An examination of the efficiency of a simple runoff plot sample splitter

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Abstract

The study investigated the effect of flow rate, sediment concentration and sediment grain size on the efficiency of a simple runoff plot sample splitter. Results of the study showed that surface tension affects sampler efficiency at low flow rates. The sample splitter achieves maximum efficiency once a critical rate of 0,15 $\ell.s^{-1}$ has been exceeded.

Introduction

Soil erosion and the problems related to it have been a matter of concern to hydrologists and agricultural engineers for several decades (Hadley, 1984). In order to understand the process of erosion, field methods, both simple and sophisticated, have been developed to measure the quantity of soil that is eroded in a specific period of time. In the field of soil erosion and conservation problems, it has been found that there is no satisfactory substitute for runoff plots (De Ploey and Gabriels, 1980). They supply basic data which can be secured only by actual measurement of the quantities of soil and water lost by runoff and erosion in the field.

The quantification of soil erosion depends entirely on data collection (Smithen, 1982). The accuracy of data collection is therefore very important because the value of erosion losses represent the basis for determining the degree of damage done by erosion as well the basis for the planning of use and protection of land (Djorovic, 1980).

Measurement and data collection in soil erosion studies frequently involve error (Roels, 1985). This is especially the case with runoff plots where measurements are based on a sample of the total amount of sediment and runoff being produced from the plots. The aim of sampling is usually to obtain an unbiased or representative sample of the total volume from which the sample is drawn, thereby ensuring that the sample has some general significance. However, under various runoff and sediment conditions, the fraction that is split by the splitter may vary from that intended by the design.

There are a number of designs of sample splitters, the most common of which is the Geib or multislot divisor (Geib, 1933). Several alternatives have been suggested as being more appropriate to the manufacturing skills found in developing countries (Hudson, 1981). These include running water through a number of pipes (Sherry, 1953), or through V-notches or holes drilled in a plate (Hudson, 1957; Wendelaar and Purkis, 1979). The only moving sampler which has achieved much success is the Coshocton revolving wheel sampler (Hudson, 1981).

The eight runoff plots at Rhodes University were established in 1986 to provide a means for teaching the basic principles of soil erosion, to initiate applied research by studens, and to study the effect of the exotic species *Acacia longifolia* on runoff and erosion rates. Each plot is 22 m long and 1,8 m wide and runoff and sediment is conveyed to a fifty litre sludge tank. If more runoff and sediment is generated from the plots than can be held in the sludge tank, a splitter samples a proportion of the overflow from the sludge tank. The splitter is situated at the outflow of the sludge tank. The sludge tank is constructed from a commercially available 78 cm by 25 cm by 28 cm asbestos flower box. The splitter consists of a metal weir over which the excess water from the sludge tank flows. A tenth of the weir width, that is 25 mm, is channelled off to a sample tank so that theoretically a tenth of the overflow from the sludge tank is sampled by the splitter (Figure 1). The aim of this study was to investigate the efficiency of the sample splitter used at the Rhodes University runoff plots, under various simulated runoff and sediment conditions.

Methods

The apparatus used in the investigation was assembled in the laboratory so as to simulate field conditions as closely as possible (Figure 1). The apparatus consisted of: a controlled water source; a sprinkler container for the input of sediment; a PVC conveyance channel; a sludge tank; the sample splitter; and a container in which to collect the sample. The investigation comprised four experiments, each of which entailed a number of steps:

1. The water, or water and sediment were introduced to the system at a known rate ($\ell.s^{-1}$). A hosepipe connected to a tap provided the source of water which could be varied to suit the required flow rate. Sediment was manually added by sprinkling it into the water, at the inflow point to the conveyance channel (Figure 1).
2. The quantity of water (ℓ) and sediment (g) passing through the system was determined.
3. The quantity of water (ℓ) and sediment (g) in the split sample was measured.
4. The actual percentage split performed by the splitter was calculated (%).

Experiment 1

To determine the effect of flow rate on the percentage water split. A number of runs were performed using flow rates varying from 0,017 $\ell.s^{-1}$ to 1,04 $\ell.s^{-1}$. This range was estimated to be typical of runoff rates at the plots.

Experiment 2

To determine the effect of flow rate on the percentage sediment split. The experiment was run using the procedure outlined above for Experiment 1. Sediment was added to the inflowing water at a concentration of 1 $g.\ell^{1}$ so that the effect of flow rate on the percentage sediment split could be assessed. Sandy loam soils

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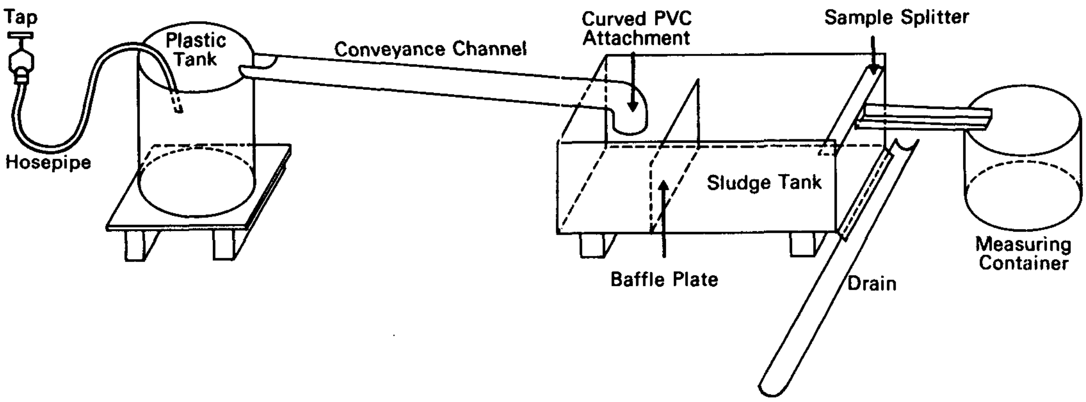

Figure 1
Sample splitter and experimental apparatus.

from the runoff plots were used in the experiment. Flow rates varied over the same range described in the previous experiment.

Experiment 3

To determine the effect of sediment concentration on the percentage split. Five runs were performed at a constant flow rate of approximately 0,15 $\ell.s^{-1}$. This represents the flow rate at which the splitter begins to behave in a manner approximate to that intended by the design. Sandy loam from the plots was used at concentrations of 0,1 $g.\ell^{1}$; 0,5 $g.\ell^{1}$; 1,0 $g.\ell^{1}$; 5,0 $g.\ell^{1}$ and 10 $g.\ell^{1}$. These concentrations cover the range that has been recorded at the runoff plots.

Experiment 4

To determine the effect of sediment grain size on the percentage split. Runs were performed using sediment of different size ranges. (Table 1). Flow rate was kept constant at approximately 0,15 $\ell.s^{-1}$ and sediment concentration was kept constant at 1 $g.\ell^{1}$.

Results

Experiment 1

The results of Experiment 1 are tabulated in Table 2 and shown in Figure 2. The graph indicates that a clear relationship exists between flow rate and percentage split. For flow rates lower than approximately 0,15 $\ell.s^{-1}$ the percentage split increases with increasing flow rate. At a flow rate of 0,15 $\ell.s^{-1}$ the percentage split starts at approximately 10%. From this point onwards flow rate appears to have no effect on the percentage split, and the curve evens out.

TABLE 1: TABLE SHOWING THE DESCRIPTION AND GRAIN SIZES OF SEDIMENT USED IN EXPERIMENT 4.

Sediment	Description	Grain size
A	Fine	25 μm
B	Medium	80 – 25 μm
C	Coarse	2 mm – 80 μm
D	Loam	Equal proportions of the above
E (Plot)	Sandy Loam	70% sand; 27% silt; 3% clay

Experiment 2

The results of Experiment 2 are tabulated in Table 3 and shown graphically in Figure 3. The graph shows that the same relationship as shown in Experiment 1 exists between the 2 variables in Experiment 2. The split of sediment appears to be governed by the percentage water split sampled at that rate.

Experiment 3

The results of Experiment 3 are tabulated in Table 4. The maximum deviation between percentage splits and the mean percentage split of the runs was 0,43% with a standard deviation of 0,25%. The results of the experiment indicate that sediment concentration has no effect on the percentage sample split, but rather that the percentage sediment split is dependent on the percentage water split at a particular flow rate.

Experiment 4

The results of Experiment 4 are tabulated in Table 5. The max-

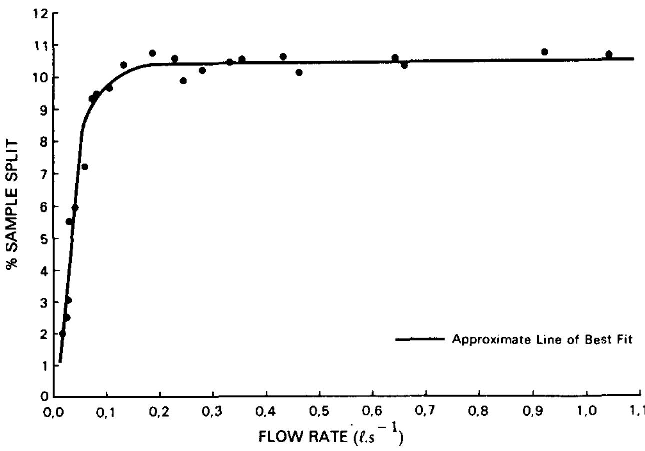

Figure 2
The relationship between flow rate and percentage water split.

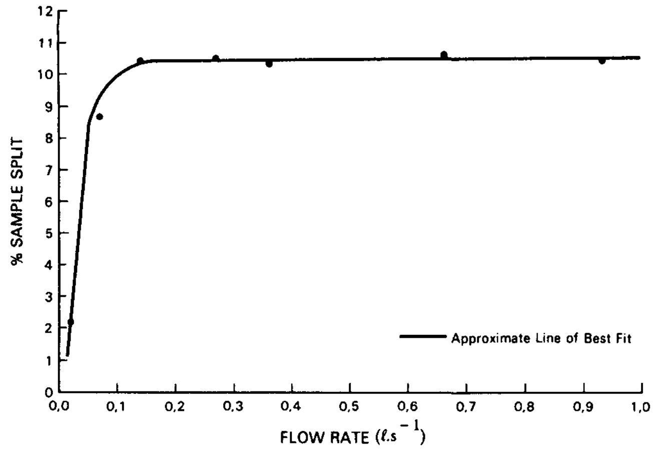

Figure 3
The relationship between flow rate and percentage sediment split.

imum deviation between percentage splits and the mean percentage split of all the runs was calculated at 0,44% with a standard deviation of 0,32%. The results of the experiment indicate that sediment grain size has no effect on the percentage sample split. The reason for this is thought to be due to the fact that in a sludge tank of this size, the inflow of water dominates over all other influences to the sediment in the sludge tank. The velocity of inflow is such that it causes turbulence sufficient enough to distribute the suspended load evenly throughout the water in the sludge tank. If the suspended sediment is evenly distributed throughout the flow entering the splitter it will have no effect on the behaviour of the splitter.

Conclusion

The results of the study show that the major factor influencing the sampling efficiency of the splitter is flow velocity. Within the

TABLE 2: RESULTS OF THE EXPERIMENT DESIGNED TO INVESTIGATE THE EFFECT OF FLOW RATE ON THE REPRESENTATIVENESS OF WATER SAMPLES

Length of run (s)	Rate (ℓ/s)	Total volume passed through (ℓ)	Amount overflowing from sludge tank (ℓ)	Amount in split sample (ℓ)	Actual % split
3 660	0,017	62,22	8,72	0,173	1,98
2 700	0,025	67,50	14,00	0,351	2,51
2 450	0,028	68,60	15,10	0,461	3,05
2 100	0,030	63,00	9,50	0,523	5,51
1 500	0,042	63,00	9,50	0,565	5,95
1 100	0,059	64,90	11,40	0,824	7,23
900	0,074	66,60	13,10	1,224	9,34
780	0,080	62,40	8,90	0,839	9,43
600	0,105	63,00	9,50	0,916	9,64
540	0,130	70,20	16,70	1,728	10,35
360	0,182	65,52	12,02	1,230	10,73
300	0,226	67,80	14,30	1,510	10,56
260	0,244	63,44	9,94	0,982	9,88
240	0,280	67,20	13,70	0,140	10,21
210	0,331	69,51	16,01	1,665	10,40
180	0,353	63,54	10,04	1,055	10,51
180	0,430	77,40	23,90	2,533	10,60
180	0,461	82,98	29,48	2,983	10,12
120	0,642	77,04	23,54	2,488	10,57
120	0,660	79,20	25,70	2,665	10,37
90	0,920	82,80	29,30	3,144	10,73
90	1,040	93,60	40,10	4,255	10,61

TABLE 3: RESULTS OF THE EXPERIMENT DESIGNED TO INVESTIGATE THE EFFECT OF FLOW RATE ON THE REPRESENTATIVENESS OF SEDIMENT SAMPLES.

Rate (ℓ/s)	Total mass of sediment put through system (g)	Mass sediment retained in sludge tank (g)	% Sediment retained in sludge tank	Mass of sediment in sample (g)	Actual sediment split %
0,02	60	54,30	90,5	0,122	2,14
0,07	60	52,36	87,3	0,662	8,66
0,14	60	51,62	86,0	0,870	10,38
0,27	60	49,42	82,0	1,126	10,47
0,36	60	47,14	78,6	1,327	10,32
0,66	60	46,30	77,2	1,450	10,59
0,93	60	43,92	73,2	1,682	10,46

TABLE 4: RESULTS OF THE EXPERIMENT DESIGNED TO INVESTIGATE THE EFFECT OF SEDIMENT CONCENTRATION ON THE REPRESENTATIVENESS OF SEDIMENT SAMPLES

Concentration (g/ℓ)	Mass of sediment put through sytem (g)	Mass of sediment retained in sludge tank (g)	Mass of sediment lost from sludge tank	Sediment retained in sludge tank %	Mass of sediment in sample (g)	Actual sediment split %
0,1	6	4,88	1,12	81	0,115	10,29
0,5	30	25,20	4,80	84	0,622	10,73
1,0	60	52,00	8,0	87	0,864	10,80
5,0	300	273,01	26,99	91	2,947	10,92
10,0	600	567,81	32,19	94	3,499	10,87

TABLE 5: RESULTS OF THE EXPERIMENT DESIGNED TO INVESTIGATE THE EFFECT OF SEDIMENT GRAIN SIZE ON THE REPRESENTATIVENESS OF SEDIMENT SAMPLES

Sediment size	Total mass of sediment put through system (g)	Mass of sediment retained in sludge tank	Sediment retained in sludge tank %	Mass of sediment in sample (g)	Actual sediment split %
A: Fine	60	45,60	76,0	1,557	10,81
B: Medium	60	52,94	88,2	0,703	9,96
C: Coarse	60	58,79	98,0	0,125	10,36
D: Loam	60	48,44	80,7	1,229	10,63
E: Plot	60	49,00	81,7	1,134	10,31

ranges used in this study, concentration and grain size of sediment do not have an effect on sampling accuracy.

The major finding of the study is that the design sample split is only attained after a critical flow rate is exceeded (Figure 2). This is ascribed to surface tension at the splitter/water interface. Surface tension causes a backing up of water behind the weir at low flow rates due to differences in forces of attraction exerted between water and metal molecules adjacent to the splitter weir (Levich, 1971). The resultant backing up effect causes uneven flow across the weir crest. These forces are overcome only after a critical flow rate (0,15 $\ell.s^{-1}$) is exceeded. The performance of the splitter improves after this critical flow rate has been reached.

The splitter tested in this study is simple to construct and is made from readily available, inexpensive material. The results of the study show that it is perfectly adequate for the plot study for which it has been designed. The study does show that inaccuracies in sampling may occur. In the case of the splitter tested they are thought to be due to surface tension. However, it is suggested that similar studies should be attempted on other splitters and that researchers are made aware of the inaccuracies that might exist.

Other than the work published by Geib (1933), there has been very little literature on plot sampler efficiency published to date (Morgan, 1986). This is a serious omission bacause data obtained from runoff plots is used to develop mathematical models which in turn enable soil erosion losses to be predicted under various regimes of climate, soil, vegetation and topography, and provide a basis for developing land management techniques to control soil erosion (Kinnell, 1982). When the dependency of researchers on field data such as that obtained from runoff plots is considered, it becomes evident that any inaccuracies present should be identified, minimised and accounted for in order to increase the value of results obtained from such field studies.

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