STUDIES OF HYDROMULCH EFFECTIVENESS

Prepared by

LANDLOCH PTY LTD

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Cover photograph :

Rainfall Simulator installation at Jimboomba Turf Queensland June 2002.

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Executive Summary

A study using simulated rain and overland flows was carried out to assess the effectiveness of a range of hydromulch materials in increasing infiltration, reducing erosion, and reducing the rate of drying of the soil surface.

The experiment was carried out on the wall of a newly-constructed water storage dam at a turf farm owned by Jimboomba Turf Company, located on Brockland Road, Allenview, not far from Jimboomba, in May 2002. The dam wall was constructed of alluvial black, cracking clay soil (a mixture of surface and sub-soil), with a gradient of approximately 25% (range 22-28%.) The experiment used a randomized block design, with three blocks, each of five treatments:

- Control (bare soil)
- Paper
- Flax
- Flax plus paper
- Sugar Cane

A simulated storm approximately equivalent to a 1:10 year storm of 20 minutes duration was applied by the rainfall simulator to plots 5 m long and 1.5 m wide. This was followed by application of two rates of overland flow (together with rainfall) to the plots to simulate longer slopes. Windy conditions during the field experimentation caused variation in the actual rainfall intensities applied, but parameters derived from the data were not affected by those variations.

Data analysis showed all the hydromulched plots (as a group) to be considerably different to the Control plots. Differences between the various hydromulch types were relatively small in comparison.

Across all the variables considered, the Paper hydromulch ranked consistently as the least satisfactory of the hydromulch materials, generally being statistically significantly poorer than Flax plus paper and Sugar Cane treatments. For most variables, Flax plus paper and Sugar Cane were not significantly different, and ranked as the most satisfactory of the hydromulch treatments.

The data for soil surface drying post-wetting suggest a functional difference between the Paper hydromulch and the various vegetative mulches, with the latter group being more effective in maintaining surface soil water content after rain. However, at this stage, it appears that the slight differences in soil water content observed between Flax plus paper and Sugar Cane hydromulches are more a function of application rate than of mulch type.

Therefore, it is concluded that vegetative hydromulches using materials such as Flax and Sugar Cane are optimal, provided application rates are adequate. From the data, it appears that rates in the order of 5 t/ha may be needed to achieve best results.

1.0 Background

Hydromulching is widely used in the revegetation of disturbed areas, especially on slopes where there is a significant risk of erosion occurring during the period of initial plant establishment.

Perceived benefits of hydromulching include:

- increasing infiltration of rainfall into the soil
- protecting the soil surface from erosion
- reducing the rate of drying of the soil surface after rain, to improve germination of seeds and establishment of plants

As well, hydromulches are commonly applied to soil surfaces that have relatively poor chemical and physical characteristics, so that long-term growth and persistence of plants can be poor. In those situations, persistence of an organic layer on the soil surface can aid in trapping water and soil, and in maintaining a more favourable growing environment over the longer term.

This study was carried out to test the effects of a range of hydromulch products on infiltration, runoff, and erosion under intense simulated rainfall and overland flows, and to assess impacts of the mulches on rates of drying of the soil surface.

A linked study will record observations of vegetation establishment on the plots studied, and also gather data on the long-term persistence of the various hydromulch types.

2.0 Experimental methods

2.1 Overview

A rainfall simulator study was carried out in May 2002 to test a range of hydromulch materials. The study considered infiltration, runoff, and erosion under simulated rain, and erosion under applied overland flows (to simulate longer slope lengths). As well, water contents in the surface 25 mm of soil were monitored for 11 days after initial wetting to assess effects of the various materials on surface drying.

2.2 Location and site properties

The study was carried out on the wall of a newly-constructed water storage dam at a turf farm owned by Jimboomba Turf Company, located on Brockland Road, Allenview, not far from Jimboomba.

The dam wall was constructed of alluvial black, cracking clay soil (a mixture of surface and sub-soil), with a gradient of approximately 25% (range 22-28%.) The surface was reasonably uniform, though some variations were visible, such as presence of significant root material in some plots. Soil bulk density (below the depth of surface tillage) varied from 1.01 to 1.14 g/cc, and water contents at that depth varied from 38 to 31% gravimetric. Surface (0-50 mm) water contents at the time of the study were in the order of 10-14% gravimetric.

Consistent with Dept of Main Roads specifications, the site was tilled to 50 mm depth prior to application of hydromulches. However, topsoil was not added, as the existing soil was perceived to be already more fertile than many of the topsoils used in commercial practice.

Whilst the soil is considerably "better" than many of the sites to which hydromulching is applied in commercial practice, the site (Figure 1) offered significant advantages in terms of:

- consistent, even, gradients
- relatively uniform soil
- easy access to water supplies (pumped directly from the dam)
- good site security
- easy access.

Figure 1: *View of study area prior to testing, with different hydromulch materials applied*

Samples of soil from the 0-10 cm layer were taken for chemical analysis. Relevant properties are shown in Table 1. They demonstrate the uniformity of the site, and the relative fertility and stability of the soil.

Table 1: *Some properties of the soil at the research site*

Analyte	Sample 1	Sample 2
pH	6.1	6.0
Electrical Conductivity (EC) (mS/cm)	0.221	0.211
Chloride (mg/kg)	72.4	64.7
Nitrate Nitrogen, aqueous (mg/kg)	55	52
Phosphorous (Colwell)	290	300
Organic Carbon (%)	2.88	3.41
Sulfate Sulfur (mg/kg)	26	22
Calcium, pH 7 (meq/100 g)	18	18
Magnesium, pH 7 (meq/100 g)	9.2	9.2
Sodium, pH 7 (meq/100 g)	0.66	0.61
Potassium, pH 7 (meq/100 g)	1.2	1.3
Copper, extractable (mg/kg)	3.2	3.4
Zinc, extractable (mg/kg)	6.3	7.2
Manganese, extractable (mg/kg)	49	50
Iron, extractable (mg/kg)	231	249
Air-dry moisture content (%)	2.39	3.13
Coarse sand (%)	6	5
Fine sand (%)	15	15
Silt (%)	37	37
Clay (%)	40	41

2.3 Treatments and experimental design

The following hydromulch treatments were applied:

- Control (bare soil)
- Paper @ 1000 kg/ha (Industry standard – Shredded Recycled Paper and 5% by weight Guar Gum)
- Flax @ 2,500 kg/ha (Chopped Flax and 5% by weight Guar Gum)
- Flax plus paper @ 3,250 kg/ha (77% Chopped Flax,15% Shredded Recycled Paper, and 8% chopped lucerne, with 5% by weight Guar Gum)
- Sugar Cane - Kriedemann's All-Terrain mix @ 5,000 kg/ha (75% Sugar Cane leaf, 25% recycled paper, and 5% guar-based binding material.)

(The above information was supplied by the groups applying the various hydromulch treatments. The added Guar Gum is not included in any of the weights or proportions of mulch ingredients reported.)

Treatments were applied in a randomized block design, with three blocks.

2.4 Rainfall simulator methods

The rainfall simulator (Loch et al. 2001) (Figure 2) applies rain with a kinetic energy similar to that of natural rain, to plots 5 m long and 1.5 m wide. To simulate a 1:10 year storm, rain of approximately 145 mm/h was applied for 20 min. (It was concluded that a shorter, higher intensity storm would be particularly relevant to the short, steep slopes that are commonly hydromulched.)

Figure 2: *Rainfall simulator in use*

Actual intensities applied varied considerably, largely due to extremely high winds (gusts up to 50 km/h) on some days, with wind blowing rain away from the plots despite presence of a windbreak. For the third block, the programmed intensity was reduced because conditions became almost completely calm. Actual rainfall applied to each plot was monitored using an array of 12 rain gauges on each 7.5 m^2 plot (Figure 3), with variations in rain accounted for in subsequent data analysis.

Runoff from the plots was collected into a monitoring system, and runoff rates were measured by tipping buckets, with data stored in a notebook computer (Loch et al. 1998). Samples of sediment in runoff were taken for measurement of sediment loads and calculation of erosion rates.

Following the 20-minute application of rainfall only, the plots were subjected to applications of overland flow and simulated rain, to simulate runoff and potential erosion on longer slopes. For blocks 1 and 2, 5-minute applications at rates of 0.15 and 0.45 L/s were used, with 0.45 and 1.0 L/s being applied on block 3. Rates of overland flow onto the plots were accurately metered using a rotameter, and runoff rates and sediment concentrations monitored over the 5-minute periods.

Figure 3: *Rainfall simulator plot (control treatment), showing rain gauges, plot boundaries, and installation for collecting runoff.*

2.5 Climate and soil water content monitoring

A weather station was installed at the site for the duration of experimentation.

Data from the weather station were used to calculate daily evaporation potential.

Samples of the 0-25 mm surface layer were taken at intervals of 1, 3, 5, 7, 9, and 11 days after application of simulated rain to follow drying of the plots, and to assess the extent to which the various hydromulch materials reduced the rate of drying (and improved conditions for vegetation germination and establishment). At each sampling, samples were taken at 3 locations on each plot and bulked.

2.6 Data analysis

Methods for derivation of some of the parameters considered are described in sections reporting those results.

Statistical analysis relied on analysis of variance for most of the data. Soil water content differences between treatments were tested using a T-test.

3.0 Results and discussion

Data for individual plots and treatment means are shown in Table 2. Statistical differences between treatments are discussed (where appropriate) in each of the following sections.

The following observations of the various treatments under rain and overland flow were recorded.

Spatial variability. All plots and treatments showed some variability, with variation being most visible for the Flax treatment, noticeable for the Paper and Sugar Cane treatments, and least noticeable for the Flax plus paper treatment. (This may be a function of application rate, with spatial uniformity being more critical for the materials applied at lower rates.) The Flax treatment was observed to have greater exposure of underlying soil than the other hydromulch treatments.

Persistence under rainfall and overland flows. For Sugar Cane and Flax plus paper, little movement of the hydromulch materials was observed. There was noticeable movement of mulch on Flax and Paper treatments, though the Flax material mostly moved only short distances and formed debris dams rather than being moved completely off the plot.

Thickness of layer The Sugar Cane treatment was observed to have the greatest thickness, which is consistent with the higher weight of material applied, and the relatively large particle size of the vegetative material used.

Trafficability when wet. Rainfall simulator staff found movement on the wetted soil surface most difficult for Control and Paper treatments, with little difference between them. Flax plus paper and Sugar Cane were most stable under foot, with Sugar Cane persisting longer under traffic.

Some plots had the hydromulch layer pierced by deer hoofprints, but observations indicated that the hoofprints had no effect on erosion. (Flows were not observed to detach significant quantities of sediment from those areas.)

***Table 2**: Data overview*

Plot no	Treatment	Rain (mm)	Intensity (mm/h)	Total Runoff (mm)	Peak Runoff rate (mm/h)	Erosion (t/ha) (rainfall only)	MUSLE Erosivity (W)	Erosion per unit of MUSLE W	Plot gradient (%)	C factor	Green Ampt Hydraulic conductivity (mm/h)	Flow sediment concn. (g/L)
2	Control	37.5	112.445	0.00	37.48	0.2730	63.4344	0.0026	23.850	1.000	17.0	89.70
6		46.7	140.180	8.33	52.47	1.2657	109.4525	0.0070	23.475	1.000	22.0	51.15
11		37.4	112.230	5.79	39.45	0.2974	70.0626	0.0024	25.275	1.000	15.0	240.70
Treatment Means				***4.71***	***43.13***	***0.6120***	***80.98***	***0.00398***			***18.00***	***127.18***
1	Paper	42.4	127.065	1.47	6.83	0.0550	81.9745	0.0004	24.625	0.0975	28.0	11.75
7		43.6	130.720	1.98	9.87	0.1312	87.2073	0.0009	25.250	0.2139	30.0	6.90
13		36.9	110.758	6.74	29.02	0.1516	68.7618	0.0012	26.725	0.2998	17.0	ND
Treatment Means				***3.39***	***15.24***	***0.1126***	***79.31***	***0.0008***		***0.2038***	***29.00***	***9.33***
3	Flax	55.3	165.980	1.33	7.56	0.0107	139.1278	0.0000	22.250	0.0122	45.0	3.63
8		45.9	137.815	0.26	9.87	0.0949	95.4853	0.0006	22.825	0.1543	32.0	4.14
14		36.6	109.650	3.00	28.99	0.1400	63.5358	0.0011	28.700	0.2813	19.0	7.32
Treatment Means				***1.53***	***15.47***	***0.0818***	***99.38***	***0.0006***		***0.1493***	***32.00***	***5.03***
4	Flax + Paper	46.5	139.535	1.30	6.01	0.0059	98.5031	0.0000	21.800	0.0097	35.0	1.95
10		44.3	132.763	2.00	19.20	ND	90.2997		24.600	ND	28.0	ND
12		35.3	105.995	3.23	39.13	0.0305	60.1928	0.0003	22.400	0.0801	16.0	2.51
Treatment Means				***2.18***	***21.45***	***0.0182***	***83.00***	***0.0002***		***0.0449***	***26.33***	***2.23***
5	Sugar cane	46.5	139.535	0.67	4.61	0.0044	98.0712	0.0000	21.800	0.0073	35.0	1.03
9		45.2	135.536	1.13	8.08	0.0089	92.9564	0.0001	22.000	0.0154	32.0	2.12
15		35.3	105.780	1.76	9.87	0.0380	57.4520	0.0003	27.300	0.0879	20.0	0.85
Treatment Means				***1.19***	***7.52***	***0.0171***	***82.83***	***0.0001***		***0.0369***	***29.00***	***1.33***

3.1 Weather

Based on days from start (on 20 May 2002), with the initial day as “day 0”, plots were run (in order from plot 1 to plot 15) as follows:

Day	Number of plots run
0	2
1	3
2	3
3	4
4	1
7	2

Rainfall and evaporation during the period of experimentation are shown in Figure 4. It should be noted that data are given for 24 hours to 9.00 am each day, so that data for day 0 is effectively recorded on day 1.

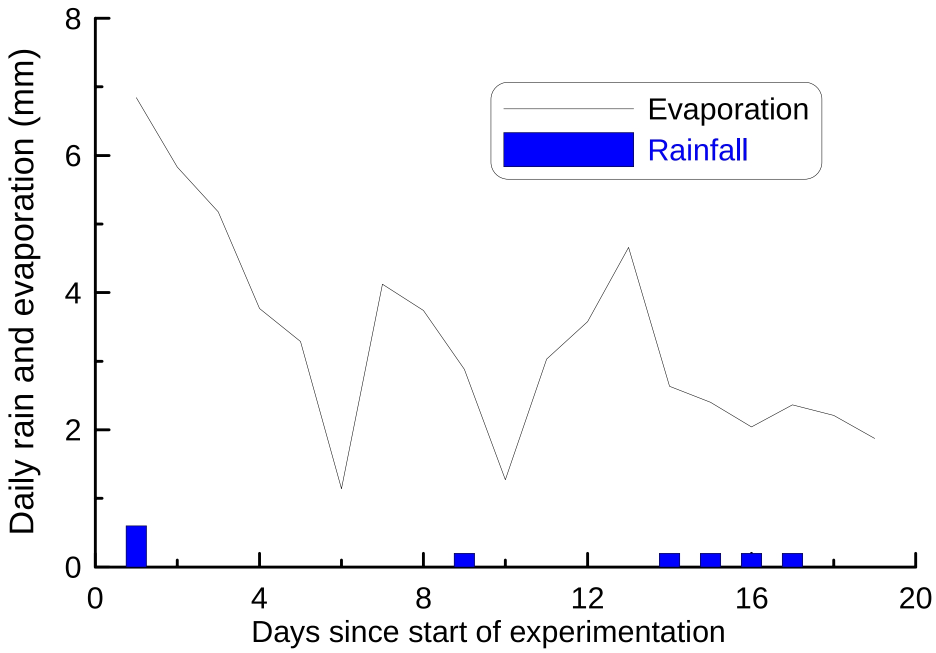

***Figure 4**: Rainfall and evaporation during the period of experimentation*

3.2 Infiltration under rain

Because of the variability in applied rain, infiltration curves were considered, and Hydraulic Conductivity values for the Green Ampt Infiltration Equation (Green and Ampt 1911) were estimated.

The Green Ampt infiltration equation calculates infiltration rate on the basis of soil water deficit and the hydraulic conductivity of the soil. Hydraulic conductivity is the parameter describing the rate at which water moves through a soil in response to an applied potential difference (soil water deficit).

The Green-Ampt equation (Mein 1980) is:

$$f = K_S \left(1 - (MS / F)\right) \qquad (1)$$

where f is the infiltration rate at the soil surface (mm h^{-1}), K_S is the effective saturated hydraulic conductivity (mm h^{-1}), M is antecedent moisture deficit (volume/volume), S is wetting front suction (mm), and F is the cumulative depth of water infiltrated (mm).

The Green Ampt infiltration equation was fitted to the data to estimate final hydraulic conductivities (K_f values). The approach used was similar to that outlined by Silburn and Connolly (1995) of fitting K_f to estimate the final infiltration rate correctly. Initial conductivity was assumed to be the same as K_f as it was assumed that surface sealing would not occur on the plots, which should be correct for at least those plots protected by a hydromulch layer. Whilst the equation fitted the data reasonably well for some plots (Figure 5), other plots (Figure 6) showed a poor fit for initiation of runoff. (Fitting to final infiltration rate is taken to be the highest priority.)

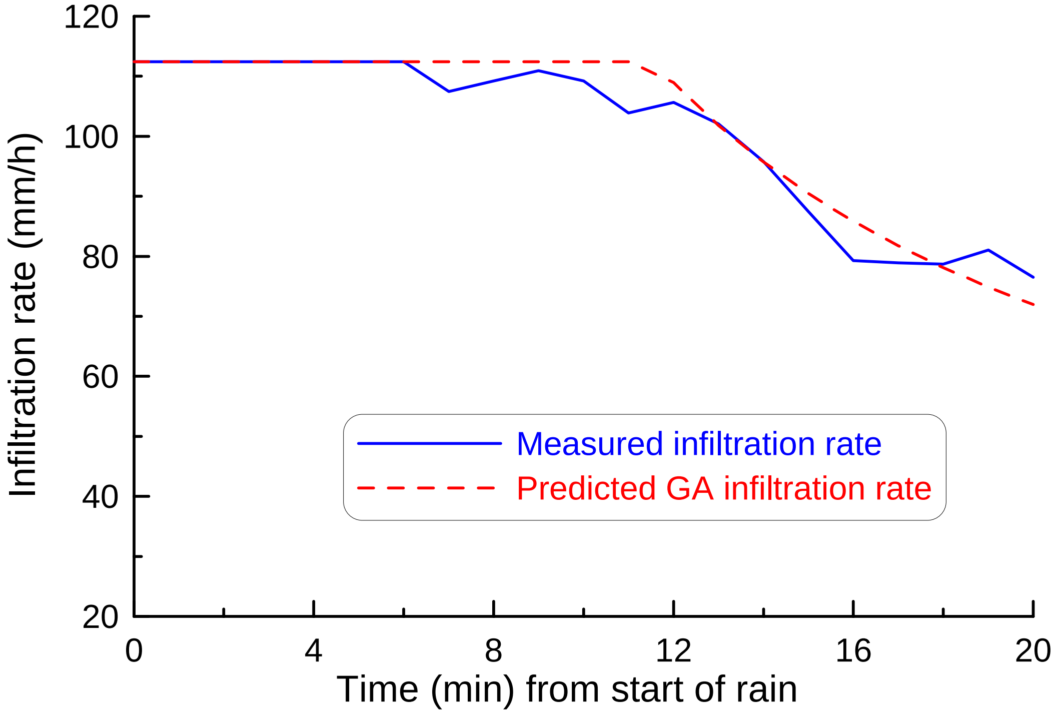

Figure 5: *Green Ampt Infiltration fitted to data from plot 2*

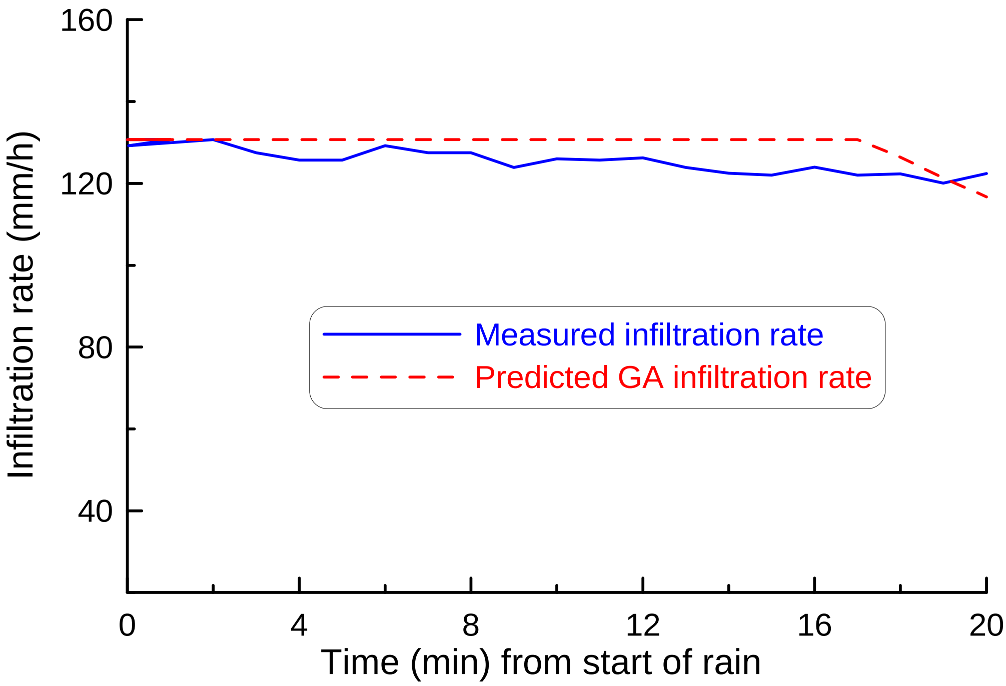

Figure 6: *Green Ampt Infiltration fitted to data from plot 7*

A "book value" of suction at the wetting front was taken as 350 mm (for a clay loam), and moisture deficit was based on measurements of initial soil water contents and bulk density.

Estimated hydraulic conductivities were quite variable (Table 2), and statistical analysis showed the following treatment means and their ranking (treatments with different letters being significantly different, P<0.05):

Control	18 mm/h	a
Paper	25 mm/h	ab
Flax plus paper	26.3 mm/h	ab
Sugar cane	29 mm/h	b
Flax	32 mm/h	b

Effectively, there was no significant difference between any of the hydromulch treatments. Improved hydraulic conductivity should be largely due to surface protection from raindrop impact, and this effect should have been similar for all the hydromulches.

However, only some of the hydromulch treatments had significantly higher hydraulic conductivity than the control plots.

3.3 Erosion by rainfall

To avoid effects of variations in rainfall intensity and plot gradient, runoff/erosion data from the plots under rainfall-only were analysed using a Modified Universal Soil Loss Equation (MUSLE) (Onstad and Foster 1975). The MUSLE calculates erosive potential as a factor W, which is based on rainfall erosivity, peak runoff rate, and total runoff. It also uses factors to account for slope gradient and length, cover, etc.

In this instance, soil loss ratios were calculated for each plot. These are the ratio of erosion from a covered area to erosion from a bare area, and are, effectively, Cover factors.

The data showed significant differences between blocks, indicating some concerns with identification of significant differences. Treatment means of soil loss ratios and their ranking (treatments with different letters being significantly different, $P<0.05$) are as follows:

Control	1	a
Paper	0.204	b
Flax	0.149	bc
Flax plus paper	0.044	cd
Sugar cane	0.037	d

These ratios indicate, on average, 80-85% reductions in erosion by Paper and Flax treatments, and approximately 95% reductions in erosion by Flax plus paper and Sugar Cane treatments.

3.4 Erosion by overland flow

The smaller flow (0.15 L/sec) applied to blocks 1 and 2 was clearly too small to have any significant impact on erosion, and was extremely slow to reach the downslope ends of some plots. For that reason, data for the 0.45 L/sec flow were used for comparison of treatments, and the data for the lower flow were discarded from statistical analysis.

To attempt to discriminate between treatments, for block 3, flow rates of 0.45 and 1.0 L/sec were used. However, the control plot on block 3 was so heavily eroded by the 0.45 L/sec flow that the second flow could not be applied to it. None of the hydromulched plots in block 3 showed any “mulch breakdown” under the high (1 L/sec) flow, indicating that all hydromulch treatments would give adequate erosion control on quite long slopes. That flow would be equivalent to 100 mm/h runoff from a slope 24 m long.

Sediment concentrations in the 0.45 L/sec flow showed large variation between the Control plots, with the plot in block 3 showing a very high concentration of sediment in overland flow (Table 2). Reasons for the variation include:

- presence of root material in the surface of one of the control plots, which would have given it considerable resistance to erosion by flow, and

- differences in surface disturbance/compaction, with some plots possibly being disturbed to greater depths. Observations suggested greater compaction at depth for the Control plot in block 3, resulting in ponding of water in the surface layer, positive pore water pressures, and greatly increased erosion potential.

Data were log-transformed for statistical analysis, and treatment means of sediment concentrations and their ranking (treatments with different letters being significantly different, $P<0.05$) are as follows:

Control	127.18	a
Paper	9.33	b
Flax	5.03	bc
Flax plus paper	2.23	cd
Sugar cane	1.33	d

Interestingly, rankings and relative effectiveness of the hydromulches in reducing erosion are similar for rain-only and rain plus overland flow situations. It can therefore be inferred that the results obtained are applicable to a reasonably wide range of slope lengths and situations.

3.5 Water contents in the soil surface following rain

Water contents of surface soil (0-25 mm layer) were sampled on each plot over a period of 11 days following application of rainfall and overland flow.

Because plots were wetted on different dates, and evaporation rates following wetting were not identical across plots (Figure 4), soil water contents were plotted against cumulative evaporation since wetting, rather than against time. The data (Figures 7 and 8) showed two separate drying patterns.

All plots showed a large decrease in surface soil water content over the first 3 days after wetting, but following that period, treatments with good surface cover (Paper, Flax plus paper, and Sugar Cane) showed no significant decrease in soil water content for the rest of the monitoring period (Fig. 7). Some data actually suggested slight increases in surface water content due to light rain (0.2 mm/day) that fell towards the end of the monitoring period for some plots, and those data were deleted from the data used in statistical analysis.

In contrast, the plots with complete or partial surface exposure – Control and Flax treatments – showed not only the initial rapid decrease in soil water, but also a subsequent steady decline in soil water content (Figure 8).

Based on those observations, it was concluded that it would be reasonable to compare the treatments on the basis of the average water content of the soil surface layer during the period of “steady” water contents. (Whilst not strictly applicable to the Control and Flax treatments, the rate of change during the “steady” periods for those two treatments was still not great.) A T-test was used for comparisons, and the results are shown in Table 3.

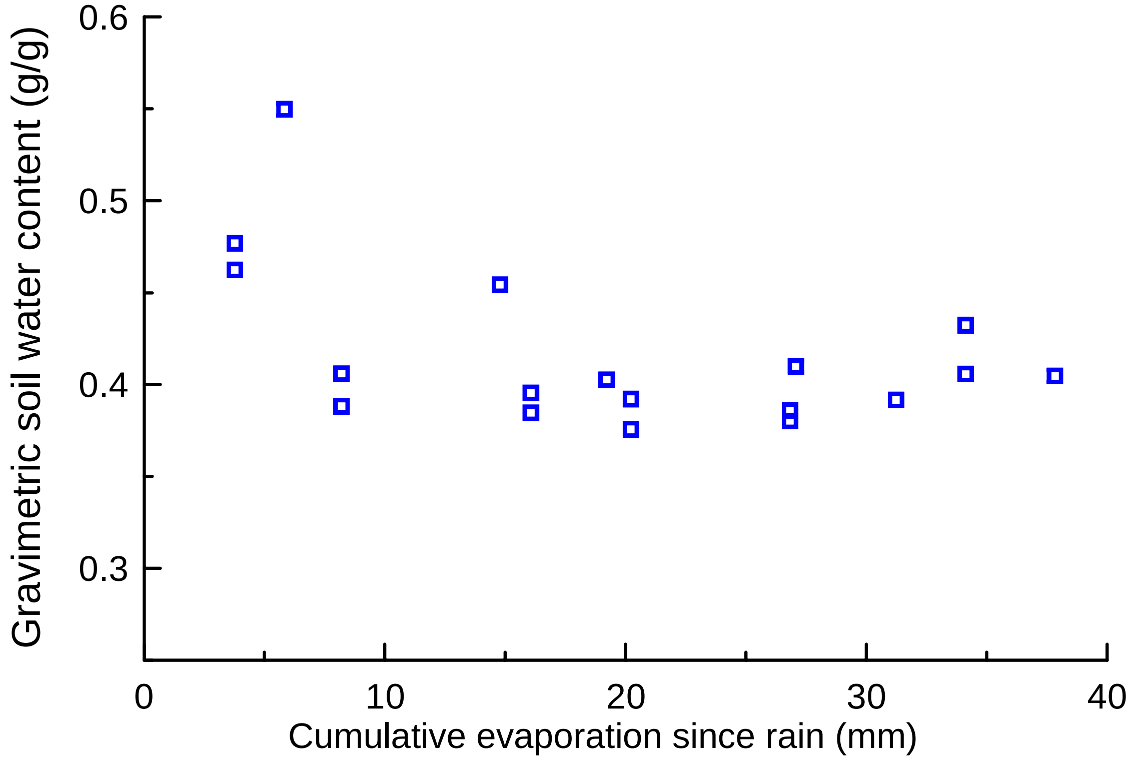

***Figure 7**: Water content in the surface 25 mm in the 11-day period following wetting for the Flax plus paper treatment (data for all 3 replicates shown).*

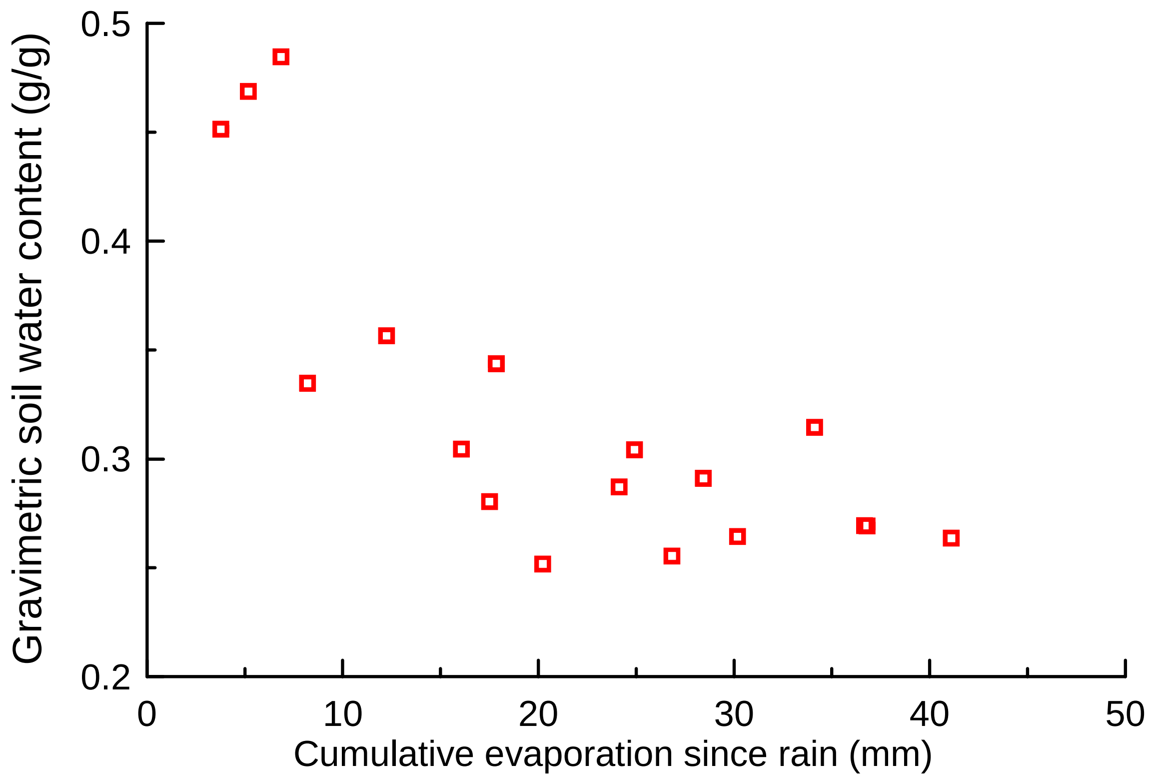

***Figure 8**: Water content in the surface 25 mm in the 11-day period following wetting for the Control treatment (data for all 3 replicates shown).*

***Table 3**: Effects of treatment on average water contents of surface soil during the 11-day period after rain, and statistical differences between treatments.*

Treatment	Average water content (%)	Standard Deviation	Significant differences [A]
Sugar cane	41.3	2.52	a
Flax plus paper	39.4	1.10	b
Flax	38.2	2.18	bc
Paper	36.5	2.09	c
Control	29.0	3.29	d

A: Treatments significantly different ($P<0.05$) are indicated by different letters

The analysis shows that:

- surface water contents for the Control treatment lay in a considerably lower range than all other treatments
- Although the Flax treatment showed a decline through time whereas the Paper treatment did not, surface soil water contents for the Flax treatment lay in a slightly higher range than for the Paper treatment
- Standard Deviations were generally quite low, so that relatively small differences in treatment means could be shown to be significantly different
- The Flax plus paper and Sugar Cane treatments, whilst significantly different, showed a difference of only 1.9% water content, and for all practical purposes could be considered similar.

It is perhaps surprising that the Paper treatment should rank lower than the Flax treatment, and the data appear to confirm observations by people in the hydromulch industry that Paper hydromulches promote surface drying by providing continuous pores from the soil to the atmosphere, whereas the other mulches tended to provide a barrier to evaporation.

The effectiveness of the barrier to evaporation created by vegetative mulches no doubt varied across the Flax, Flax plus paper, and Sugar Cane treatments, with surface soil water contents being consistent with mulch application rate and therefore, mulch layer thickness and completeness of surface coverage (highest for Sugar Cane, lowest for Flax). From this it appears that for Flax, Flax plus paper, and Sugar Cane, the results reflect differences in the rate of application rather than showing any inherent benefit of either type of vegetative mulch over the duration and scope of this experiment.

4.0 Conclusions

In general, the data showed all the hydromulched plots (as a group) to be considerably different to the Control plots. Differences between the various hydromulch types were relatively small in comparison.

Across all the variables considered, the Paper hydromulch ranked consistently as the least satisfactory, generally being significantly poorer than Flax plus paper and Sugar Cane treatments.

For most variables, Flax plus paper and Sugar Cane were not significantly different, and ranked as the most satisfactory of the hydromulch treatments.

The data for soil surface drying post-wetting suggest a functional difference between the Paper hydromulch and the various vegetative mulches, with the latter group being more effective in maintaining surface soil water content after rain. However, at this stage, it appears that the slight differences in soil water content observed between Flax plus paper and Sugar Cane hydromulches are more a function of application rate than of mulch type.

Therefore, it is concluded that vegetative hydromulches using materials such as Flax and Sugar Cane are optimal, provided application rates are adequate. From the data, it appears that rates in the order of 5 t/ha may be needed to achieve best results.

Further research would be needed for proof of the proposition, but it is likely that lower rates of hydromulch could be satisfactory if spatial variability in application rates could be reduced.

5.0 Recommendations

In addition to being a valuable marketing and management tool for the commercial companies involved this study has highlighted the need for further research in the area of hydromulch effectiveness.

The authors would like to highlight the following immediate possibilities:

1. The effectiveness of all the mulch covers is obviously effected by the application rate – comparative assessments at various rates would be beneficial in defining optimal rates;

2. The rate required is likely to be soil type and slope dependent and again experimentation could be undertaken to allow site optimized application recommendations;

3. The process of site risk assessment in relation to providing hydromulch application recommendations needs to be validated again in order to provide optimized management/hydromulch application recommendations; and

4. The performance of the mulches over time is critical – further rainfall simulation assessment at 6 or 12 months would be useful in understanding the impact of the breakdown process on erosion management.

6.0 Acknowledgments

Site access, site preparation, and application of three of the hydromulch treatments were provided by Jimboomba Turf Company Pty Ltd, who also provided logistical support with access to water and power, and carried out some of the necessary soil water content sampling.

The Sugar Cane treatment was applied by Evergreen Power Seeding Pty Ltd.

The weather station used was provided by the National Centre for Engineering in Agriculture, University of Southern Queensland.

Field rainfall simulator operations were carried out by Tim Loch and Cameron Vacher of Landloch Pty Ltd.

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APPENDIX: Observations of the hydromulch treatments

Sugar cane treatment

Flax treatment, showing exposure of soil following application of overland flow

Flax plus paper treatment

Paper treatment