SOIL LOSS AND RUNOFF FROM DEMONSTRATION GARDENS IN MATALAU VILLAGE EAST NEW BRITAIN PROVINCE

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BY

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ABSTRACT

Demonstration gardens were set up on a steep hillside in Matalau Village, East New Britain Province, to investigate soil loss and runoff. One garden was clean weeded and the other used a soil conservation method of logs across the slope and plant debris left on the soil surface.

Over the 16 months of the project, there was much more soil loss and runoff from the clean weeded garden than from the conserved garden.

The results indicate that the use of logs across the slope and plant debris left on the soil surface was effective in reducing soil loss and runoff from the garden.

INTRODUCTION

The Rabaul area of East New Britain Province has been affected by soil erosion. Large amounts of soil have been washed onto roads and some roads have been severely damaged.

Land pressure has contributed to this problem by forcing many people to clear land on the sides of valleys and steep hillsides to make gardens. The custom of clean weeding of gardens is followed here as in many areas of Papua New Guinea.

Another factor that may also have contributed to the erosion problem, has been the redevelopment of village cocoa plantings on flat land and hillsides. This redevelopment process involves the clearing of old cocoa and shade trees and the planting of food crops such as bananas, Xanthosoma taro, Colocasia taro and aibika (Abelmoschus manihot) to give temporary shade to the cocoa. The food crops are clean weeded.

Very little research has been done on soil erosion in Papua New Guinea. Studies were started in the highlands by Humphreys (1984) and Wood (1984) at about the same time as this study.

In 1980, no information was available on soil loss and runoff in the Gazelle Peninsula. A report by Williams (1980) stressed the need for demonstration gardens and data collection in the Gazelle Peninsula. This project was then set up as a demonstration garden. It also aimed to collect basic information on the amounts of soil loss and runoff from both a clean weeded garden and a garden using soil conservation methods (conserved)[1] on a steep hillside. Assessment of crop growth was also included in the project.

The demonstration gardens were set up in a cocoa redevelopment block at Matalau Village, Kombiu Community Government, in the Gazelle Peninsula of East New Britain Province.

1 *For convenience the term 'conserved' is used throughout the rest of this report for the garden using soil conservation methods.*

METHODS

The gardens were established on well drained volcanic soils (Jeffrey 1982, Appendix 1) on a 29° slope with a 16° east aspect.

The project design was a simple comparison between two gardens, walled with corrugated iron, each being 23 m^2 (2 m wide, 10 m long) and with 3 m sloping sides leading to a metal spout at the bottom of the garden. Below each spout was a drum containing an open weave fertilizer bag to collect soil washed from the garden (Figure 1). These drums were then connected to a series of drums, also with spouts, placed down the hill for collecting runoff (Figure 2).

This project ran for 16 months from 2 December 1980 to 2 April 1982.

Figure 1: In the centre of this drum is a bag to collect the soil washed from the clean weeded garden. The depth of runoff water in the drum is shown being measured.

Figure 2: To collect runoff, there is a series of drums with spouts below each garden.

Treatments

There were two treatments: a clean weeded garden and a conserved garden with logs across the slope and plant debris on the ground.

For the clean weeded garden, the felled cocoa and shade trees and branches were removed, then the remaining plant debris burnt. In the conserved garden, logs from the felled trees were put across the slope two metres apart down the length of the garden, and the plant debris was left in the garden.

In each garden, 11 banana suckers were planted using Tolai spacing of 1 to 1.5 m. One cocoa budding was also planted and four self sown paw paws were left to grow in each garden.

The old banana leaves were removed and the gardens weeded as necessary according to Tolai custom. The old leaves and weeds were thrown out of the clean weeded garden, but were left lying on the soil surface in the conserved garden.

Maintenance was usually carried out on the dates measurements were taken.

Measurements

The equipment and methods of measurement used were limited to what could be obtained. As a result, most methods were crude.

Apart from rainfall, measurements were generally taken at 14 day intervals. Runoff measurements were made as frequently as seven day intervals when very wet. They were made less frequently during dry periods because of the limitations of the equipment to measure small quantities of soil loss and runoff. The rain gauge was generally read daily except during weekends.

The amount of runoff from each garden was determined from the volume of water that ran into the drums. This was calculated from measurements of the depth of water in each drum in which there was runoff.

The total soil loss from each garden included the soil collected in the bag in the first drum, and the soil in suspension in each drum in which there was runoff. The soil in suspension was calculated from water samples. Soil loss was quoted as dry weight.

Ground cover was measured in each garden three times, and the canopy covering the gardens was measured midway through the project.

To assess crop growth and health, various records were taken regularly: leaf counts, number of plants alive, time of first flowering, and fruit production. Circumference and height were measured three times.

Soil samples were taken for analysis at the start and end of the project.

RESULTS

Soil loss and runoff.

The amounts of soil loss and runoff from each garden are shown in Table 1.

Table 1: Soil loss and runoff

Data from 28 measurements over the 16 month period[1]	Clean weeded garden	Conserved garden
Soil loss[2] per 23m^2 (kg)	127.4	1.3
Soil loss (depth) (mm)	6.2	0.1
Soil loss tonnes/hectares equivalent (t/ha)	55.4	0.6
Soil loss per year [3] (t/ha/yr)	38.2	0.2
Percentage of soil loss in suspension (%)	8.0	34.5[4]
Runoff (mm)	187.1	7.3
Runoff (litre)	4315.4	168.5
Rainfall (mm)	3237.5	3237.5
Rainfall (litre)	74462.5	74462.5
Percentage of rainfall becoming runoff mean (%)	5.8	0.2
range (%)	0-25.0	0-2.0

1. For detailed results see Appendix 2.
2. Four of the 28 measurements were not usable.
3. Complete record for 12 months 3 March 1981 - 2 March 1982.
4. This figure appears large. As little soil was collected in the bag the proportion of the soil loss collected in suspension was much larger than for the clean weeded garden.

Much more soil was lost from the clean weeded garden compared to the conserved garden during the 16 months of this project. There was also more runoff from the clean weeded garden than the conserved garden. The percentage of the rainfall becoming runoff was low even for the clean weeded garden.

Ground Cover

In the clean weeded garden, ground cover was five per cent before weeding and nil after weeding. The regular weeding kept the amount of ground cover low.

Halfway through the project, the ground cover in the conserved garden was 70 per cent before weeding and 50 per cent after

weeding. By the end of the project the amount of ground cover had decreased to 40 per cent.

Canopy

The canopies of four coconut palms (9 to 11 m tall) and a cocoa tree (2 m tall) gave a 40 per cent cover over the two gardens.

Halfway through the project the banana leaf canopies covered about 35 per cent of the clean weeded garden and 50 per cent of the conserved garden. By the end, the banana canopy in the clean weeded garden was almost nil, while the conserved garden still had some cover from five unhealthy banana plants. The paw paw canopies were fairly similar for each garden throughout the project.

Crop growth

The banana and paw paw growth tended to be better in the conserved garden compared to the clean weeded garden. However, none of the bananas grew well.

At the end of the project there remained only one unhealthy banana sucker, circumference 23 cm and height 1.3 m, in the clean weeded garden. The 11 parent plants had died. In the conserved garden, five unhealthy banana plants, including one sucker, remained out of the 11 parent plants. These five parent plants in the conserved garden had an average circumference of 41 cm and average height of 2.5 m. No plant in either garden produced a flower. Banana weevil attacked plants in both gardens. It was therefore not possible to make a realistic comparison of banana growth in the two gardens.

There was an indication that paw paw development was more advanced in the conserved garden. Flowering and fruiting commenced earlier in the conserved garden. The four plants in the conserved garden produced fruit 16 weeks before all of the three female plants in the clean weeded garden. The average circumference of the paw paw trees in the clean weeded garden (29 cm) and conserved garden (32 cm) were similar.

Figures 3 and 4 illustrate crop growth and ground cover 11 months from the start of the project.

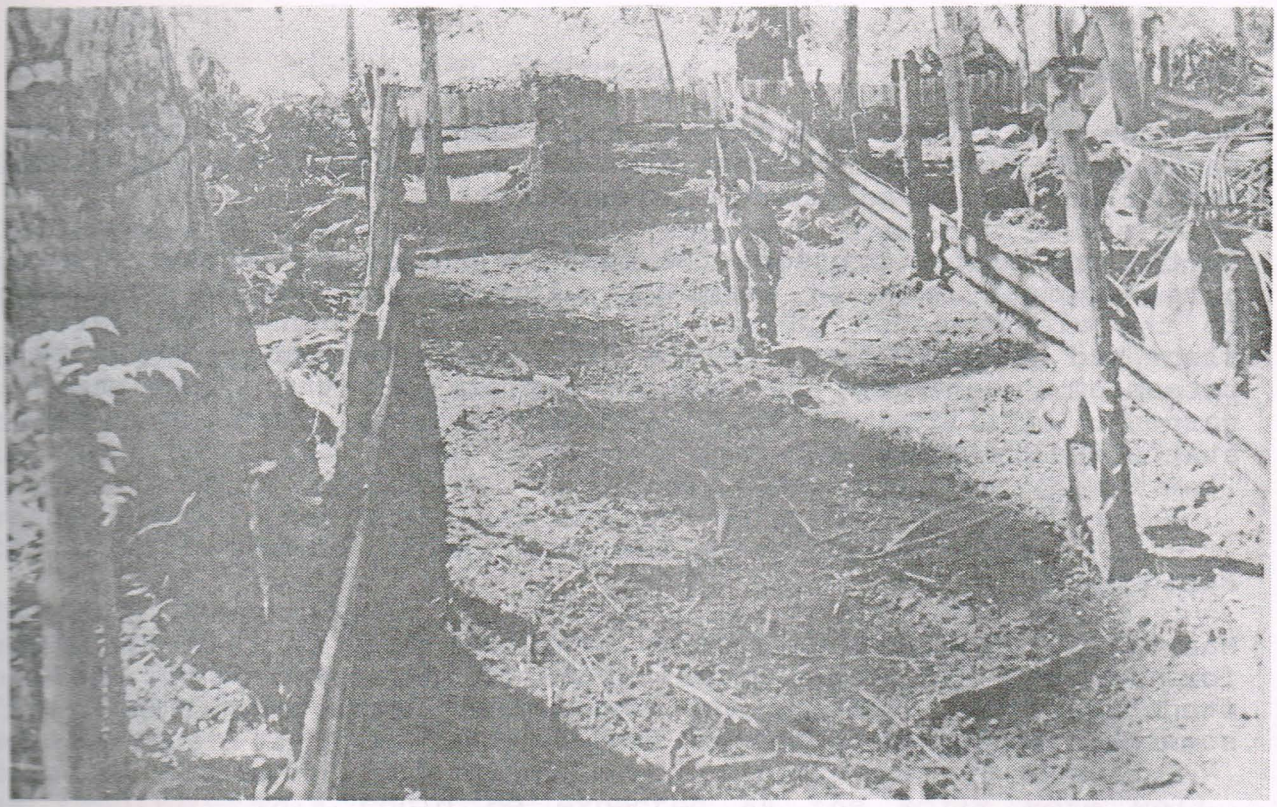

Figure 3: The clean weeded garden 11 months after the start of the project. The soil is bare and the roots are exposed due to the loss of soil from this garden. The trunks of the bananas are smaller than in the conserved garden.

Figure 4: The conserved garden 11 months after the start of the project. The logs across the slope and the plant debris left on the soil surface show the soil has more ground cover than in the clean weeded garden. The trunks of the bananas are larger than those in the clean weeded garden.

Soil fertility

The results from the analysed soil samples were variable but there were some differences between the samples from the clean weeded and conserved gardens (Appendix 1).

At the end of the project, the soil in the conserved garden had a higher mean level of available nitrogen (126 kg/ha) compared to the clean weeded garden (73 kg/ha). The conserved garden also had higher mean levels of cation exchange capacity, potassium, magnesium and organic matter than the clean weeded garden (Williams 1982). These results have not been statistically analysed.

Field days

Many field days on soil erosion have been held at these gardens for village people, Agricultural College and High School students, field staff of the Division of Rural Development and some politicians and Heads of Divisions.

DISCUSSION

Soil loss and runoff

These results show that much more soil was lost from the clean weeded garden than from the conserved garden. Runoff was also greater from the clean weeded garden than the conserved garden.

This suggests that the speed of the runoff water was reduced sufficiently in the conserved garden to prevent the runoff removing and carrying much soil with it. The logs also reduced the length of the slope so making it more difficult for the runoff to flow fast down the slope. However, in the clean weeded garden the runoff was able to flow freely and fast down the hillside and so could remove and carry soil with it.

The mean percentage of rainfall becoming runoff for the clean weeded garden (5.8%) is likely to be an underestimate. This is because the measurements of runoff did not allow for evaporation from the runoff drums during the dry season. However, the actual range of 0 to 25 per cent suggests that most of the rainfall soaked into the ground, leaving only a small proportion as runoff. This could be expected as the soils were well drained and derived from volcanic ash (Appendix 1).

The soil loss of 38.2 tonnes/ha/year from the clean weeded garden on a 29^{o} slope would be considered moderate according to the classification of soil loss by FAO (1978) cited in Humphreys (1984). In contrast the soil loss from the conserved garden of 0.2 tonnes/ha/year would be in the none to slight category.

In Chimbu Province, Humphreys (1984) found soil loss of about 30 tonnes/ha/year on a 20^{o} slope from clean weeded plots with a disturbed soil surface. This amount of soil loss has some similarity with the soil loss found from the clean weeded garden in this study.

Despite the limitations of the equipment and methodology, the results obtained for soil loss and runoff showed large differences between the clean weeded and conserved gardens on a 29^{o} slope.

These results also show that the method of putting logs across the slope and plant debris left on the soil surface was effective in reducing soil loss and runoff. However, caution must be taken when using logs across the slope as a soil conservation method. Large logs could cause damage if water flows through small holes under them or if it flows over them. Small logs, branches or coconut fronds as small fences reduce this problem by allowing space for water to pass through. Both logs and fences act as a barrier to the flow of runoff water. They reduce its speed down the hillside, and at the same time retain most of the soil.

Ground cover

By the end of the project there was only 40 per cent ground cover in the conserved garden. This decrease may have been due to increased levels of shade, from the banana and paw paw canopies, reducing weed growth. This suggests that it may be difficult to obtain complete ground cover in conserved gardens with bananas and other tree crops.

Canopy

Runoff and soil loss would have been reduced to some extent by the banana and paw paw canopies breaking the impact of the raindrops on the gardens. This would have had more effect on the conserved garden, where more bananas survived, than in the clean weeded garden.

Crop growth and health

More investigation is needed on the effects of soil conservation methods on crop health and production. The custom of clean weeding in Papua New Guinea must be acknowledged. However, it needs rethinking in areas of land pressure. The amount of soil loss and runoff from clean weeded gardens on hillsides cannot be ignored. This study has shown that logs across the slope and plant debris on the ground can successfully reduce soil loss and runoff.

It may be necessary to accept a higher level of pest and disease activity in crops with soil conservation methods that use plant debris as a trade off against the long term effects of continued soil loss. However, crop yields obtained when using plant debris on the soil may not be reduced as greatly as expected (Phillips 1982).

CONCLUSION

On a 29° slope, there was little soil loss and runoff from the conserved garden, compared to the clean weeded garden. This indicates that the use of logs across the slope and plant debris left on the soil surface in the conserved garden was effective in reducing soil loss and runoff from the garden.

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APPENDIX 1

A. Soil description from Matalau erosion plots

(Prepared by Peter Jeffery, Lowlands Agricultural Experiment Station, 1st July 1982 and edited by B.M. Wayi, Department of Agriculture and Livestock, 1989).

Plot 1 (Clean weeded garden)

Profile drainage: Well drained
Soil condition : Moist
Parent material : Quaternary Pyroclastic materials.

Horizon	Depth (cm)	Description
A	0-10	Brownish black (10YR 2/2), loam; apedal to weakly developed very fine sub-angular blocky; very friable; with 5% (vol %) parent material of Pumice gravel up to 10 mm diameter; clear to -
Bw	10-80 +	Dark brown (10YR 3/3), coarse sandy loam; weakly developed fine sub-angular blocky; very friable; with 10% (vol %) parent material of Pumice gravel up to 12 mm diameter.

Plot 2 (Conserved garden)

Profile drainage: Well drained
Soil condition: Moist
Parent material: Quaternary Pyroclastic materials.

Horizon	Depth (cm)	Description
A11	0-10	Brownish black (10YR 2/2) loam, apedal to weakly developed fine sub-angular blocky; very friable; with 5% (vol %) parent material of Pumice gravel up to 10 mm diameter; clear to -
A12	10-50	Dark brown (10YR 2/3), fine sandy loam; apedal and structureless (single grain); loose; clear to -
Bw	50-70	Dark brown (10YR 3/3) coarse sandy clay loam; apedal to weak developed very fine sub-angular blocky; very friable; with 3% (vol %) comprising mainly of fine pumice gravel; clear to -

C 70-80 +	Brown (10YR 4/4), sandy clay; apedal to weakly developed very fine sub-angular blocky; loose; with 80% (vol %) parent material of fine pumice gravel up to 3 mm diameter.

B. Soil analysis results

Garden	Horizon	Bulk Density	Cat. Exch Cap. me/100g	PH	N kg/ha	P ppm	Na	K	Ca	Mg	% org. matter
							me/100g				
Start of Project, October, 1980. means of two samples											
Clean Weeded	A	-	10.3	6.9(0.13%)		1.0	0.10	0.7	3.6	1.9	-
Conserved	A	-	10.1	7.1(0.14%)		3.5	0.09	0.7	3.9	3.3	-
End of Project, April 1982. means of six samples from top to bottom of gardens											
Clean Weeded											
Site 1 Top of Plot	A_1	1.00	9.0	6.6	61	3	0.07	0.33	4.3	1.7	3.0
Site 2	A_1	0.98	11.0	6.7	64	2	0.17	0.33	5.8	2.3	2.8
Site 3	A_1	0.97	11.0	7.0	100	4	0.04	1.10	6.5	2.3	3.4
Site 4	A_1	1.10	8.0	6.8	43	3	0.04	0.29	4.4	1.8	1.8
Site 5	A	1.00	11.0	6.8	96	2	0.06	0.37	7.5	2.2	3.0
Site 6 Bottom of Plot	A	*0.94*	*13.0*	*6.8*	*75*	*2*	*0.07*	*0.61*	*7.6*	*2.2*	*3.8*
MEANS	A_1/A	1.00	10.5	6.8	73	2.7	0.08	0.51	6.0	2.1	3.0
Conserved											
Site 1 Top of Plot	A_1	0.82	18.0	6.6	170	3	0.10	0.75	9.1	4.9	6.2
Site 2	A_1	0.78	25.0	7.3	210	4	0.09	1.40	14.0	8.9	7.4
Site 3	A_1	0.94	12.0	6.8	79	2	0.14	0.50	5.6	2.7	3.7
Site 4	A	1.00	12.0	7.1	85	3	0.07	0.68	6.3	3.2	3.5
Site 5	A	0.96	12.0	7.2	120	4	0.08	1.40	6.9	2.9	3.6
Site 6 (Bottom of Plot)	A	0.90	12.0	7.0	89	3	0.07	0.43	7.5	2.6	3.1
MEANS	A_1/A	0.90	15.2	7.0	126	3.2	0.09	0.86	8.2	4.2	4.6

Garden	Horizon	Bulk Density	Cat. Exch Cap. me/100g	PH	N kg/ha	P ppm	Na	K	Ca	Mg	% org. matter
							me/100g				
Clean Weeded											
Site 1	A_2	1.2	5	6.9	35	2	0.06	0.17	2.8	0.76	1.2
Site 2	A_2	1.1	6	6.9	32	5	0.06	0.16	3.3	0.94	1.1
Site 3	A_2	1.1	7	7.0	57	3	0.04	0.20	4.4	1.30	1.9
Site 4	A_2	1.1	6	6.9	38	5	0.06	0.34	3.1	1.10	1.3
MEANS	A_2	1.1	6	6.9	40.5	4	0.06	0.22	3.4	1.03	1.4
Conserved											
Site 1	A_2	1.10	7	7.0	42	2	0.06	0.40	3.1	1.5	1.6
Site 2	A_2	0.95	12	7.7	51	3	0.12	2.60	6.2	3.4	2.0
Site 3	A_2	1.20	5	7.1	39	3	0.04	0.28	2.9	1.1	1.2
MEANS	A_2	1.10	8	7.3	44	3	0.07	1.09	4.1	2.0	1.6
Clean Weeded											
Site 1	B	0.73	19	6.6	27	3	0.88	1.30	7.5	3.3	1.8
Site 2	B	0.83	15	7.0	22	3	1.30	0.94	6.6	2.1	0.7
Site 3	B	0.82	14	6.6	23	4	1.40	0.52	5.8	1.8	0.6
Site 4	B	0.81	14	6.8	29	3	0.83	1.40	5.3	2.8	0.9
Site 5	B	0.80	15	7.0	37	2	0.25	3.00	6.9	2.5	0.9
Site 6	B	0.85	14	7.0	27	1	0.42	1.02	7.2	2.6	0.8
MEANS	B	0.81	15	6.8	28	3	0.85	1.36	6.6	2.52	1.0

Garden	Horizon	Bulk Density	Cat. Exch Cap. me/100g	PH	N kg/ha	P ppm	Na	K me/100g	Ca	Mg	% org. matter
Conserved											
Site 1	B	0.74	18	6.9	42	2	0.20	2.70	8.1	3.2	2.1
Site 2	B	0.83	15	7.2	47	2	0.80	1.10	7.4	3.40	0.6
Site 3	B	0.84	14	7.2	17	1	1.50	0.88	6.8	1.50	0.7
Site 4	B	0.84	15	6.9	27	1	0.84	1.10	7.4	2.50	0.9
Site 5	B	0.81	14	6.9	48	1	0.39	2.20	6.5	2.20	1.0
Site 6	B	0.84	13	6.9	32	2	0.36	2.10	6.2	1.70	0.8
MEANS	B	0.82	15	7.0	36	2	0.68	1.68	7.1	2.42	1.0
Sample collected from bag in drum, from clean weeded garden:											
	A	0.89	16	6.8	160	7	0.04	0.64	9.9	3.7	6.2

Raw Data: Soil and Water loss records

Sample Date	Rainfall (total)	Sampling interval	Soil loss				Runoff		% Rainfall as runoff	Runoff		% Rainfall as runoff
			Clean weeded garden		Conserved garden		Clean weeded garden			Conserved garden		
	mm	days	gm/23m^2	t/ha	gm/23m^2	t/ha	mm	litres	%	mm	litres	%
2/12/80	Start											
16/12/80	182.0	14	10381	4.514	769		10.5	241.860	5.8	0.9	20.298	0.5
23/12/80	15.0	7	+	+	+		0	0	0	0.3	7.337	2.0
30/12/80	39.5	7	3501	1.522	61		1.7	39.373	4.3	0.3	7.902	0.8
6/1/81	62.0	7	1553	0.675	12		1.9	42.552	3.1	0	0	0
20/1/81	141.6	14	NA	NA	NA		35.1	807.260	24.8	1.6	37.661	1.1
3/2/81	87.4	14	NA	NA	NA		0.6	14.673	0.7	0	0	0
17/2/81	99.0	14	NA	NA	NA		9.8	224.498	9.9	0.7	16.629	0.7
3/3/81	75.9	14	719	0.313	16		1.2	27.390	1.6	0.7	15.162	0.9
10/3/81	156.2	7	9001	3.913	47		20.6	474.672	13.2	0.5	11.249	0.3
17/3/81	48.8	7	8715	3.789	78		12.0	275.953	24.6	0.5	12.228	1.0
24/3/81	61.0	7	5568	2.421	26		9.9	226.698	16.2	0.3	6.358	0.5
7/4/81	98.7	14	340	0.148	38		1.9	43.041	1.9	0.1	1.712	0.1
21/4/81	85.0	14	367	0.160	43		1.0	23.477	1.2	0	0	0
16/6/81	121.2	56	1377	0.599	33		1.5	33.503	1.2	0	0	0
30/6/81	190.8	14	1942	0.844	15		1.3	29.346	0.7	0	0	0
25/8/81	406.7	56	356	0.155	40		0	0	0	0	0	0

Sample Date	Rainfall (total)	Sampling interval	Soil loss				Runoff		% Rainfall as runoff	Runoff		% Rainfall as runoff
			Clean weeded garden		Conserved garden		Clean weeded garden			Conserved garden		
	mm	days	gm/23m^2	t/ha	gm/23m^2	t/ha	mm	litres	%	mm	litres	%
20/10/81	207.1	56	286	0.124	42		0	0.978	0	0	0	0
1/12/81	174.2	42	13369	5.813	27		3.8	88.038	2.2	0	0	0
8/12/81	61.0	7	5551	2.414	1		4.4	101.488	7.2	0.1	2.201	0.2
22/12/81	118.1	14	4223	1.836	5		2.0	46.709	1.7	0	0	0
29/12/81	57.0	7	8062	3.505	3		5.3	122.030	9.3	0.2	5.136	0.4
12/1/82	69.1	14	2682	1.166	1		4.3	98.798	6.2	0	0.734	0
2/2/82	318.6	21	16216	7.050	64		19.4	445.570	6.1	1.1	24.700	0.4
9/2/82	26.5	7	2958	1.286	1		3.6	81.924	13.6	0	0	0
2/3/82	49.8	21	6186	2.690	5		5.0	115.428	10.0	0	0	0
16/3/82	80.8	14	1321	0.574	3		2.9	65.784	3.6	0	0	0
6/4/82	135.0	21	16625	7.228	3		17.5	402.530	13.0	0	0	0
20/4/82	69.5	14	6097	2.651	4		10.5	241.860	15.1	0	0	0
TOTALS	3237.5	504	127396	55.390	1337	0.581	187.1	4315.433	5.8 (Av)	7.3	168.497	0.2 (Av)

Note: + - Some soil from 16.12.80 was left in drums and collected 23.12.80. This soil was added to the amount for 16.12.80. The recordings for runoff for 23.12.80 may have been due to some water left in drums after 16.12.80.

NA - Results not useable

For the calculation of the volume of soil in the bag and the displacement effect, 0.9 was used for the bulk density of the soil. This was only done for the clean weeded plot as too little soil was collected from the conserved plot.

Conversion factor used for calculating dry weight of soil from fresh weight (drained overnight) -
Plot 1 - 0.59
Plot 2 - Until 20.10.81 - 0.59
1.12.81 onwards - Nil - as total air dried weight used.