment quantification was an underestimate for the 50 mm $h^{-1}$ rainfall intensity and 20 degrees slope angle. Previous research attempted to quantify the soil erosion from DEM, although numerical data were rarely given on the status of soil erosion quantification compared with the measured collected sediment at the outlet.

### 3. 3 Spatial Distribution of Soil Erosion

The spatial distribution indicating whether the soil was eroded or deposited was generated in this study by overlaying the erosion grids and deposition grids (**Fig. 5**). This method is widely used in the analysis of large-scale and long-term land formation. This technique can also be useful in a micro-scale and short-term soil erosion evaluation in order to define the hot erosion source areas (Valette *et al*., 2005).

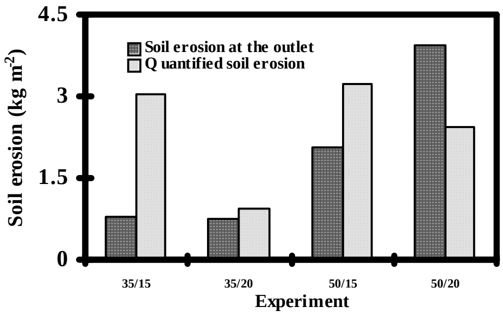


**Fig. 4. Soil erosion quantification.**

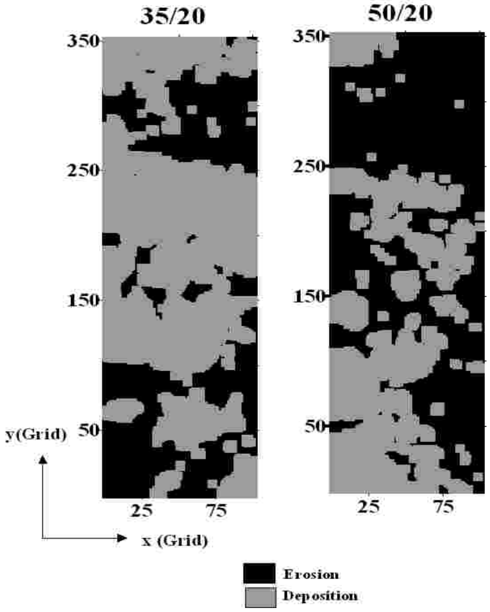


**Fig. 5. Spatial distribution of interrill soil erosion.**

## 4. Conclusions

The main objective of this study was to assess the potential use of close range photogrammetry for soil erosion evaluation. The average RMSE was 7.52 mm, 9.69 mm and 7.61 mm in the x, y, and z direction, respectively. Although the difference between observed outlet sediment and the calculated amount of soil from the DEM was distinct, this study presented comparable figures to previous studies. Also, this study suggested that the use of soil surface features development (surface roughness and rill formation) as indicators for interrill soil erosion has a potential rather than the direct elevation comparison.

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## References

Abd Elbasit M.A.M., Yasuda H., Anyoji H. (2008): Development and application of digital elevation model rectification method in monitoring soil microtopography changes during rainfall. *Journal of Japan Society of Hydrology and Water Resources*, **21**(2): 114-125.

Chandler J. (1999): Effective application of automated digital photogrammetry for geomorphological research. *Earth Surface Processes and Landforms*, **24**: 51-63.

Favis-Mortlock D. (1998): A self-organizing dynamic systems approach to the simulation of rill initiation and development on hillslope. *Computer and Geosciences*, **24** (4): 353-372.

Flicísmo A.M. (1994): Parametric statistical method for error detection in digital elevation model. *ISPRS Journal of Photogrammetry and Remote Sensing*, **49** (4): 29-33.

Meyer L.D. (1981): How rain intensity affects interrill erosion. *Transaction of ASAE*, **24**(6):1472-1475.

Rieke-Zapp M., Nearing M.A. (2005): Digital close range photogrammetry for measurement of soil erosion. *Photogrammetry Records*, **20**(109): 69-87.

Valette G., Prévost S., Lucas L., Léonard J. (2006): SoDA project: A simulation of soil surface degradation by rainfall. *Computer Graphics*, **30**: 494-506.