# Simulated Acid Soil Erosion Linked to Selected Physical Properties

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## 1. Introduction

Erosion by water from acid soils, particularly with increasing acidity under cropping from deforested land is a major issue, more specifically in developing countries tropical environment, such as that found in Madagascar. Crop yield reduction due to increases in acidity after deforestation are well documented and usually associated to high soluble Al concentrations or Al toxicity (Menzies, 2003). On the other-hand the impact of acidity on soil physical processes, particularly in relation to runoff (RO) and sediment (SD) generation from cropland of deforested land has received relatively less attention. Thus, the objectives of this study were to investigate (i) the changes in RO and SD generation processes and (ii) link and explore the physical mechanisms that modify these processes in a simulated acid soil.

## 2. Materials and methods

The soil used in this study was taken from Tohaku in Tottori prefecture, Japan. The soil was collected from the B-horizon which is come from a red volcanic ash. It was air-dried, ground to an aggregate larger < 5 mm, and then sieved through a 2 mm screen and the material < 2 mm was used in the study. The textural composition; 53.9 % clay, 28.3 % silt, and 17.8 % sand, indicates that according to the USDA classification it is a clay soil. The soil material < 2 mm were mixed with different dilutions of 0, 25 and 50 times of 2N pure sulfuric acid solution in tap water. The acidification was made under free percolation condition. The drainage percolate was collected and mixed again with the soil and this procedure was repeated until there was no percolating water. The acidified soil hereafter referred to as simulated acid soil was then air-dried. The properties of the soil are shown in **Table 1**.

Modified fast-wetting in water of < 2 mm air-dried soil material was used for aggregate size distribution determination. The aggregate size fractions; 2-1 mm, 0.5-1 mm, 0.25-0.5 mm, 0.106-0.25 mm, 0.075-0.106 mm, and <0.075 mm collected after wet sieving were treated with Na-hexametaphosphate for sand fraction adjustment. The proportional mass of each size fraction and the corresponding average diameter were used for mean weight diameter (MWD) and geometry mean diameter computations.

Air-dried acid treated soil material < 2 mm was packed in a small soil plot trays, 30 cm by 50 cm by 5 cm. The bottom of the trays was uniformly filled with 1.5 cm gravel filter layer and on which 3 cm thick soil layer was packed to average dry bulk density of 1.35 g $cm^{-3}$. The trays were at a 10 ° slope and subjected to tap water rain (EC, 0.13 dS $m^{-1}$). Runoff sample at 5 min intervals were collected and quantified and the sediments in RO sub-samples were determined gravimetrically after oven-drying at 105 °C for 48 hrs.

## 3. Results and discussion

### *3. 1. Runoff and sediment generation*

The time incremented runoff (RO) and sediment (SD) generation from the small soil plots subjected to 30 and 60 mm $hr^{-1}$ shown in **Fig. 1** indicate qualitatively similar patterns regardless of the treatments. In general there were three phases; the first phase is characterized by near zero, slow, and small RO/SD, the second phase by a rapidly increasing linear phase reaching a maximum, and the third phase by a relatively constant rate equal to the maximum value that was reached during the linear phase. The time dependent phase behavior indicates three different factors or variables controlling each phase. The phase I temporal dynamics indicates a time lag for significant RO to occur and we define this lag period as time to runoff (TR), and in this study the TR includes the time to ponding also. The TR increased in the order; control> low acidity > high acidity, suggesting that RO commenced much earlier at high acidity than at low (**Fig. 1**).

The time incremented SD generation exhibited three distinct phases very similar to RO (**Fig. 1**). This is not surprising, because the SD carrier was carried in RO and the strong dependency of SD on RO is statistically supported by the strong positive correlations. However the mechanisms involved in SD generation will determine the amount that will be available for transport by RO. The least amount of SD per minute was generated during phase I and the most amount during phase III. The SD generation increased with rain intensity during all 3 phases, and there was 5 to 6 fold increases under high intensity in phases II and III regardless of the acid treatment.

### *3. 2. Soil aggregate size distribution*

The water stable aggregate size distribution (ASD) data shown in **Fig. 2** indicate significant reductions in 1.0 - 2.0 mm and 0.5 - 1.0 mm fractions after acid treatment. These decreases were reflected as increases in 0.25 - 0.50, 0.100 - 0.25, 0.106 - 0.075 mm and less than 0.075 mm size fractions. These data indicate that aggregate fractions

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in the size range > 0.50 to < 2 mm broke down into smaller fractions during wetting (under simulated rain) and the increases in the smaller size fractions increased with increasing acidity. The decreases in soil organic matter (SOM) with increasing acidity were at least partially responsible for break down of larger size aggregates into smaller size fractions (Chenu et al., 2000). The geometric mean diameter (GMD) and mean weight diameter (MWD) data (**Table 1**) that mathematically characterize ASD indicate that these values decreased with increasing acidity and is consistent with the theoretical expectations the broken down soil material was dominated by larger proportion of smaller size fractions. It is known that saturated hydraulic conductivity (Ks) is positively correlated with larger size fractions in ASD. The reduction in Ks with increasing acidity might be due decreases in the proportion of larger size conducting pores and pore clogging in the sub-soil. The increased availability of smaller size fractions with increasing acidity might have led to increased washed down of these particles into larger size pores and subsequent deposition of their walls and/or necks.

From the foregoing discussion in acidity induced changes in ASD, and consequently in the proportion of pore sizes, pore clogging, and slaking and these in turn on Ks, indicate that ASD is the primary soil physical variable that controlled the magnitude of RO and SD generation in acid soil. In this regard the dynamics of soil organic matter (SOM) concentration in acid soils need special attention, because of the important role played by it in aggregate stability, i.e. ASD. The SOM decomposition in non-acidic soils is largely a biological process, but in acid soils it could be both inorganic and biological processes. The decreases in SOM by acid treatment in our study indicate it is primarily an inorganic process. The importance of SOM maintenance and management in cultivated soils is widely recognized for their sustainable use of soil resource, but the pathway of SOM losses (inorganic vs. biological) in acid soils indicates the need for special attention. The data indicating the decreasing SOM with increasing acidity suggests that acid soil use and management practices, particularly in tropics, should take into consideration the adoption of best options to maintain SOM for long-term sustainable use of acid soil resource.

## 4. Conclusion

The results from this study show that time incremented runoff (RO) and sediment (SD) generation from a simulated acid soil are characterized by three phases indicating different soil factors or mechanism controlling the different phases. We show these three phase processes can be mathematically described by a time dependent elongated S-shape curve, indicating the factors or mechanisms controlling the different phases varied with time. Soil acidity and rain intensity modified the parameters of functional relationships of the curves indicating the factors/mechanism controlling RO and SD generation processes were modified by acidity and intensity. The generation of larger proportion of smaller size particles is controlled by the soil use management variable soil organic matter (SOM). The SOM decomposition in non-acidic soils is largely a biological process, but in acid soils it could be both inorganic and biological processes. Thus we conclude greater emphasis should be placed in the maintenance of SOM in acid soils to reduce acidity induced increases in RO and SD, and consequently for long term sustainable use of the soil resource.

**Table. 1** Selected chemical and physical properties of studied soil

| Properties | Treatments | | |
|---|---|---|---|
| | Control | Low acidity | High acidity |
| SOM (%) | 4.53±0.10 | 4.09±0.08 | 2.59±0.13 |
| pH-$_{H2O}$ [1:2.5] | 5.56±0.03 | 4.56±0.02 | 3.11±0.005 |
| Exc. Al (cmol$_c$ kg$^{-1}$) | 1.29±0.40 | 2.98±0.20 | 20.47±1.50 |
| Exc. H (cmol$_c$ kg$^{-1}$) | 0.18±0.05 | 1.63±0.06 | 15.60±2.80 |
| ECEC (cmol$_c$ kg$^{-1}$) | 12.97±2.98 | 15.31±2.20 | 39.87±5.90 |
| Ks (cm hr$^{-1}$) | 5.73±0.77 | 3.75±0.28 | 1.42±0.43 |
| MWD (mm) | 9.84 ±0.45 | 5.26±0.10 | 4.41±0.15 |
| GMD (mm) | 0.37 ±0.02 | 0.26±0.001 | 0.23±0.004 |

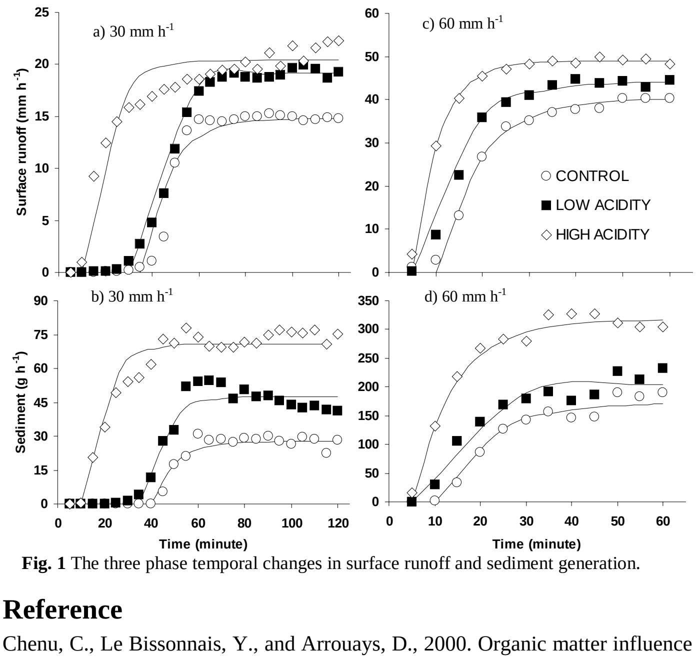


**Fig. 1** The three phase temporal changes in surface runoff and sediment generation.

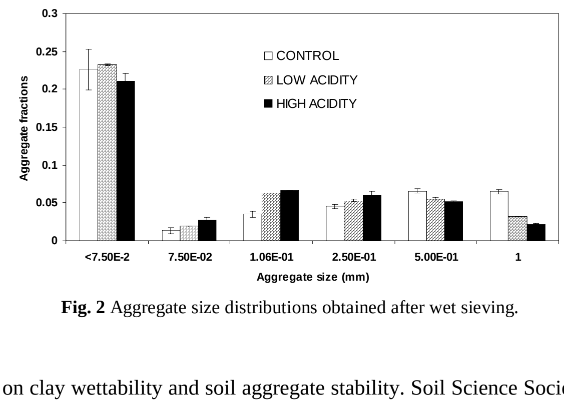


**Fig. 2** Aggregate size distributions obtained after wet sieving.

## Reference


Chenu, C., Le Bissonnais, Y., and Arrouays, D., 2000. Organic matter influence on clay wettability and soil aggregate stability. Soil Science Society of America Journal **67**, 1479-1486.

Menzies, N. W., 2003. Toxic elements in acid soils: Chemistry and measurement. In: Rengel, Z. (Ed.), Handbook of soil acidity. Marcel Dekker, Inc. New York, Basel, pp. 267-298.