REPORT ON AN EROSION AND REVEGETATION INVESTIGATION AT WAN CHUK YUEN, PAT HEUNG AND K.A.R.C., NEW TERRITORIES, HONG KONG

R.D. Hill

Reader in Geography

Research Fellow, Kadoorie Agricultural Research Centre

University of Hong Kong

March 1993

Abstract

This Report first sets out the objectives, methods and the first year of results of a study of surface erosion at a grass- and fern - land site in the New Territories H.K., as well as directions that the experiment will take in future. The study covers only erosion by surface wash, since this is more or less continuous. Three separate methods, erosion-pin measurement, splash-trap (near-ground) collection to measure sediment mobilization, sediment-trap (ground-level) collection were employed to compare estimated levels of erosion on four 6 x 20 m paired plots. In each pair, on slopes matched for soils, slope-angle, shape and orientation, one plot was maintained uncut and the other was cut annually. Towards the end of the first year a pair of burnt plots, also 6 x 20 m, was added to the experiment. Results suggest that on uncut plots only small amounts of sediment are mobilized and that rapid regeneration of the vegetation on the cut plots, following a 'burst' of sediment after cutting, results in similarly low levels of sediment mobilization and movement.

The second part of this Report details the objectives, methods and results of an experimental oversowing of rough grassland at the Kadoorie Agricultural Research Centre with the tropical legume *Stylosanthes scabra*. Since native grasslands produce dry matter of generally low quality, especially in protein and fat, oversowing was attempted using low-cost methods involving no or minimal tillage in order to minimize soil disturbance on sloping sites. Sowings were into grassland either undisturbed, initially slashed before sowing and initial slashing combined with maintenance slashing. Since none of these treatments proved successful, high-rate sowing in contour furrows followed by maintenance slashing was employed and this proved successful in establishing *Stylosanthes* stands.

Part One - Erosion Study

Introduction

It is commonplace knowledge that the bareing of the soil surface, whether by fire, tillage or clearance of the vegetation, results in most circumstances in an increase in sediment yield by surface wash and possibly, though the evidence is much less clear, also by slope failure in the form of mudflows and landslides. Nye and Greenland, for example, reported the annual loss from a small plot of tropical forest with 12-15% slope of about one tonne per hectare. By contrast a similar plot of 7-8% slope under bare fallow lost some 113 t/ha (Nye and Greenland, 1960, 87). By contrast they noted rather small losses where grass was closely planted (Nye and Greenland, 1960, 89). A great number of subsequent studies have confirmed that sediment yields from bare slopes tend to be in the range of one to three orders of magnitude higher than under forest or other closed-canopy vegetation. In Hong Kong, Shen (in Lam 1978, 55) has reported that soil loss from a barren slope was about a hundred times greater than from a similar pine-covered slope. Where crops or natural regeneration rapidly cover the soil a short-lived 'burst' of high sediment yield occurs, followed by a reduction to levels which may be similar to or slightly higher than those under the original closed vegetation. There is also some evidence, reviewed by Lee (1985, 9), that deforestation leads to enhanced rates of slope failure and consequently enhanced delivery of sediment to the drainage. However, direct measurement of such enhanced yields deriving from slope failure requires long periods of observation given the highly periodic nature of such failures and this has not been attempted here.

In the Hong Kong situation it is possible that slopes under grass and fern have became stabilized to that circumstance given the long history of deforestation. Early descriptions of

Hong Kong Island and the adjoining New Territories suggest that many slopes were already in grass and fern with scrub and low forest in the valleys by the middle of the nineteenth century (Hinds and Bentham, 1842; Seemann, 1852-57). Many also bear the scars of landslides as well as of sub-parallel lineaments or terracettes which may be a residuum of the cultivation of sweet potatoes or other dry-land crops. But as to the details of deforestation, cropping and burning on specific slopes virtually nothing is known. Consequently it has been necessary to take the condition of the slopes studied as a 'given'. One thing is certain however, similar slopes are widespread in the southern China region although in Hong Kong burning frequency may be higher than in some other parts of the region. The practice of cutting phytomass, mainly for fuel, has largely been abandoned in Hong Kong although substantially persisting elsewhere. The study site is thus broadly similar to grass- and fern-land in the region generally.

Objectives and Methods: Introduction

The basic objective was to compare the amount and rate of sediment production directly from slopes (rather than delivery to and transportation by streams), either vegetated or cut-over once a year. The terms under which the site (on Crown land) was used precluded the erection of any structure so that capture of the expected large amount of sediment at the slope foot was impractical. (This method has the major advantage of producing absolute data for erosion rates though it may create problems of sampling of the large quantities which may be produced). The methods employed were thus designed to provide relative rather than absolute measures.

A further objective was to employ low-cost, replicable methods which required minimum materials and labour. The latter precluded the use of a portable erosion measuring frame such as that used by Lam whose 15-month study of two badland and one forested catchment in Hong Kong generated about 79 000 point measurements (Lam, 1977, 322).

The study site was chosen to be reasonably near road access to facilitate the transportation of equipment and sediment samples. Two pairs of rectangular 6 x 20 m plots were initially laid out with the contours lying as near as possible parallel to the short axis. Each plot in a pair was matched by eye in terms of vegetation cover, slope angle and slope shape. Since one plot in each pair was an uncut control and since the dense cover of grasses and *Dicranopteris* fern masks the microtopography it was impossible to be absolutely sure that each plot of each pair was exactly matched. Two surveyed transects of each plot (except Plots 4 & 6 which remain unsurveyed) were made and the levels below arbitrary datum points were marked on the ground. Following the fortuitious hill-fire of 4-5 November 1992 (which threatened one pair of experimental plots, fortunately protected by fire-breaks) the opportunity arose to set up two further 6 x 20 m plots on the burnt area.

The width of the plots, 6 m, was chosen arbitrarily to allow the setting up of erosion pins, which double as sampling points for the estimation of coverage, at two-metre intervals, one metre in from the edge of the plot. The length of the plots, 20 m, was chosen to fit the slopes concerned. It was expected that ridge-tops would produce little sediment so that the plots were laid out approximately 2 m below the crest of each slope. Consequently the long axis of each plot encompassed only the straight mid-section of each slope, avoiding both the near-crest convexity and the very sharp concavities, virtual breaks-of-slope, at the slope-foot.

Mean slope-angles, from two transects, are given in Table 1.

Table 1 Mean Slope-angle by Plot

		Angle (°)*
Pair A:	Plot 1, control, uncut	14
	Plot 2, cut 29/1/92	15
Pair B:	Plot 3, control, uncut	26
	Plot 4, cut 13/3/92	to be surveyed
Pair C:	Plot 5, burnt 4-5/11/92	25
	Plot 6, burnt 4-5/11/92	to be surveyed

*to nearest degree

Geologically, the plot sites are not uniform. Plots 1 & 2 are mapped as being on Upper Jurassic granodiorite whereas Plots 3-6 are mapped as being on Jurassic-Cretaceous tuff. However, field examination and subsequent laboratory analysis (of texture) showed that in terms of texture, structure and depth the soils at all plots are very similar with the major exception that the soils developed at Plots 1 and 2 contain some boulders. However, since the study is concerned with surface phenomena there is no reason to believe that differences in geology would influence results.

In order to minimize trampling of the vegetation, no detailed contouring of the plots has been attempted though this remains an option to be carried out at the end of the study.

The vegetation history of the pairs of plots is not accurately known except that Pair A had been burnt in February 1988 and Pair B in 1990 with Pair C having been burnt on 4-5 November 1992 as noted earlier. Both cut plots 2 and 4 were in grass and *Dicranopteris* fern with a very small quantity of woody vegetation in plot 2 and a slightly higher proportion (estimated by eye) of fern in plot 4 than in plot 2. These plots were clear-cut on the dates shown in Table 1 when they had respectively 47.8 kg (398 g/m^2) and 40.7 kg (339 g/m^2) of total dry matter.

Method for Long-term Estimates of Erosion

Since the experiment will produce better results the longer it is continued, given that annual and seasonal rates of erosion are unknown for grassy uncut and cut slopes, some means of allowing estimates of erosion for up to ten years or longer was necessary. Lam's and Cheng's work on granitic badlands elsewhere in Hong Kong as well as other studies in badlands (Lam, 1977, 324) suggested that annual rates of slope-wash from bare slopes on sandy soils (65-75 per cent sand) would be in the range 1.5-2.5 cm/yr. It was expected, in the present experiment, that the cut plots would remain substantially bare for the first three or four months following cutting, which in indigenous practice is usually timed for the dry season, roughly late September to early March. Consequently, with a ten-year time-frame and allowing for the expected diminution in the rate of erosion following revegetation of the cut plots, it was decided to use the relatively crude (and relatively cheap) erosion pin method.

Though this method is known to be liable to significant errors, including operator error and measurement error it was felt that using 30 evenly-spaced pins (i.e. a systematic sample) with a four-fold replication of the measurement of each pin (i.e. once at each cardinal point of each pin), to give 120 measurements per plot for each round of observations, reasonably satisfactory results would be obtained provided that care was taken to measure to the top of the litter, allowing it to be compressed by the weight of the steel ruler employed. To have removed the litter would, of course, have possibly accelerated sediment production while retaining it necessarily leaves the method vulnerable to a further possible source of error from seasonal variations in the thickness of litter at the base of each pin. Scour at the base of each pin is also a possibility, a source of error that can be reduced, where the eroding surface is bare, by using a removable ring placed over the pin at each measurement (see, for example, Hill, 1966, 20). Since the cut plots revegetate and the control plots are vegetated, this was not an option.

Each pin was a simple mild steel rod, 1 m long, diameter 10 mm, painted for protection, inserted into the soil to distance of a least 40 cm and until it was firm. (The soil in Pair A proved to be rather stoney and two pins could only be hammered in to about 30 cm). Since long-term soil creep was expected to rotate the pins downslope by an unknown amount a vertical insertion was used rather than one normal to the slope since rotation from vertical would be expected to reduce the standard deviation of the set of four measurements of each erosion pin (see Figure 1). Finally, the objective was to estimate erosion for the whole of each plot while retaining the option of using the data derived from individual pin measurements for more detailed analysis such as down-slope variation in erosion rates, if they proved sufficiently sensitive to detect such variation. Based upon earlier work and upon casual observation of plots cut by farmers in Guangdong it was expected, incorrectly as it turned out, that erosion pins would provide an adequate centimetre-scale measure of long-term erosion. One hundred and twenty (30 x 4) separate measurements at each plot for each round of observations were expected to be adequate and were within budget.

Method for Estimation of Mobilization of Surface Material by Rain-splash

The work of Lam (1977, 320) and many others suggests that slopewash material is commonly mobilized by both rainsplash and surface flow. The relative proportions of sediment and organic matter obviously vary according to conditions at specific sites with sediment being dominant where vegetation and litter are limited, as at Lam's sites, and organic matter predominating where there is a closed vegetation. Mobilization of materials by rainsplash from bare surfaces is related also to the amount of rainfall, its intensity and to droplet size, the last usually being strongly and positively correlated with intensity. No standard method of estimating mobilization seems to exist so that any reasonable method applied to each plot could be expected to produce adequate relative results.

In the design of pans to measure mobilization of surface materials three main parameters are involved, size, shape and height. Obviously, other things being equal, a large pan will catch more than a small one though given the fact that the trajectories of large mobilized particles are quite limited a large pan may catch little more than a smaller one, for the edge effect is likely to be substantial. Shape is thus also important. A long, narrow catcher is likely to catch more than a round or square catcher having the same surface area though this is likely to apply only in still air conditions which are rare at the site. Height is a crucial parameter. Casual observation and Lam's work (1977, 320) suggested that splash from bare surfaces would deposit mobilized sediment to a height of at least 20 cm but obviously a catcher with sides so high would trap just a small proportion of the material and then only the finest. On the other hand a pan with very low sides, while catching more material, might also result in the removal of already-caught material by splash directly into the pan. It was also felt desirable that some means of avoiding over-topping of the pan be provided for the reason that at high rainfall intensities with much material being mobilized some material, especially fines, would be lost. Consequently each trap was fitted with a funnel on the one side with a Whatman 42 ashless filter paper carefully stuck into it. Testing on a bare soil surface in a rain-chamber demonstrated that the pans could cope with a rainfall intensity of at least 800 mm/hr without overtopping. The pans were not fitted with a gauze over the catching surface to exclude possible wind-borne organic matter. Since fairly frequent removals of the catch were expected the catch was expected to be quite small. The use of an excluding gauze was thought both to be time-consuming and to introduce possible errors in ensuring that any sediment adhering to it was washed off and incorporated in the measured catch. Failure to exclude such wind- and rain-borne material may be something of a design error but is partly compensated by the fact that at each plot two traps were mounted at 60 cm above ground level, well above reported or observed levels of splash, in order to obtain a measure of error introduced by wind-borne material not mobilized by splash.

In the event square traps, made of plastic, fitted with a filter-funnel, were employed. The catcher area was 160 cm^2 and the height 7 cm, the exact dimensions being dictated by the availability of sandwich boxes which were then modified by fitting a filter. These were set out at ground level in a row of five pans, equidistantly down the centre of the long axis of each plot, wire pins being used to hold them in place. As mentioned, two additional pans in each plot were set out to catch wind- and rain-borne materials, their catch to be used as a 'deflator' of the ground-level catch.

The total catch of each pan was oven-dried in the K.A.R.C. laboratory (48 hours at 70°C) after decanting any retained water in the field via the filter fitted to each pan. Large pieces of organic matter were removed on the ground that they were unlikely to have been mobilized by splash. The total weighed catch was then ignited in a muffle furnace for 12 hours at 400°C and again weighed. While this procedure may somewhat over-estimate the amount of organic matter present in the total catch (because it drives off, amongst others water of constitution in soil particles) it is quick and easy compared with 'wet' (chemical) methods as well as being a long-established standard method.

Method for Estimation of Mobilization of Surface Materials by Surface Wash

As was mentioned earlier, a condition of use of Crown land for the experiment was that no structure be erected. Equally, the site was at least potentially open to uncontrolled visits by the public which raised security concerns (though in fact no evidence of such visits has been seen). These considerations severely limited the choice of methods to trap sediment moving over the soil surface. The use of a slope-foot apron feeding into a receptacle with appropriate catch-splitters to reduce the catch to manageable proportions, though standard, was thus not feasible in the circumstances. Consequently a simple sediment trap of the type used by A. Young (in litt.) was designed and installed. This consisted of a 3.8 l (1 U.S. gallon) tin-plate oil-can with the upper side cut lengthwise about one-third across its width and bent through a little less than 180° to form an apron. The edge of the apron was then securely attached and sealed to the soil surface to allow sediment-bearing water to enter and be retained in the body of the tin. The cap of the tin was pierced to allow the drainage of water and this was screwed down onto a glass-fibre filter (Whatman GFD). The tin was thoroughly painted before installation in a small pit carefully cut in the soil to receive it.

Experimentation before installation showed that the design could cope with substantial overland flow and observation of the 'water-mark' inside the trap has shown that no trap has been overtopped. In order to minimize the possible inadvertent catch of sediment mobilized by splash, over each trap a metal splash-protector was installed at a height of about 30 cm. This was substantially larger than the sediment-trap with at least a 20 cm overlap all round but was not built larger for fear that typhoon winds might more readily dislodge it. (In the event, no protector was dislodged by wind during the first year of observations).

At each plot four traps were installed en echelon and equidistantly down the slope. The total catch was removed using a brush and scoop aided by a hand-pump if especially wet. The material was air-dried if necessary and then oven-dried and ignited as for the catch of the splash-pans previously described. However no organic matter was discarded since it could not have directly fallen into the trap and could only have been blown in or washed in by surface flow.

Since surface flow, and consequently the amount of sediment, was expected to increase downslope there was a need to ensure as far as possible, that no trap intercepted flow directly upslope of another, lower, trap dictated both the number and the staggered (en echelon) spacing of the traps. Moreover, installation inevitably meant some disturbance of the soil and the possible creation of a source of sediment though care was taken to remove excavated material and thoroughly to tamp down material around the sides of the traps as they were installed in their pits.

Method for Estimation of Vegetation Cover

On the cut and burnt plots (numbers 2, 4, 5, 6) the regeneration of the vegetation was expected to affect mobilization and the yield of sediment quite substantially. No data on the rate at which grass and fernland regenerates were found. Consequently successive measurements were made on each plot, except the controls (plots 1 and 3), to estimate coverage. These were done using a standard 1 m^2 frame with nylon threads at 10 cm intervals to give 100 intersections. The frame was laid on the soil/vegetation at each of the 30 erosion pins in each plot. The number of 'contacts/no-contacts' with live vegetation directly below each grid-intersection were recorded. Thus for each plot 3 000 (30 x 100) 'contact/no-contact' observations were made from which the mean coverage was calculated. Since by convention coverage refers to coverage by living plants a 'contact' with litter was counted as 'no-contact'. There was a further reason for adopting this practice in that the litter, especially on the steeper slopes, was expected to be very mobile so that to lump both litter and living materials could result in an anomalous fall in coverage as litter was washed away possibly before much new growth came away. (In retrospect it is clear that a four-fold classification of cover should have been adopted - bare soil, litter, standing dead, living - since the three last categories all represent cover of different kinds. See 'Discussion')

Timing of Observations

As the experiment began early in 1992, various problems arose - manpower, materials, weather, other commitments - which prevented the simultaneous initiation of all observations, but by March some measurements were being made on all four plots initially set up. Since erosion occurs during rain it was decided to time the sediment-trap collections following rainy periods. It was felt that a regular collection schedule was impractical since collection on a 'due-day' that happened to be wet might result in the mobilization of sediment by the trampling the observer's feet. Moreover after-rain collection would allow greater precision in linking the catch of sediment to rainfall intensity whereas within a standardized catch-period there might be several rainfall episodes of differing intensities.

The timing of splash-trap collection was more difficult. Although the mobilization of sediment by splash is obviously related to rainfall episodes, just like surface wash, prior experiment with the splash-traps suggested that low-intensity rainfall, characteristic of much spring weather, would probably not mobilize much, if any. Moreover, a very short catch-period, even if it did mobilize sediment, would not produce measurable amounts of material in the pans at 60 cm above the ground. Therefore a longer interval between collections was adopted.

Since the measurement of erosion pins and the estimation of coverage were relatively quick and simple procedures it was decided to carry these out at around the same time as the sediment collections. It had been expected that substantial erosion, including shallow rills, would develop on the cut plots (numbers 2 and 4) if sufficient high-intensity rain fell. Such development could be captured using erosion pins for which reason relatively frequent measurement was done. Since erosion pins doubled as markers for the systematic sampling of coverage the two procedures could be conveniently done together.

Results and Discussion of Erosion-pin Measurements

The results of erosion-pin measurements are summarized in Table 2 which also includes the mean standard deviation of each set of four measurements of each pin. Thus, for example, Pin 1 in Plot 2 on 13 March 1992 had a mean length of 46.9 cm, S.D. 2.5 mm; Pin 2 mean length 47.5 cm, S.D. 4.2 mm .... The mean S.D. is thus the mean of the 30 standard deviations at each site. This statistic better reflects variation in measurement than the mean standard deviation of pin heights since that statistic is influenced not only by spread in measurement but also by the spread in the actual length of the pins above the soil surface and, as has been explained already, it was not possible to insert them into the soil to a uniform distance.

Table 2 Summary of Mean Erosion-pin Heights 1992-3

Pair A - Moderate Slope

Date of observation	Days elapsed	Plot 1 control, uncut Mean Height (cm)	Mean S.D. of each pin measurement (mm)	Plot 2 cut 29/1/92 Mean Height (cm)	Mean S.D. of each pin measurement (mm)
13/14 Mar.	-	55.39	3.3	53.21	3.2
28/29 Apr.	45	55.22	2.8	53.17	3.9
22/23 June	100	55.36	3.0	53.37	3.7
25/26 Aug.	156	55.24	3.6	53.24	4.2
29 Dec.	281	55.30	2.4	53.57	2.4

Pair B - Steep Slope

Date of observation	Days elapsed	Plot 3 control, uncut Mean Height (cm)	Mean S.D. of each pin measurement (mm)	Plot 4 cut 13/3/92 Mean Height (cm)	Mean S.D. of each pin measurement (mm)
13/14 Mar.	-	44.45	4.8	40.19	3.4
28/29 Apr.	45	44.50	4.7	39.65	6.1
22/23 Jun.	100	44.47	5.0	40.09	5.5
25/26 Aug.	156	44.08	5.8	39.81	5.8
3/4 Jan	285	44.56	4.3	40.25	4.6

Thus far the data show no significant change in mean pin length which would indicate erosion - lengthening pins - or accretion - shortening pins, within the limits of sensitivity of the method. (This may be taken to be about 3 mm on the moderate slope and about 5 mm on the steep slope).

However, the detailed pin-by-pin data (not presented here) show considerable apparent erosion and sedimentation activity, some of it clearly involving more than just a few millimeters of change which might be accounted for by changes in the thickness of the litter, operator error or measurement error.

Results and Discussion of Splash-trap Measurements

It proved possible on most occasions to install new traps and remove the old ones on the same day so that the catch-period is generally the same for all plots allowing ready comparability. Results are set out in Table 3. At ground-level, five pans were installed at each site so that the means and standard deviations are for that number of observations. At 60 cm only two pans were installed. No standard deviation was calculated in that case. The percentage figure for loss on ignition is calculated from the total loss as a proportion of total dry matter. Determinations were done trap-by-trap, the samples not being bulked. However trap-by-trap data are not presented here since inspection shows no readily-observable pattern - which may nevertheless exist and be revealed by yet-to-be-performed statistical analysis.

Overall, at ground-level and at 60 cm, each splash-pan trapped some measurable quantity of dry matter though in some cases the amount was only a few hundredths of a gram. At ground-level the dry-matter catch on the cut plots was strikingly higher only during the first catch-period, 32 days to 28 April. Unfortunately, for logistical reasons, that period did not coincide exactly with the period which elapsed since cutting on plots 2 and 4, the former having been cut on 29 January and the latter only on 13 March. It seems likely, therefore, that dry matter mobilization peaks soon after cutting and rather rapidly falls thereafter so that the only consistent pattern is one of rather small mean catches, less than

Table 3 Summary of Splash-pan Measurements 1992-3

Date of catch removal	Catch-period (days) rainfall (mm)	Plot no.	Level (on/above soil)	Mean total catch per pan (g)	S.D. (g)	Mean loss on ignition per pan (g)	S.D. (g)	Mean loss on ignition per pan (%)	Mean residue per pan (g)	S.D. (g)
Pair A - Moderate Slope										
28 Apr.	32	1	G	0.40	0.45	0.18	0.04	44	0.23	0.44
	343	2	G	2.14	2.21	0.74	0.58	34	1.41	1.93
		1	60	0.09	-	0.08	-	89	0.01	-
		2	60	0.11	-	0.09	-	86	0.02	-
23 Jun.	56	1	G	0.28	0.18	0.19	0.12	69	0.09	0.11
	694	2	G	0.58	0.47	0.14	0.07	24	0.44	0.41
		1	60	0.11	-	0.05	-	41	0.06	-
		2	60	0.03	-	0.02	-	67	0.01	-
25 Aug.	63	1	G	0.84	0.50	0.76	0.47	90	0.08	0.03
	908	2	G	0.29	0.20	0.21	0.19	70	0.09	0.02
		1	60	0.13	-	0.12	-	89	0.02	-
		2	60	0.26	-	0.07	-	28	0.19	-
31 Oct.	68	1	G	0.44	0.19	0.36	0.19	82	0.08	0.02
	170	2	G	0.33	0.31	0.27	0.29	81	0.06	0.02
		1	60	0.14	-	0.08	-	54	0.07	-
		2	60	0.11	-	0.06	-	55	0.05	-
4 Jan.	65	1	G	0.53	0.23	0.47	0.23	89	0.06	0.03
	83	2	G	0.23	0.11	0.21	0.11	91	0.02	0.02
		1	60	0.04	-	0.02	-	57	0.02	-
		2	60	0.04	-	0.02	-	63	0.02	-

Pair B - Steep Slope

28 Apr.	32	3	G	0.31	0.14	0.20	0.06	65	0.11	0.09
	243	4	G	5.00	2.77	0.90	0.46	18	4.10	2.36
		3	60	0.11	-	0.10	-	91	0.01	-
		4	60	0.12	-	0.09	-	75	0.03	-
23 Jun.	56	3	G	0.72	0.77	0.21	0.11	29	0.50	0.76
	695	4	G	0.92	0.16	0.16	0.06	17	0.77	0.16
		3	60	0.05	-	0.03	-	67	0.02	-
		4	60	0.46	-	0.06	-	12	0.41	-
25 Aug.	63	3	G	0.57	0.18	0.43	0.10	75	0.14	0.11
	908	4	G	0.31	0.17	0.16	0.01	51	0.15	0.16
		3	60	0.06	-	0.04	-	67	0.02	-
		4	60	0.21	-	0.08	-	38	0.13	-
31 Oct.	68	3	G	0.66	0.25	0.57	0.27	85	0.49	0.10
	170	4	G	0.46	0.42	0.36	0.41	79	0.48	0.10
		3	60	0.17	-	0.06	-	65	0.11	-
		4	60	0.19	-	0.14	-	74	0.05	-
4 Jan.	65	3	G	0.68	0.35	0.59	0.35	87	0.09	0.02
	83	4	G	0.32	0.20	0.28	0.19	88	0.04	0.05
		3	60	0.03	-	0.02	-	67	0.01	-
		4	60	0.04	-	0.03	-	71	0.01	-

\- indicates that the standard deviation was not calculated (only two splash-pans).

one gram, in which random factors may be responsible for the variation observed.

Some reasons for a sharp peak of dry matter mobilization may be suggested. Obviously cutting not only produces considerable amounts of organic matter (about 400 g/m^2) not all of which is raked up, but it also allows sunlight to penetrate to the soil surface, drying it out and perhaps reducing aggregate cohesion. The trampling of workers may also break down surface aggregates. At the same time, it seems likely that the removal of most of the vegetation - only cut stems remain - may substantially increase the wind-speed in the soil-surface boundary-layer and wind removes some of the now dry and easily-transportable litter and debris not raked up when cutting. Evacuation by wind and downslope washing of organic matter especially, combined with possibly enhanced rates of decay following cutting, may account for the substantial and rapid decline in catch. However, a further major factor must be the rather rapid regeneration of the vegetation. On Plot 2 coverage was measured at 59 per cent 90 days after cutting. On Plot 4 the coverage was 40 per cent after 40 days (see Table 7). These factors are likely to explain the substantially lower total catch on the cut plots from late June to early January (Table 4).

Fall in the total ground-level catch with time, despite substantial rainfall, is paralleled by a change in composition of the catch. Initially, organic matter, as measured by loss on ignition, formed a relatively small proportion of the total catch, especially on the cut plots (numbers 2 and 4). But this situation changed through time as is shown in Table 4.

Table 4 Changes in Total Catch in Splash-pans and Proportion of Loss on Ignition through Time (Pooled Data) 1992-93

	Date	Catch-period (days)	Plots 1 & 3 (uncut) Total catch (g)	LOI (%)	Plots 2 & 4 (cut) Total catch (g)	LOI (%)
Ground-level (10 traps)						
	28 Apr.	32	3.57	53	35.72	23
	23 Jun.	56	4.99	40	7.49	19
	25 Aug.	63	7.03	84	3.02	60
	31 Oct.	68	5.51	84	3.92	80
	4 Jan.	65	6.01	88	2.76	89
60 cm (4 traps)						
	28 Apr.	32	0.90	90	0.45	80
	23 Jun.	56	0.31	48	0.98	15
	25 Aug.	63	0.37	84	0.93	32
	31 Oct.	68	0.62	60	0.60	67
	4 Jan.	65	0.13	62	0.15	67

In contrast to the fairly clear pattern of change through time in the quantity and composition of the ground-level catch, the catch at 60 cm was, expectably, rather small. The total catch arises from both rain-borne and wind-borne materials and may be something of an under-estimate since the relatively exposed location of the pans at 60 cm above the ground could render them liable to have the caught material evacuated by wind subsequent to its having been caught. No clear pattern of results emerges though the uniform fall of the amount during the 65-day period to 4 January may reflect the relatively dry conditions then prevailing. Certainly it cannot be suggested that variations in the catch may be explained by the fact that two plots were cut and two uncut. Obviously there is no reason why catch in such locations should vary for that reason.

A further question is whether or not the pan-by-pan data, not reported here, show any association between catch and location of the catcher on the slope. This requires statistical analysis but inspection tentatively suggests that there is no such association. Indeed only if the amount of material available for mobilization by splash varied in some manner on the slope, for example by deposition downslope or the pattern of vegetation regeneration, might catch vary other than randomly.

Results and Discussion of Sediment-trap Measurements

The ability of splash to mobilize material is directly related to both the availability of detachable material at the surface upon which it falls and to the vegetative cover. Surface wash by contrast, may occur regardless of the nature of the cover being related to rainfall intensity, surface permeability, the absorptive capacity of the soil and the degree to which it is already wet. (Vegetative cover, of course, has an indirect influence on soil characteristics via the litter). At the study site the soils are notably sandy being apparently derived from granodiorite (Plots 1 & 2) and tuff (Plots 3 & 4) of Mesozoic age. Plots 1 & 2 contain boulders, many small ones and a few large ones outcropping at the surface. Wash is thus likely to be limited to periods of high rainfall intensity when the soil is close to saturation. The results of the sediment-trap measurements are set out in Table 5. Unlike the splash-trap measurements, the amount of sediment caught was expected to increase downslope, especially as the traps were installed en echelon so as to attempt the catching of any stream of entrained sediment from the whole of the slope upwards of the point at which the trap was installed. However, spatial analysis of the results remains to be done.

Table 5 Summary of Sediment-trap Measurements 1992-93

Date of catch removal	Catch-period (days)	Total rain-fall (mm)	Plot no.	Mean total catch per trap (g)	S.D. (of 4 catches) (g)	Mean loss on ignition per trap (g)	S.D. (of 4 catches) (g)	Mean loss on ignition total (%)	Mean residue per trap (g)	S.D. (of 4 catches) (g)
Pair A - Moderate Slope										
20 July	7	449	1	10.79	5.93	1.42	0.62	13	9.37	5.39
			2	60.17	46.28	9.87	7.88	16	50.30	38.49
24 July	4	68	1	3.04	2.98	0.66	0.44	22	2.39	2.56
			2	5.15	1.57	1.15	0.37	22	4.00	1.24
30 July	6	6	1	1.32	0.48	0.19	0.09	17	0.92	0.49
			2	1.86	1.21	0.36	0.15	19	1.51	1.13
11 Aug.	12	38	1	1.57	1.58	0.29	0.30	19	1.27	1.28
			2	1.98	0.65	0.14	0.19	21	1.56	0.47
15 Aug.	4	8	1	0.66	0.21	0.10	0.05	15	0.56	0.19
			2	0.46	0.24	0.07	0.01	16	0.39	0.25
22 Aug.	7	32	1	0.39	0.27	0.06	0.05	15	0.34	0.22
			2	0.87	0.18	0.12	0.01	14	0.74	0.18
24 Aug.	2	45	1	0.91	0.36	0.08	0.02	9	0.83	0.33
			2	1.43	1.30	0.16	0.15	11	1.27	1.15
28 Aug.	4	35	1	0.39	0.08	0.07	0.04	17	0.32	0.11
			2	0.87	0.53	0.16	0.10	18	0.72	0.46
31 Aug.	3	23	1	0.62	0.40	0.11	0.07	17	0.51	0.35
			2	2.00	1.49	0.27	0.17	14	1.72	1.33
6 Sept.	6	35	1	0.43	0.16	0.07	0.02	16	0.35	0.16
			2	1.10	0.56	0.12	0.03	11	0.98	0.52

8 Sept.	2	70	1	0.42	0.31	0.05	0.04	12	0.37	0.28
			2	1.73	0.72	0.20	0.09	11	1.53	0.64
13 Sept.	5	10	1	No catch in three traps						
			2	0.30	0.27	0.08	0.05	26	0.22	0.24
17 Sept.	4	6	1	No catch in three traps						
			2	No catch in two traps						
20 Sept.	3	8	1	0.31	0.20	0.07	0.05	23	0.24	0.18
			2	0.85	0.97	0.15	0.15	17	0.71	0.83
28 Sept.	8	1	1	0.31	0.24	0.18	0.24	71	0.12	0.09
			2	0.25	0.17	0.09	0.09	38	0.15	0.08
1 Oct.	3	2	1	No catch in four traps						
			2	No catch in three traps						
28 Oct.	28	0	1	0.82	0.27	0.22	0.09	27	0.59	0.22
			2	0.85	0.46	0.17	0.12	20	0.68	0.35
4 Jan.	67	83	1	1.00	0.82	0.45	0.31	45	0.55	0.53
			2	1.94	1.04	0.48	0.25	25	1.46	0.80
Pair B - Steep Slope										
20 July	6	441	3	25.08	13.19	1.82	0.67	7	23.26	12.68
			4	80.43	39.62	6.49	3.47	8	73.98	36.12
24 July	4	68	3	3.39	0.77	0.74	0.47	22	2.66	0.90
			4	5.22	1.42	0.67	0.22	17	4.55	1.25
30 July	6	8	3	0.98	0.45	0.13	0.05	13	0.85	0.41
			4	1.00	0.07	0.18	0.05	18	0.82	0.02
11 Aug.	12	38	3	1.40	0.55	0.12	0.08	8	1.28	0.53
			4	1.05	0.35	0.13	0.03	12	0.92	0.35
15 Aug.	4	8	3	0.56	0.38	0.08	0.04	13	0.49	0.35
			4	0.30	0.20	0.06	0.04	19	0.25	0.16

22 Aug.	7	33	3	0.85	0.32	0.11	0.03	13	0.74	0.29
			4	0.59	0.34	0.07	0.02	12	0.52	0.32
24 Aug.	2	45	3	1.25	0.95	0.09	0.04	7	1.67	0.91
			4	0.61	0.29	0.05	0.01	9	0.55	0.29
28 Aug.	4	35	3	0.93	1.10	0.11	0.14	12	0.82	0.96
			4	0.38	0.18	0.19	0.08	18	0.31	0.13
31 Aug.	3	23	3	2.34	3.27	0.20	0.25	9	2.14	3.03
			4	2.03	0.72	0.22	0.05	11	1.81	0.67
6 Sept.	6	35	3	0.70	0.50	0.05	0.02	8	0.65	0.49
			4	0.45	0.15	0.05	0.02	11	0.40	0.14
8 Sept.	2	70	3	0.72	0.59	0.10	0.06	14	0.62	0.55
			4	0.41	0.14	0.07	0.06	17	0.34	0.12
13 Sept.	5	10	3	No catch two traps						
			4	No catch three traps						
17 Sept.	4	6	3	No catch two traps						
			4	No catch three traps						
20 Sept.	3	8	3	0.31	0.13	0.06	0.01	18	0.25	0.13
			4	0.51	0.64	0.13	0.17	26	0.38	0.48
28 Sept.	8	1	3	0.21	0.08	0.07	0.03	31	0.15	0.05
			4	0.15	0.07	0.03	0.01	22	0.12	0.08
1 Oct.	3	2	3	No catch three traps						
			4	No catch four traps						
28 Oct.	27	0	3	0.93	0.55	0.35	0.24	35	0.64	0.33
			4	0.41	0.11	0.13	0.07	32	0.28	0.14
4 Jan.	67	83	3	1.25	0.77	0.78	0.42	63	0.47	0.47
			4	1.52	1.04	0.66	0.23	44	0.85	0.95

Note: totals may not add up because of rounding.

The mean total catch per trap was generally higher from traps on the cut plots, as might be expected, but there were some exceptions, when the total catch was low, notably on the cut steep plot (Plot 4) in August and September, but this may be coincidental. Traps were installed just in time to catch the very heavy rain recorded at the Kadoorie Agricultural Research Centre in July. By that time the vegetation coverage on the cut plots, numbers 2 and 4, was quite similar at around 90 per cent so that it is likely that the large sediment yield recorded during that episode reflects substantial mobilization and flow there. By comparison, the uncut control plots, numbers 1 and 3, also showed a substantial but consistently lower catch. Thereafter the mean catches per trap fell away although for Plot 2, the moderate-slope cut plot, the total catch, 16.49 g, remained higher than its fellow, the uncut Plot 1 with a total catch of 9.15 g. By contrast, the catch on the steep-slope cut plot (number 4) after the episode of 14-24 July, at 9.4 g was actually less than that on the corresponding control plot (number 3) from which the total catch was 12.43 g per trap. See Figure 2 for a cumulative plot of the mean total catch per trap by plot, and rainfall (also cumulative).

As with the splash-trap catch there seems to be some change in the composition of the catch through time although the tendency is much less marked and during only one catch period did the loss on ignition exceed 50 per cent of the total catch. This result is consistent with the view that once the vegetation has substantially regenerated on the cut plots, the yield is fairly similar to that from the uncut plots. At the same time, the production of dead material from the vegetation increases as the dry season takes hold so that the rise in the proportion of the total catch lost on ignition probably reflects the increasing availability of shed organic matter as well as the limited mobilization of sediment.

Table 6 Changes in Total Catch in Sediment-traps and Proportion of Loss on Ignition through Time (Pooled Data), 1992-93

Date	Catch-period (days)	Rain-fall (mm)	Plots 1 & 3 (uncut) Total catch (g)	Lo I (%)	Plots 2 & 4 (cut) Total catch (g)	Lo I (%)
20 July	6-7*	449	143.44	9	562.39	12
24	4	68	25.74	22	36.20	20
30	6	6	8.34	15	11.44	19
11 Aug.	12	38	11.84	14	12.09	18
15	4	8	4.87	14	3.06	17
22	7	32	4.97	13	5.81	13
24	2	45	8.62	8	8.14	10
28	4	35	5.24	13	5.01	18
31	3	23	11.83	10	16.08	6
6 Sept.	6	35	4.51	11	6.22	11
8	2	70	4.56	13	8.54	12
13	5	10	No catch in 5 traps		No catch in 3 traps	
17	4	7	No catch in 5 traps		No catch in 5 traps	
20	3	8	2.47	20	5.44	20
28	8	1	2.03	48	1.57	32
1 Oct.	3	2	No catch in 7 traps		No catch in 6 traps	
28	27	0	7.18	32	5.04	24
4 Jan.	67	83	8.99	55	13.79	33

* Traps and splash-protectors installed on different days.

Results and Discussion of Coverage Measurements

The data presented in preceding Tables serve to underline the major role of the vegetative cover in reducing the mobilization of sediment by rain-drop splash and by surface wash for it is clear that only a major intense fall has much effect. Consequently data on the rate of regeneration of the cover on the cut plots are important. Unfortunately observations in the early stages of regeneration were insufficiently frequent to provide good data, regeneration having been unexpectedly rapid, probably because of unusually wet weather. Nevertheless, the estimates of live-plant cover given in Table 7 show rapid regeneration, the 40 per cent cover in 40 days on Plot 2 being quite remarkable.

Table 7 Estimates of Live-Plant Coverage on Cut Plots, 1992-3

Date	Days elapsed	Mean cover (%)	Standard deviation (%)
Plot 2, cut 29 Jan., 1992			
28 April	90	59	11.0
26 June	145	85	8.4
25 August	209	93	9.9
29 December	335	95	6.1
Plot 4, cut 13 Mar., 1992			
28 April	40	40	7.2
23 June	71	83	8.4
25 August	134	94	4.6
4 January	266	96	4.3

It is clear that crucial points in the process of regeneration were missed because of insufficiently frequent observations. In 1993 it will be important to secure observations sufficiently close together to derive regeneration curves.

General Discussion: Experimental Design

The results are generally in line with expectations, showing quite clear differences between the uncut and cut plots and, during a major episode of heavy rain - and only then - clear differences between plots on the steep slope and plots and the moderate slope. Unfortunately, the installation of sediment traps immediately prior to that episode raises a question about the total catch though not necessarily the relativities amongst the plots. Though great care was taken to avoid undue disturbance of the soil at installation and surplus soil was carried away at the time, there was possibly inadequate time for the traps to settle down before the onslaught of the wet weather. Nevertheless, pooling the data (Table 6) reduces the likelihood that variation in the amount of disturbance during trap installation has affected the results so that the comparisons a likely to be valid.

Another unfortunate occurrence is that the timing of the collection of sediment-trap catches and of splash-trap catches was not synchronized (except for 4 January). This means that no proper comparison between the catches can be made. In part this reflects the problem of determining over how long a period and under what weather conditions could a measurable catch obtained bearing in mind that very small catches are liable to variation, e.g. in the ratio of loss on ignition to total catch, arising from quite random and indeterminate causes. However, future scheduling will allow improved synchronization especially between sediment-trap and splash-trap measurements, the erosion-pins being less sensitive to delays in observation.

There is also a further motive for rescheduling. In the course of observation it became clear that the vegetation did not recover well from trampling by the observers as they collected samples. Though it will lead to some loss of precision in determining the timing of mobilization and movement of material on the slopes there is a clear need to avoid the possibly progressive opening up of the cover on the control plots by trampling and a possible consequential, but quite artificial, increase in the mobilization of material. Similarly, the measurement of cover also causes trampling with visits to 30 points on each plot, not just seven for the splash-pans and four for the sediment-traps, and these visits are concentrated at precisely that period when the vegetation is most fragile, i.e. as it regenerates. Hopefully it will be possible to use a non-intrusive method such as false-colour photography to reduce this intrusion. Alternatively, it might be necessary to cut more plots on which regeneration and that alone is measured. However, since the locations of the splash-pans and the sediment-traps is partly coterminous with the location of the sampling points for coverage, the amount of trampling would be only somewhat be reduced by adopting this alternative.

However there is a further dilemma here in that a longer period between collections of the sediment-traps and splash-traps may lead to over-topping or other loss of already-captured material. In particular, as collections from the recently-established burnt plots are added to the experiment, this could be a problem. The answer probably lies in synchronizing as far as possible all observations but sampling more frequently only on the cut and burnt plots, albeit with the possible penalty of loss of precision in timing on the control plots.

So far as the erosion-pin data are concerned the lack of short-term sensitivity inherent in the method prevents any conclusion other than a suspension of judgement until longer-term observations are to hand. Overall, what appears to happen on the cut slopes (Plots 2 and 4) is that cutting followed by rain results in the mobilization of significant quantities of sediment and organic matter, as reflected in the splash-trap and sediment-trap catches (see Tables 3-6). But only a portion is actually evacuated from the slope. On Plot 2, for example, inspection of the slope below the bottom edge of the plot in April 1992 revealed little sediment and organic matter from upslope trapped by the very dense array of in situ litter and the many stems per square meter of fern and grass. On Plot 4, the steeper slope, rather more material was found trapped in the same situation, but no more than perhaps a kilogram or two. Rather, the large number of stems, 5-10 cm in height which remain, following cutting, and incidentally the erosion pins, form the framework of a sponge-like series of structures, a centimeter or two high. Against these multitudinous stiff stems organic matter accumulates: litter, newly-cut plant debris not removed by the two successive rakings each plot was given. These sponge-like structures form what are probably rather short-lived 'micro-dams' which retain materials moving downslope. How long they do this is not known but casual observation of organic matter breakdown suggests that humification takes of the order of a year to eighteen months. But re-establishment of a closed vegetation cover takes substantially less time than this. In the atypically wet spring of 1992 both plots regained a 45-49 per cent living-plant cover within six weeks of their having been cut. Thus the micro-dams may persist for several years, the material behind them moving only rather slowly down the slope.

Two possible approaches to examine this phenomenon immediately occur. One is to mark and measure micro-dams as they form and decay. The other is to supply at the top of a slope an easily-identifiable material (ground glass?) of a texture that for preference as nearly as possible approximates the texture and particle shape of the soil and then to observe what happens to it. It is clear that significant quantity of material is mobilized and moves quite spasmodically, 'significant' being used here in a relative sense. As was expected, when slopes are less than fully vegetated erosion is marked. Otherwise it is less so. For example, following the 14-24 July high-rainfall episode the total sediment-trap catch and its composition was quite similar on uncut and cut plots alike, the cut plots in fact having by then substantially regenerated (Table 6). In terms of the total catch in splash-pans the amount on the cut plots was actually lower than on the uncut plots, a rise in the proportion lost on ignition rather than any increase in total catch reflecting regeneration of the vegetation (Table 4).

A further question is that of wind erosion, a topic thus far seemingly unresearched in Hong Kong. Data from the splash-traps at 60 cm, the observed evacuation of mainly-dead plant material from the plots as they were cut and a brief (5-day) experiment using greased watch-glasses set at heights of to 1 m, all suggest that organic matter and particulates may be removed by wind. A first step will be to make measurements of wind speed at the surface of the paired plots and to refine methods of trapping such materials since on exposed sites loss of material by wind may be significant, at least so long as the soil surface is exposed.

A fundamental question is how long should the experiment be continued. The year 1992 had an exceptionally wet spring. As measured at the Royal Observatory the period March to May experienced a total rainfall of 1336.9 mm against the mean of 545.2 mm. i.e. 245 per cent of normal. As a consequence, regeneration was probably much faster than usual (though few, if any data exist). But this, at least, may offer some approach to one extreme. Obviously a year with an exceptionally dry spring would offer another but there is no way of forecasting this. The amount and, especially, the timing of rainfall are quite variable. It will thus be important to keep the experiment going for as long as possible for the results thus far are suggestive rather than indicative.

Part Two - Revegetation

While a good cover of grass and fern is reasonably efficacious in controlling erosion, except perhaps during periods of intense rain, that cover is, itself, often has only indirect economic value, for erosion control and as a potential nursery for regenerating woodland. The latter function however, is rarely fulfilled by reason of the high frequency of fires. Even in the absence of fire it seems likely that the succession to woodland would occupy some decades. Afforestation is more rapid. In the region *Cunninghamia lanceolata* and *Pinus massoniana* have been widely used, the latter, in Hong Kong at least, being liable to devastating attack by the pine nematode *Bursaphelenchus*. From the economic viewpoint too, afforestation with quick-growing species such as those named, while ultimately giving fair returns, requires both a substantial initial outlay and a long lead-time till harvest - minimum

10-15 years for poles and more for millable timber. These characteristics suggest that alternatives may be desirable, alternatives that give quicker but sustained yields. One possibility here is the improvement of the upland vegetation as a source of good-quality fodder, especially for 'cut-and-carry', rather than merely as a source of fuel, the only economic value of which is that it is a good 'free' for the cost of cutting it and carrying it away.

Oversowing, as a means of upland pasture improvement, is a well-established technique in temperate regions such as Australia and New Zealand where the sowing, usually from the air, of pelletized fertilizer and seed is highly cost-effective. However, in monsoonal lands this approach has scarcely been attempted, possibly because of the limited place of herd animals in traditional agricultural systems. But the stall-feeding of cattle and pigs, using agricultural wastes and maize grown in the lowlands, where it competes with human food - rice - in land-use systems, is quite common. There is, contrary to some impressions, a good demand for liquid milk - especially for children and the elderly - and as stock for the manufacture of ice-cream. Pigs, of course, have long been known and used as efficient converters of material not fit for human consumption. Consequently it was decided in 1988 to attempt a low-cost approach to oversowing.

One rationale behind oversowing is that because the existing vegetation is neither cleared nor burnt, rates of erosion will not be increased by the improvement process, though if carefully done, limited tillage or burning do not necessarily result in large, and especially, to sustained increases in sediment yield. The choice of appropriate species suited to the region was somewhat difficult. No indigenous leafy legume was known to be used as fodder and legumes were a first choice given the universally-low levels of this nutrient locally. Since levels of phosphorous are also low, a species tolerant of that situation was obviously desirable. Equally desirable was good seedling vigour though any shortcoming here might be to some degree offset by profuse seed production. Even though a low-cost strategy was to be adopted, perennials were to be preferred because 'low-cost' is not 'no-cost'. The monsoonal climate of southern China is a fairly close analogue of that of northern coastal Queensland, though somewhat cooler in winter. Because the researcher had been involved with the promotion of *Stylosanthes* in Peninsular Malaysia (where it is of perennial habit), it was decided to use that genus, a native of Brazil now widely employed in Queensland where it is the basis of a significant beef industry. Subsequently, at the request of ICRISAT, the pigeon-pea *Cajanus cajan* was added since it offered some prospect of providing adequate dry-season production.

The first major choice was which *Stylosanthes*, Stylo for short. *S. gracilis* seemed likely to be insufficiently tolerant of low temperatures. While a cultivar with a low spreading habit might be expected to suppress competing natives if oversown, the fact of low seedling vigour seemed likely to place such a cultivar at a disadvantage. Consequently *S. scabra* cv. *seca* was chosen. This had already been trialled, on good nursery soils at K.A.R.C., by C.T. Wong who reported (in litt. 1988) that it made excellent growth for eight or nine months of the year but became rather woody in winter. In view of the facts that a start had to be made somewhere and that in the meantime prospective winter-peak species could be searched for it was decided to start with *S. scabra*.

Table 8 Species and Lines Trialled

Species	Source	Line
Stylosanthes scabra cv. *seca*	CSIRO	A170
Cajanus cajan (pigeonpea)	ICRISAT	11298 ICP8094 ICPL88040

Stylosanthes Experiment - Phase I

The grassland area at KARC used to lay out the 1 m^2 plots was cut during the winter of 1988-9 and by the time the first sowings were made on 1 June 1989 this had rather variably regenerated. Most of the grass was 30 cm to 1 m high. A split 3 x 2 design was adopted employing:

(a) no treatment
(b) slash to ground level followed by no further treatment
(c) slash to ground level followed by cutting of competing vegetation at (nominally) six week's intervals during the wet season (planting to early October).
(1) simple broadcast sowing
(2) sowing into cleared soil within 8 cm diameter polyurethane ring, 5 cm high, set into soil as a sowing site marker.

Seed was sown at 1 g m^2, representing the lower end of the standard sowing rate of 1-2 kg ha. Successive replicates were sown on 1 June, 1 July, 1 August and 7 September to give a total of 24 plots. Establishment was notably low on all untreated plots, no seedlings being seen on any plots by the end of September 1989. By the end of the wet season, early October, 1989 it was clear that plants with treatments (b) and (c) with both forms of sowing were well-established. During the following wet season, the plants reached a height of almost two metres, but were not cut. Slashing of competing vegetation within each plot was therefore reduced to three-monthly intervals for treatment (c).

By early May 1991, however, five plots had been inadvertently burnt by prisoners engaged to clear grass in the vicinity and a further four had been totally extirpated by the same inadequately supervised workers. However on three of the burnt plots new shoots were coming away quite vigorously from root stocks (Table 9). These, however, were subsequently submerged in a mass of new growth of indigenous grasses. At the same time the surviving plants were seeding vigorously. Phase I was continued to 1993 with results as summarized in Table 9.

Table 9 Summary of Stylosanthes Plantings as at 6 May 1991
(Pooled data from all sowings in 1989)

Treatment	Result
No initial clearance	
Seed broadcast/sown in rings (8 plots)	No surviving plants
Initial clearance only	
Seed broadcast (4 plots)	No surviving plants
Seed sown in rings (4 plots)	15 individuals, resprouting from rootstock, 10-15 cm high on 2 plots only
Initial clearance followed by weeding	
Seed broadcast (4 plots)	3 individuals, 30-50 cm high on 2 plots only
Seed sown in rings (4 plots)	2 individuals, 35-150 cm high on 4 plots

All survivors seeding vigorously.

Table 10 Summary of Stylosanthes Plantings as at 13 Jan. 1993
Pooled data from all sowings in 1989)

Treatment	Result
No initial clearance (8 plots)	No survivors, plots abandoned
Initial clearance only	
Seed broadcast (4 plots)	No survivors, plots abandoned
Seed sown in rings (4 plots)	6 survivors in 1 plot, 2 m tall, flowering
Initial clearance followed by weeding	
Seed broadcast (4 plots)	1 survivor in 1 plot, flowering
Seed sown in rings (4 plots)	14 survivors in 3 plots, flowering

The field examination in January 1993 also revealed that within one metre of the boundary of each of the eight then-remaining plots only 9 seedlings near 3 plots had established themselves, a remarkably low number given that vigorous seeding had previously been observed. It is possible, however that staff were unable to identify seedlings and that they were removed during routine clearance in the vicinity. (It is seems possible that some staff, though well-acquainted with 'normal' research station practice have difficulty in coping with the disorder inherent in oversowing experimentation).

Overall, it was clear early in 1991 that none of the no-tillage treatments was likely to be successful in providing significant amounts of quality dry-matter. It was therefore decided first to continue Phase I so long as any plants survive though it seems likely that few will. Second, it was decided to try a 'hedge-planting' approach using a high seeding-rate in furrows around which, following an initial slashing of competing vegetation, further slashing back would be done as required. At the same time, in order to mitigate the problem of low seedling vigour and competition with re-establishing natives, it was decided to use the rather high-cost approach of raising seedlings in a standard nursery soil mixture and then to plant them out on tilled patches on the hillside. With the objective of avoiding enhanced erosion and because of possible control problems, the use of fire to prepare a seed-bed continued to be eschewed. The experiment continued to Phase II.

Stylosanthes Experiment - Phase II

During the winter of 1990-91 Phase I was reviewed. While plants survived on eight of the thirteen undamaged plots, it seemed likely that the initial low sowing rate coupled with failure to cut back the plants in the spring of 1990 - for fear that they would not sprout successfully - may have led to the growth of tall spindly plants with rather little usable forage. Another reason for not cutting back in the spring was that seed was still being shed -

and vigorously. Although the Stylo competed against the indigenous plants, in the sense that it survived, it did not produce much dry matter. Consequently it was decided to adopt an alternative strategy, one involving limited tillage followed by sustained slashing of the competing vegetation. Following information that the soils at KARC were molybdenum-deficient and that an Mo response could be expected it was decided to incorporate this aspect into the wet-reason program for 1991. At the same time, following a request from ICRISAT, it was decided to make a trial with three lines of *Cajanus* (pigeon-pea) on the reasoning that it might prove to be a satisfactory crop for the dry season since it performs well - up to 10 t ha yr - in relatively dry locations (Ariyanayagam, in litt. 1991).

An initial planting of Stylo was made on 13 June 1991. A pair of double furrows 30 cm apart and 3 m long was opened up along the contour using a hoe and all vegetation within one metre was splashed to ground-level. The sowing rate was 30 g per metre of double furrow. One double furrow was sown with seed soaked overnight in 5 l sodium molybdate solution and the other sown with seed soaked in 5 l tap-water, the solution and water being applied with the seed. The initial strike was excellent and by mid-November seedlings were so vigorous as to form a dense hedge and to suppress the regrowth of native vegetation. A further pair of 3 m double rows was also planted to *S. scabra* cv. *seca* under the same conditions on 9 July.

By late November 1991 the first double-row pair, planted 13 June showed good growth but the Mo-treated now showed clearly-inferior growth with plants only 10-15 cm high compared with 20-40 cm high for the tap-water seed. Growth of the other double-row pair was, however, beginning to be suppressed by the vigorous growth of native vegetation since, contrary to instruction, this had not been regularly cleared. However, some damage by wild pig and/or deer, which have free access to the site, led to the conclusion that it would be unwise to continue planting until protection could be ensured. This was a serious set-back in that while in many areas in southern China these animals exist in the wild, their numbers are normally kept down by vigorous hunting, an activity prohibited by law in Hong Kong.

However the good growth and vigour of the hedge-planted Stylo continued through 1992 though with minor weed problems. Some seed set during the 1991-2 dry season was clearly washed downslope and seedlings established themselves on a plot cleared and cultivated for a pigeon-pea experiment. One hedge, however, was 'accidentally' cut in December 1992 and it will be important to note how well regrowth from the root-stocks occurs. No further damage by pigs/deer has been noted and it is likely that an electric fence will be installed by early in the 1993 wet season to provide protection.

The experimental transplanting of Stylo seedlings raised in the nursery was less successful. One hundred polybagged seedlings in each of two cleared and hoed plots were planted at 30 cm spacing in May 1991. The seedlings were 50 cm tall at planting and for unknown reasons, possibly excessive nitrogen, simply elongated, in some cases to 2 m, without branching. They will be cut in spring and will continue to be watched to see if they survive but basically this high-cost approach failed and will not be repeated.

Pigeon-pea Experiment

Pigeon-pea was selected as an appropriate legume for its capacity to supply both human food and fodder - up to 10 t/ha/yr at ICRISAT, Pathancheri, India - as well as the fact that it is deep-rooting and adapted to moderately dry conditions such as are typical of the Hong Kong dry season. Soils in the region appear to contain sufficient clay for them to hold water in the top 30 cm for some time after the onset of the sunny dry season in late September or early October, though no soil-water budgets appear to have been published - at least for Hong Kong. It was expected to perform reasonably well provided the soil was initially tilled. The fact that nothing was known of its resistance to fire or to its regeneration after fire was an additional motive for trial. The lines trialled were ICP 11298, ICP 8094, and 88040.

Two plots were 5 m wide were cleared, hoed and sown on 2 July and 3 September 1991 respectively. Seed was soaked overnight either in a warm sodium molybdate solution (see previous description of a suspected Mo deficiency) or in tap-water and sown at a depth of 2-3 cm at a rate of 20 g/m of contour furrow. The planting pattern was a double furrow for each line, one being Mo treated and the other not, each furrow 30 cm from its neighbour and the double furrows being 1 m apart. The initial strike was poor and some rows soon showed pig and/or deer damage.

A survey of the plots on 22 November 1991 showed the following (pooled data):

Table 11 Summary of *Cajanus cajan* Plantings as at 22-11-91

	Line	Result
11298	Mo-treated	no survivors
	Not Mo-treated	8 survivors
8094	Mo-treated	22 survivors
	Not Mo-treated	27 survivors
88040	Mo-treated	2 survivors
	Not Mo-treated	no survivors

It is clear that 8094 is the superior line but the growth subsequently has been extremely poor. In the rows occupied by this line a few struggling survivors remained at the end of 1992 but none was more than a metre high. However, *Cajanus* should be persisted with, preferably on another site, while attempts are also made to find reasons for its poor performance. The site may simply be too damp, although on sandy loam with a slope of about 8°. In any case observation should continue so long as there are surviving plants.

<u>Discussion</u>

In respect of *Stylosanthes scabra* the oversowing experiment established several basic points which may be listed:

1) Low seedling vigour renders establishment by any of the low-cost no-till systems tried very problematic.

2) Although vigorous seeding occurs, the progeny do not survive in significant numbers since self-seeding is effectively equivalent to simple broadcast sowing which provenly does not work for the reason given in 1).

3) Transplanting is high-cost and ineffective offering no real solution to the problem of low initial vigour, unless a specific, superior raising and transplanting technique can be devised.

4) The poor foliage growth and woodiness of Stylo in the dry season is confirmed.

5) 'Hedge' sowing at high rates in simple contour furrows, followed by the slashing of competing regrowth nearby, as required, is promising, at least in the first two seasons. New foliage growth in spring appears to keep pace with competing regrowth. In the first season the space between the furrows of each pair was almost entirely free of competing weeds.

6) The long-term persistence of oversown Stylo appears to be limited but it may persist better in hedges, especially if they are harvested.

Future Activities

Further work with Stylo will focus on a number of specific areas. In the short run additional trials of 'hedge' sowing are needed, preferably on burnt-over areas in which regeneration of the natives is expected to be slower than where they are merely slashed down. Experiments should continue on slashed areas since these pose only limited erosion risks. The trial should aim to create Stylo hedges along the contour which, in the first wet season will be separated by bands of slashed native vegetation. In the second or subsequent season such bands may be removed and planted to Stylo ultimately to create a continuous cover of Stylo. The same approach can be used on burnt-over land, where however, it is desirable to use contour plantings of Vetiver to control run-off and erosion. Indeed, on a burnt area at Wong Chuk Yuen a start has been made with a contour planting of Vetiver at 1 m vertical interval in mid-January 1993. Between the Vetiver hedges, contour furrows were planted with Stylo and Cajanus in February. Further plantings through the wet season are envisaged. Since the *seca* cultivar is now obsolete a more modern one will be used.

Another short-term line of approach is to investigate the introduction of *Rhizobium* with the seed. *Rhizobium* is known to improve yields of a number of tropical legumes. At K.A.R.C. Griffiths has unsuccessfully attempted to isolate this organism from existing Stylo. Since a commercial source of both improved Stylo and an inoculant have been identified it will be an easy matter to begin a simple split experiment using or not using the inoculant and comparing results.

In the longer run two problems remain - low seedling vigour and possibly lack of persistence in field conditions. Dr H. Corke is keen to investigate the former. This will require some additional expenditure for equipment and consumables. Details are set out in Appendix B.

The substantial need for an appropriate dry-season fodder producer points towards the desirability of continued work on *Cajanus cajan* despite the poor results thus far. A possible reason for the failure of the sowings in 1991 was the use of warm water to pre-treat the seed. This will not be done in future. Since fully-grown *Cajanus* forms a tall shrub or low tree it would seem appropriate to combine it in contour-furrow planting with Stylo, also contour-furrow planted. Indeed a beginning with such experimentation has already begun at the Wan Chuk Yuen hill-fire site, burnt in November 1992. There an initial planting of Vetiver grass was made on 18 January 1993 the slips being set out 10 cm apart in single rows on the contour at a one-metre vertical interval. The purpose of this was to control surface wash on a slope on which little regeneration of the native vegetation had taken place - only about 5% live-plant cover at the time. Between the contour-rows of Vetiver two rows of *Cajanus* have been sown in a contour furrow, lines 11298 and 88040, along with a row of Stylo. The sowing rates were 5 g/m for *Cajanus* and 2.5 g/m for Stylo. These plantings will be extended through the 1993 wet season.

At K.A.R.C. a similar line of approach will be adopted but without plantings of Vetiver since slopes are more gentle and no native vegetation has been burnt. This will involve slashing down the vegetation, planting Stylo and *Cajanus* in double contour-furrows as described earlier. One imponderable continues to be possible damage by wild herbivores.

At K.A.R.C., which is reasonably secure from public intrusion, an electric fence will be installed to protect the site but this is less feasible at Wong Chuk Yuen.

So far as the erosion study is concerned, the main aim will be to keep it running for as long as possible, given the considerable variation in the amount and timing of the rainfall. There is little prospect of extending it to cover erosion by mass movement. Slope failures are extremely erratic in their occurrence and there is the major and serious problem of establishing an appropriate base-line, for example, the 'natural' rate of failure in forested terrain. In any case, given the (still very-tentative) results of the current experiment, there is no reason to believe that annual harvesting of phytomass would lead to a higher incidence of slope failures than on slopes not harvested or slopes which are burnt. Certainly in practical terms the question cannot be investigated experimentally.

However, a wider but very much related issue remains. This is the question of upland - lowland nutrient transfers. Interviews with farmers and researchers in the region suggest that the transfer of nutrients via irrigation water is deliberately facilitated by the burning of grass, scrub and fern on the hillsides which form the gathering-grounds for such waters. Burning, where frequent, appears to lead to accelerated erosion, especially on granitic terrains widespread in the region. Certainly it inhibits forest regeneration. In the next several decades it seems likely that demands for the reduction or cessation of upland burning will increase. This is so for several reasons. First is the spread to the general populace of the realization that excessive sedimentation in the lowlands has very large costs, borne by the population as a whole. Second is that lowland agriculture seems to have reached a production plateau beyond which it will be technically difficult and possibly economically impossible, under free market conditions, to advance. Third is that the permanent withdrawal from agriculture of significant areas of lowland, as a result of industrial, urban and infrastructural development, will not only place the remaining lowland areas under severe pressure to increase production but will increasingly require the development of high-yielding, sustainable agricultural and forestry systems in the uplands That will require the retention in the hills of as much nutrient as possible. It has been suggested, for example, that in wet-rice cultivation, as much as two-thirds, though usually less, of the nutrients comes from the irrigation water rather than the soil. Thus it will be important to establish the importance of the addition to such waters of nutrients released by hill-fires. Proposals for such a study, to be carried out mainly by M.R. Peart, hydrologist, and A.W. Jayawardena, hydrological engineer, are currently with the University of Hong Kong authorities.

References

Hill, R.D., 1966, 'Changes in beach form at Sri Pantai, northeast Johore, Malaysia, Journal of tropical geography, 23, 19-27.

Hinds, R.B. and Bentham, G., 1842, 'Remarks on the physical aspect, climate and vegetation of Hong-Kong, China', London Journal of Botany, 1, 476-494.

Lam, K.C., 1977, 'Patterns and rates of slopewash on the badlands of Hong Kong', Earth surface processes, 2, 319-332.

Lam, K.C., 1978, 'Soil erosion, suspended sediment and solute production in three Hong Kong catchments', Journal of tropical geography, 47, 51-62.

Lee, W.Y., 1985, 'A review of vegetative slope stabilisation', Journal of the Hong Kong Institution of Engineers, 13(7), 9-21.

Nye, P.H. and Greenland, D.J., 1960, The soil under shifting cultivation, Commonwealth Agricultural Bureaux, Farnham Royal.

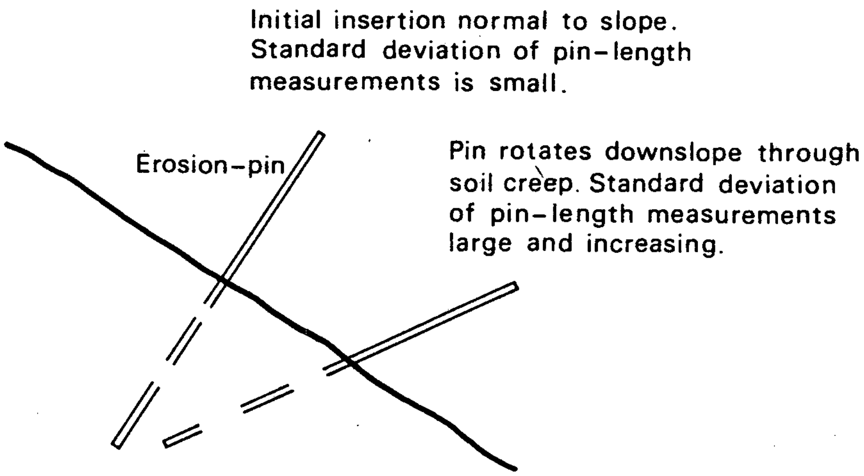
Seemann, B., 1852-57, The botany of the voyage of H.M.S. Herald under the command of Captain Henry Kellett, R.N., C.B., during the years 1845-51, Lovell Reeve, London.

Acknowledgements

The assistance of the Director, Kadoorie Agricultural Research Centre, University of Hong Kong, his deputy and their staff are gratefully acknowledged. The erosion study is supported by a grant from the Universities and Polytechnics Grants Committee while the revegetation study was supported by the Hui Oi Chow Fund.

Able field and laboratory assistance was provided by Chen Rongjun, Guan Dongsheng, Andrew Benton and Mervyn Peart.

<u>Appendix A</u>



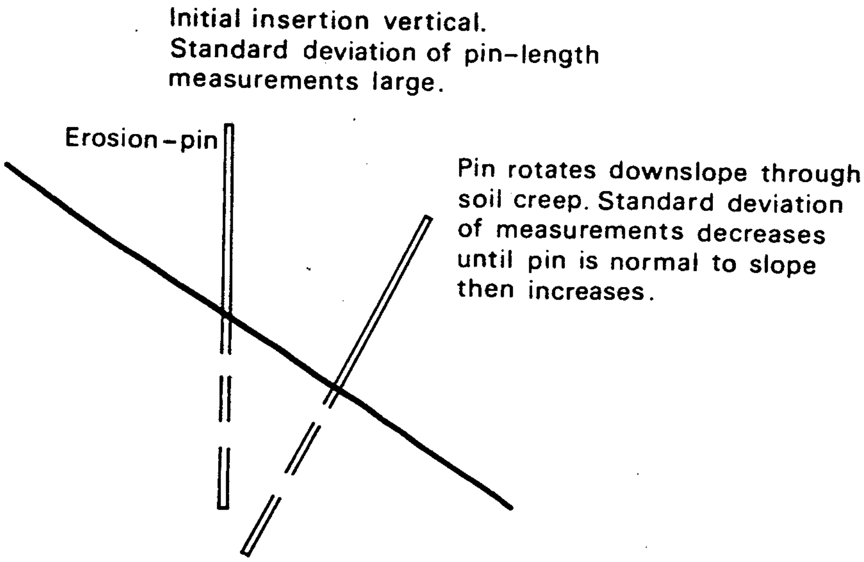
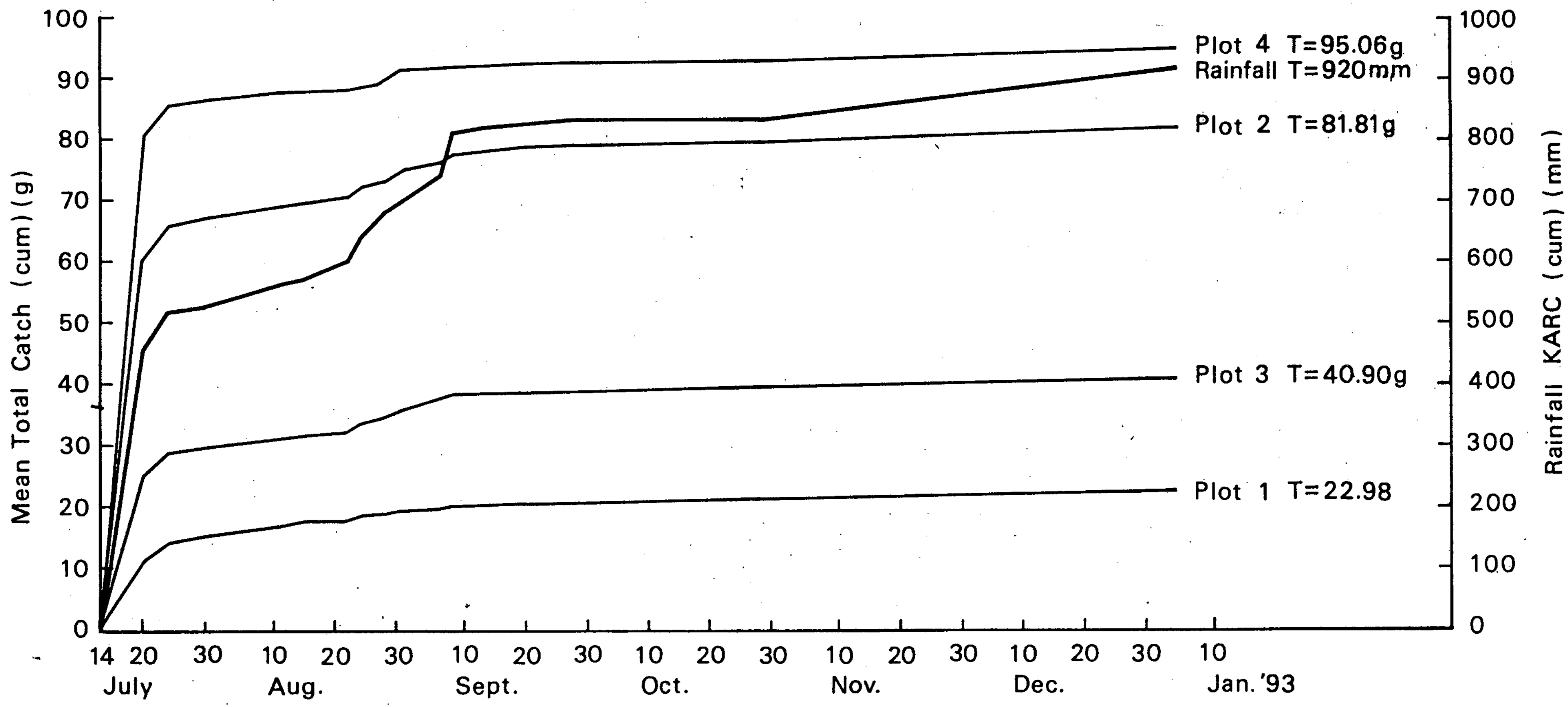


Figure 1

Figure 2 MEAN TOTAL CATCH (DRY WEIGHT) PER TRAP AND RAINFALL (CUMULATIVE)

JULY '92 - JAN. '93



Appendix B

Research Proposal for Immediate Implementation

Dr H. Corke

Department of Botany

Inter-species competition and seedling vigor in the establishment of Stylosanthes in upland pastures in Southern China

Aim-purpose:

A barrier to the success of *Stylosanthes* in improving pasture quality in Southern China is the high competitive ability of some native grasses and broadleaf plants. This project aims to 1) to determine allelopathic interactions and growth rate variation in *Stylosanthes* genetic material affecting its competitive success against native species; 2) assess the potential of chemical growth suppressants to control grass growth prior to establishment of *Stylosanthes*.

A small stock of seeds for some 104 lines of *Stylosanthes* has been obtained. Before further work can be undertaken it will be necessary to multiply this stock for which purpose the following budget is proposed.

Budget	HK$
Controlled germination cabinet	48,000
Casual labour	12,000
Pots, soil, fertilizers & sundries	12,000
	72,000