SOIL EROSION

IN

SOUTHERN CHINA

R.D. Hill

Introduction

The broad dimensions of Chinese "man-land problem" are well-known. Though great strides have been made in controlling population growth, using draconian measures of family limitation, the population continues to grow at around 1.2 percent per year. With some 22 percent of the world's population on just seven percent of the world's arable land there is no question that the land itself is under severe pressure. According to Leeming, who warns that data may be less than fully accurate, the per-person extent of arable land fell from some 1800m^2 in the 1950, through 1100m^2 in the 1970s to about 900m^2 at the present time (Leeming, 1994, 83). However, given that the total area of arable land, some 96 million ha in 1989, has been estimated to be falling by around 366 000 ha a year in the early '90s, it seems that a per-person arable land area of only 650m^2 estimated for the year 2000 is of the correct order (Edmonds, 1994, 156; Leeming, 1994, 83).

R.D. Hill is Professor of Geography, Department of Geography & Geology, University of Hong Kong, Hong Kong.

The question of whether the land can sustain continued growth and at what standard of living has recently attracted the attention of senior Chinese scientists. As summarized by Edmonds (1994, 156) their analysis suggests that the land can support about 950 million people "at a good standard of living", a figure already exceeded by 200 million. The current predictions are that the population will peak at 1500-1600 million between 2020 and 2030 if the current stringent population controls are maintained, though without them, that peak could well be reached before 2015. That level of population, it is thought, represents the number that can be fed and kept warm at a low standard of living and then only if the country pushes its resource base to the limit.

As a means of outlining the broad context in which erosion problems exist a crude balance-sheet can be drawn up. On the credit side are the following:

- a significant structural transformation is under way, involving privatization of agriculture, growth in manufacturing (though many uneconomic state-owned enterprises remain), rapid expansion of foreign trade and some growth in internal trade (though that is still hindered by weak infrastructure and bureaucratic rigidities).

- government are firmly committed to growth and to the infrastructural expenditures necessary to facilitate that growth.

- government are committed to foreign participation in the growth process.

- foreign debt is low and readily serviced by foreign trade earnings.

- inflation is under reasonable control though farmers, especially these producing significant produce for purchase at low, state-controlled quota prices are currently caught in a severe "cost-price squeeze" which has seen a substantial increase in the cost of inputs without matching increases in the prices they receive.

- modest average levels of income exist, levels at least two to three times higher, in terms of purchasing power, than indicated by G.D.P. figures, though very marked and increasing regional and rural-urban disparities exist.

On the debit side of this national balance-sheet can be placed the following:

- Continued large, though not rapid population growth, growth which may accelerate as families succeed in avoiding control measures, or, if they are not majority Han people, are not subject to those measures.

- an estimated 200 million workers could be withdrawn from the labour-force without depressing production.

- continued growth in the number, though not the proportion of farmers, and they are, on the whole, poorer and more heavily taxed (both formally and by differential pricing) than their urban counterparts.

- limited land resources (36 percent of global average on a per-person basis).

- limited forest resources (13 percent of global average on the same basis).

- limited water resources (25 percent of global average on the same basis).

- rapid loss of prime arable land not fully compensated for by reclamation.

- loss of arable land unable to be compensated by increased intensity of production for reasons of climate, or water-supply, because intensities are already high in many areas and because farm-level production is close to the maximum under current technical and economic conditions (e.g. rice at six tonnes per ha per crop).

- reduction in land-use intensity as parts of families migrate or are drawn into rural industries, petty trade or urban employment (e.g. areas within reach of coastal 'economic boom zone').

- severe soil nutrient loss (estimated to be equivalent of some 40 million tonnes of fertilizer annually, roughly the same as annual production).

- soil erosion seriously affects between one-sixth and one-third of the arable land and, despite strong efforts, is increasing in extent and severity.

- there is no national-level upland development policy nor any specific government organ responsible though local and regional organizations research upland problems.

- only half of the provinces have farm-extension services of any kind and their activities, where they exist, generally do not extend to upland areas unless, as in Hainan and parts of mainland provinces in the southwestern region, they produce high-value or strategic commodities (e.g. rubber).

- with the demise of the commune system and substantial privatization of rural production no formal mechanism now exists to enforce conservative management of upland areas.

- while the state Council directs that cultivated lands steeper than 25° are to be progressively taken out of production and returned to forest or to animal husbandry, actual performance has been extremely limited since farmers cannot afford the risks of such a transition nor can government supply food to facilitate it.

- local, provincial and national governments succeed in collecting no more than about half of the revenues due to them.

- the economic returns to the investment of the revenue surplus are seen to be greatest in the burgeoning economies of the coastal provinces.

Soil Erosion and Land Use

The "balance-sheet" presented above could doubtless be substantially added to but it does at least indicate something of the broad and complex matrix within which soil erosion and its amelioration must be considered. In the body of the paper the focus is narrowed to some of the specifics of soil erosion in the region, one which has only recently begun to attract scientific attention much of which has hitherto been directed to such major problems as desertification in the semi-arid lands of the north-west, the peculiar problems of managing land use on the Loess Plateau or the question of the proposed Three Gorges Dam. Yet the south, with its semi-tropical climate, high rainfall (mostly 1500-2500 mm per year), high rainfall intensity, variable, but mostly highly erodible soils once the vegetative cover is removed, has seen significant erosion problems emerge. Edmonds (1994, 161), for example, notes that soil erosion in Sichuan is now four times what it was in the 1950s and indicates the existence of serious soil erosion in areas such as Yunnan, Hainan and Fujian. Hill (1992) and Watters and Hill (1991) in their reports on Guizhou province, where 70 percent of the land is limestone, note significant and increasing rates of erosion leading in extreme cases, to total removal of the soil down to bedrock. Wõlke and his collaborators (1988, 110) note the loss of 80 000 ha of agricultural land annually in the Jialing Jiang Basin of Sichuan. Chen Chaohui (1993, 139) has indicated that data for the ".... nine provinces in South China show the area of soil erosion increased from 60 000 km^2 in the 1950s to 170 000 km^2 in the 1980s. The soil erosion index in the 1950s was 100-300 t/km^2/yr but grew to 300-600 t/km^2/yr in the 1980s. The highest erosion rate reached was at least 1000-2000 t/km^2/yr ...". That level, in fact, is nothing spectacular for Watters (in litt. 1993) has reported levels of 50000 t/km^2/yr near Bijie, northwestern Guizhou.

The remainder of the paper focusses upon this region, drawing together recent published literature (in English), presenting preliminary results of a current investigation being made by the author and his colleagues at the University of Hong Kong, making some comparisons with other experiments in Southeast Asia and concluding with some remarks on management. Discussion is confined exclusively to the relationship of land uses to surface erosion and yield since reports on the incidence of mass movement as related to land use are extremely scanty. (One such is Peart, 1992).

Table 1 sets out a compilation of reports of land uses, erosion and, for some, runoff. Most of the data presented refer to plot studies since, except in very small catchments, land uses are rarely uniform. (Reference to "whole-basin" studies is made in the Bibliography). Parenthetically, it should be noted that the contribution of mass movement to total sediment yield may well be substantial. Luo and Li (1993, 91) for example, report that in the Jian River basin of southwestern Guangdong, a total area of 9 464 km^2, 490 km^2 is "seriously eroded" of which, in turn 234km^2 were landslides - 2.5 percent of the total area. Similarly, Ong (1993, 67) reported at least 50 landslides each at least 10m deep in shale terrain in an area of only 4.8 km^2. It is well-known, as Sidle and Terry (1992, 289) note, that areas cleared of forest are most susceptible to landsliding about two to twelve years after cutting. While few "age-specific" data on forest clearance are available, it is clear that it is substantial and recent. (See, for example, Wöhlke *et al.*, 1988). Similarly, systematic study of the incidence of rilling and gullying as related to land management practices scarcely exists though Li *et al.* (1994) and the University of Toronto and Guangzhou Institute of Geography (1987, 1988) present useful data on the subject.

Table 1 Land Use, Erosion and Run-off Southern China

Land Use	Location	Erosion $t/km^2/yr$	Run-off (mm)	Source
Forest & Woodland				
Forest	Hainan	2.7	n.s.	Jiang, 1993, 61
	E. Hainan	6.2	98	Feng & Song, 1993, 65
	Hainan	1.8	17	Xu Deying, 1993, 72
	Xishuangbanna	6.3	99	Xu Zaifu, 1993, 131
	Xishuangbanna (17° slope)	4.2	68	Feng Yao-zong, 1986, 238
China fir	Dejiang, Guizhou (27-28°)	187	13	Yong & An, 1992, 467
'Woodland'	Hainan	10	n.s.	Jiang, 1993, 61
Planted Eucalypts and crops, wet season - maize & soy, dry season - vetch	Luodian, Guizhou 16-27°	4168	235	IBSRAM, 1992, 5
Cultivation				
'Shifting cultivation land'	Hainan	3210	n.s.	Jiang, 1993, 61
'Slash & burn'	Hainan	543	n.s.	Jiang, 1993, 61
Upland rice	E. Hainan	4860	3395	Feng & Song, 1993, 65
'Shifting cultivation'	Hainan	3125	1072	Xu Deying, 1993, 72
Shifting cultivation	Xishuangbanna	4890	3395	Xu Zaifu, 1993, 131
'Cropfield'	Xishuangbanna (17°)	5471	163	Feng Yao-zong, 1986, 238

Ploughland	Dejiang, Guizhou (27-28°)	1785	39	Yang & An, 1992, 467
Pineapples	Longhai, Fujian			Zhu, 1990, 377
	5°	750	n.s.	
	10°	7350	n.s.	
	15°	9300	n.s.	
	20°	15950	n.s.	
	25°	21300	n.s.	
Wet season - maize & soy, dry season - vetch	Luodian, Guizhou 16-27°	5757	237	IBSRAM, 1992, 5
As above but alley crop with *Tephrosia* & *Coronilla* hedges	Luodian, Guizhou 16-27°	4664	238	IBSRAM, 1992, 5
Rubber & tea	E. Hainan	209	206	Feng & Song, 1993, 65
Rubber	E. Hainan	265	293	Feng & Song, 1993, 65
Rubber & tea	Xishuangbanna	224	206	Xu Zaifu, 1993, 131
Rubber	Xishuangbanna	269	283	Xu Zaifu, 1993, 131
Rubber & tea	Xishuangbanna (17°)	7.6	13	Feng, 1986, 238
Rubber	Xishuangbanna (17°)	25.7	19	Feng, 1986, 238
Tea, terraced, cover-crop	Taoyuan, Taiwan (10°)	124	n.s.	Lo, Chiang & Tsai, 1992, 1214
Oranges, bahia grass, cover	Nantou, Taiwan (11-13°)	167	n.s.	Lo, Chiang & Tsai, 1992, 1214
Grazing, pangola grass	Tainan, Taiwan (20°)	245	n.s.	Lo, Chiang & Tsai, 1992, 1214

Scrub/Grass				
Grassland	E. Hainan	258	288	Feng & Song, 1993, 65
Shrubs & grass	Dejiang, Guizhou (27-28°)	243	19	Yang & An, 1992, 467
Cultivation-abandoned 3 years	Dejiang, Guizhou (27-28°)	199	12	Yang & An, 1992, 467
Fern (single storm 68 mm rain)	Deqing, Guangdong ($10m^2$ plot)		litres	Univ. Toronto *et al.* 1988, 81
100% cover		n.s.	1.2	
75% cover		n.s.	42.2	
50% cover		n.s.	79.4	
25% cover		n.s.	176.7	
0% cover		n.s.	699.4	
Other				
Soil kept bare	Luodian, Guizhou 16-27°	10632	374	IBSRAM 1992, 5

Notes 1) Many of the original reports fail to give details of slope, rainfall, soils, or, for shifting cultivation, the year or years of the cultivation cycle to which the data refer.

2) The data of Xu Deying (1993) are clearly in error by two orders of magnitude, probably as a result of faulty 'translation' from the Chinese system of counting to the Western one. They have been corrected here.

3) Data have been converted into the measures used here as required.

Discussion of Recent Studies

Adequate discussion of the studies summarized in Table 1 is hampered more than a little by the lack of detail provided in the reports of the studies to which they refer. In particular data on three fundamental parameters, vegetative cover, slope and soil characteristics are often missing. While Rijsdijk and Bruijnzeel (1990, 81) may be correct in holding that density of the plant cover over-rides any topographical factor, this is not to suggest that topographical and soil factors are unimportant, as the Hong Kong study reported here clearly indicates.

So far as forest and woodland are concerned - the exact character of the latter being unknown - it is clear that erosion is in the range of 2-10 $t/km^2/yr$, mostly towards the lower end of that range. The case of "China fir" - so reported but probably plantation-grown *Cunninghamia lanceolata* - is interesting for it confirms the view that the replacement of natural forest by conifers leads to increased erosion in many instances. This is probably because at usual planting distances (4 x 4 - 6 x 6 m) the crowns quickly come to interlock as the trees grow, effectively suppressing all but a scanty growth of ground cover which in addition may be periodically slashed or burnt as part of normal silvicultural practice. Trimming lower branches, to reduce the size of knots in the timber also has the effect of reducing canopy density with the result that drops falling from it may well come close to or reach terminal velocity and maximum ability to detach soil particles. (Five to seven metres is generally taken to be the distance over which terminal velocity is reached). These considerations have important repercussions in the control of soil erosion. The case of "woodland" is similarly instructive for most secondary forests have particularly dense canopies - "jungle", after all, refers to secondary forest. If, as is possible, "woodland" here refers to the common situation of scattered *Pinus massoniana* over a ground cover of indigenous grasses and *Dicranopteris* fern, then again good protection is being offered.

Erosion from cultivated land, expectably, is fairly uniformly three orders of magnitude higher than from forest, though that from tree-crops such as rubber and tea is only one order of magnitude higher. (Feng's data appear to be an order too low. See Table 1). The data from Taiwan for tea and oranges, with low cover, confirm these findings. These may be compared with coffee on terraced slopes in east Java which are somewhat lower (Rijsdijk and Bruijnzeel, 1990, 75). The Chinese figures are roughly an order of magnitude lower than rates for a sub-basin of the Kelang River, Malaysia, occupied by rubber and oil-palm plantations and calculated using the USLE. The latter were reported by Balamurugan (1991, 282) as 1500-3000 t/km^2/yr. (He also reports erosion on forested land as 100-200 t/km^2/yr, which seems rather on the high side). Most of these results would appear to refer to lands with slopes in the range 20°-30°. However, within a single use-category, slope is clearly of crucial importance in explaining substantial differences in erosion, as Zhu's study of pineapple cultivation demonstrates (Zhu, 1990, 377). He found that on 5° slopes erosion was 750t/km^2/yr, rising to 21300 t/km^2/yr on land with a 25° slope. (These data, given originally in t/ha/yr, seem rather high, though not inconceivably so).

Amongst the key variables, slope angle, soil characteristics, vegetative cover (or canopy density), terracing (or other sediment-trapping structures), and tillage, the last seems to be crucial, for the erosion levels under perennial crops and grazing are mostly at least an order of magnitude lower than those where tillage and/or consequent baring of the soil surface have occurred. In a sense, however, the data for shifting cultivation are misleading. Not only do authors fail to state to which year of the cultivation cycle, presumably the first, their data refer but, and this must be emphasised, it has been well-known since the work of Nye and Greenland (1960), that erosion from slash-and-burn plots is at a maximum early in the cycle of cultivation but rapidly diminishes as crops and adventitious vegetation are re-established. (It is confidently predicted that in the Hong Kong study, reported below, erosion on burnt plots will be substantially lower in the second year following burning, i.e. 1994). Similarly, the establishment phase of perennial cropping usually sees the mobilization of large quantities of sediment but, given good management, those levels quickly fall. The data for perennial crops summarized here clearly refer to established perennial crops, not to their establishment phase.

The study of erosion from secondary grass, fern and scrub terrains has received rather little study though such lands probably occupy several hundred thousand square kilometres in the region - much more than is occupied by forest. In Guangdong Province alone, there was in 1987 some 53 400 km^2 of uncultivated land, most of it occupied by these three plant communities (Guan, 1993, 2). Overall erosion levels appear to be comparable to those of perennial tree crops. Why they should be one to two orders of magnitude higher than those from forest is not altogether clear given that vegetation coverage is usually complete and sediment mobilization by drip from the canopy is likely to be very limited given the low height of the cover and short trajectory of falling drops. The concentration of stems, which trap sediment, is also much greater than under forest, usually several score per square meter. Possibly the answers lie in the respective depths of litter and of the depth, structure and texture of the A horizon, other things being equal.

The detailed study of the effects of variation in fern cover (University of Toronto *et al.*) are particularly interesting though data for water, rather than sediment yield are given. A reduction of cover from 100 percent to 75 percent reportedly gave an increased yield, from a single storm, of over 40 times, though a further 25 percent reduction in cover only doubled the water yield. As will be seen from the Hong Kong study in similar terrain, high sediment yields from cut and burnt plots occurred essentially in February and March when surfaces were substantially unprotected by living plants, demonstrating again the crucial role of vegetative cover. Of particular interest, however, are the data from the IBSRAM-reported study in Guizhou Province. There the initial year's results (for 1991) show remarkably high levels of erosion even for agroforestry which involved an 'upper storey' of young Eucalypts with crops below. Between early May and the end of July the Eucalypt canopy spread rapidly, from 12 percent cover to 83 percent cover. Under this a summer crop of intercropped maize and soyabean and a winter crop of vetch (*Vicia sativa*) were taken. Such high levels of erosion may be attributed to the fact that intense heavy rain fell from 2-6 June when the plant coverage had yet to reach 15 percent and also to the disturbance of the soil by tillage necessitated in this form of land use. The data for the 'kept-bare' plot is also of interest as identifying an absolute upper limit. The Hong Kong study, reported in the following section, was also modified, in 1994, to include the measurement of surface wash and splash erosion from a sloping surface kept bare.

The Hong Kong Study : Grass and Fernland

The Hong Kong study aimed primarily to establish order-of-magnitude levels erosion under three regimes of grass and fernland use : annual cutting, burning and a control (no use). In respect of the first and last of these, two year's data are now available though not yet fully analysed. A fortuitous hill-fire in November 1992 allowed the addition of two plots to the existing four. Observations began in mid-July 1992 and will continue to the end of 1995 provided that the experiment is not wiped out by hill-fires.

In brief, the study is now based upon six 6 x 20 m unbounded plots on straight slope segments on a sandy clay loan (sand 62.0%, silt 12.3%, clay 25.7%) derived from basic volcanics of Mesozoic age. Plots are paired as follows in Table 2. Pair A had been burnt previously - in February 1988 and Pair B in 1990 though when work began cover was 100 percent on Pair B and roughly two percent lower on Pair A where a few boulders protruded through the cover of grasses and *Dicranopteris* fern. Plots 2 and 4, when first cut had

Table 2 Hong Kong Study : Mean Slope by Plot

Pair A	Plot 1, control, uncut	14°
	2, cut annually early January	15°
Pair B	Plot 3, control	26°
	4, cut 13/3/92 and 4/1/93	27°
Pair C	Plot 5, burnt 4-5/11/92	25°
	6, burnt 4-5/11/92	26°

respective standing crops of 398 and 339 g/m^2. (These values were slightly lower on re-cutting the plots in January 1994). Annual cutting was chosen because this is the most common practice in nearby Guangdong where twice-annual cutting also occurs, though it is less common (Chen Rongjun, 1993). Following cutting, data were collected on cover, in 1992 and initially in 1993 only live-plant cover, using a portable 10 x 10 point square sampling frame one square metre in size, each cut or burnt plot being systematically sampled at 30 points to give a total of 3000 point samples per plot at each round of observations. These were carried out at appropriate intervals as the plots regenerated. Data for 1993, which also include cover by "standing dead" and "litter" components of the vegetation, are shown in Figure 1.

Erosion could not be measured by the capture of all sediment and runoff since the conditions of use of the site, on government land, required minimum disturbance. Three sets of measurements have been made : erosion pins (30 per plot) to measure long-term change (not reported here); splash, collected using five square pans per plot, each pan with an area of 180 cm^2 and sides 7 cm high (also not reported here) and sediment, collected using four Young traps per plot arranged an echelon downslope, each having a catcher opening 25 cm wide and fitted with a Whatman GFD filter to evacuate surplus water.

In the first year of observations (1992) the contents of sediment traps (and splash pans) were removed followed every significant rainstorm to give 18 sets of observations. However, it was noticed that the regeneration of vegetation on the cut plots was being hindered by the trampling of observers as they moved about on the plots so in 1993 the frequency was reduced to only eight rounds of observation with consequent loss in precision with respect to timing but a reduction in damage to the vegetative cover.

Results from all four plots for 1992 are given in Figure 2 which may be compared with those for 1993 for selected plots in 1993. (Note that the scales of these figures are different since for 1993 the scale for sediment trapped had to be changed to accommodate the very much larger amounts from the burnt plots). For 1992 the mean total catch 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 nearby 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).

There seems to have been some change in the composition of the catch through time being around 20 percent "organic" during the middle of the year but later rising to at least double that level. 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 from August onwards probably reflects the increasing availability of shed organic matter as well as the limited mobilization of sediment.

The second year of observation began in January 1993 and quickly showed large amounts of material moving on the cut and burnt slopes - much larger on the latter, especially during the period before mid-May when live-plant cover reached some 95 percent, compared with five percent in late January. The nature of the catch also changed as is shown in Table 3.

While loss on ignition is not a wholly satisfactory measure of organic matter content, it is clear that on the uncut plots a substantial proportion of the catch, when the catch is smallest in the earlier part of the year, is organic. That proportion falls as the vegetation enters its growth period and rises slightly later in the year as it senesces. The cut plots behave similarly with lower proportions of LoI, even though abundant dried organic matter lies on the surface after cutting.

Table 3 Total Catch (4 traps) (g) and Weighted Mean of Loss on Ignition by Plot

		Total Catch (g)	LoI (%)
Days 1-84			
Plot 1	14° uncut	3.44	67.7
2	15° cut	60.99	40.4
3	26° uncut	5.81	53.0
4	27° cut	85.06	47.3
5	25° burnt	377.03	14.3
Days 85-215			
Plot 1	14° uncut	28.77	24.8
2	15° cut	209.90	18.4
3	26° uncut	41.71	34.1
4	27° cut	1567.16	8.4
5	25° burnt	8564.60	10.1
Days 216-336			
Plot 1	14° uncut	7.46	34.9
2	15° cut	8.86	29.9
3	26° uncut	11.99	29.4
4	27° cut	29.14	17.5
5	25° burnt	34.49	22.2
Whole Period (336 days)			
Plot 1	14° uncut	39.67	30.4
2	15° cut	279.75	23.6
3	26° uncut	59.51	35.0
4	27° cut	1681.36	10.3
5	25° burnt	8976.12	10.3

Note : No data for Plot 6 in early January, so omitted, but similar to Plot 5 otherwise.

Most striking, however, are the order-of-magnitude differences in catch according to management, far outweighing the nevertheless significant differences in slope. (It would have been interesting to have had a burnt plot on a modest slope to match with Plots 1 and 2 but the incendiarism necessary to its creation was not to be encouraged in a Hong Kong dry season). Clearly, while annual cutting does result in increase in the catch of material on the slopes, especially on the steeper one, it is quite short-lived, especially on the gentler one. Obviously a longer period of observation is necessary to settle the matter for it is possible that with continued cutting its effects may persist later into the year. If such is so they would be expected to show up to a greater degree on the steeper slope first.

By contrast burning triggers a flood of sediment and that is by no means stemmed by the regenerating vegetation. While regeneration is marginally slower on burnt plots than cut ones (compare upper and lower bar-graphs in Figure 1) these seems unlikely to account for the very substantial differences observed. Rather it seems probable that fire to a degree "waterproofs" the soil as field observation indicates. Moreover it burns away all litter, whereas cutting adds to it. In fire addition leads, in all probability, to rapid oxidation of humus in the near-surface soil, thus reducing its absorptive capacity and increasing runoff. Heat may also result in the creation of stable aggregates at and near the surface which then could be readily moved by the increased runoff. Obviously there is considerable scope here for further observation and experimentation.

Scientific and Management Considerations

From the foregoing discussion it will be seen that in southern China a great deal remains to be learnt about erosion, let alone its management, not least in respect of what happens to sediments as they move down slopes and are delivered to watercourses. In particular there exists a clear need for many more studies aimed at "ground-truthing" the USLE, if indeed that equation can properly be applied. Rijsdijk and Bruijnzeel, 1990, 95, have done this for an area in east Java where they found reasonable agreement between calculated and observed rates of erosion. In southern China manuscript maps of soil erosion estimated by using the USLE exist and are used in land management despite the fact that actual measurements on the ground are quite scanty. But, as the Dutch authors note, the Equation can easily lead to highly erroneous predictions of erosion since the use of unreliable information for any parameter is magnified by the fact that values for its various component factors are multiplied rather than simply added. Is this, then, a possible reason why most estimates of reservoir siltation have been seriously in error?

Perhaps the largest question to be addressed is the degree to which the existing highly productive lowland agriculture of southern China is founded upon upland to lowland transfers - of sediment (where these are not so excessive as to bury existing productive soils) of water for irrigation and of nutrients to sustain crop growth. Is it possible that the hills are deliberately maintained in something other than forest in order to obtain adequate yields of water for irrigation, even at the cost of increasing sediment, provided that does not become excessive? Anecdotal evidence from Guangdong farmers suggests that deliberate firing of grass and scrub on the hills improves the nutrient content of irrigation water. And grassy hills certainly yield more water than do forested ones. In a word, would the spread of productive sustainable systems of land use in the uplands possibly have the unintended effect of triggering falling yields in the lowlands which would have to be compensated for in some manner? Unlikely, perhaps, but who knows?

A second large question is that of soil budgets in upland areas though clearly the life-span of upland soils, especially under uses that involve tillage, is likely to be quite limited (Elwell and Stocking, 1984). This author has never seen a soil budget for anywhere in the region though he was informed that in Guizhou Province it took between 150 000 and 350 000 years to form a metre of soil. Obviously the loss of 200 t/km^2/yr of soil is a matter of no great concern, at least to hill farmers, where soils are deep, formed on rich easily-weathered parent materials, as for example, in much of Java. It is quite another matter on steep lands with soils formed from hard limestone or quartzite, for instance. The rates and locations at which soils erode and sediments accumulate are quite crucial and using Ce^{137}, are readily accessible to study. Yet, as far as this writer is aware, virtually nothing has yet been attempted using this method.

The third question, one of particular scientific interest, is where do the sediments generated by various agricultural activities go? An anecdote will illustrate the question. While visiting an upland farming region in northern Thailand, close to the Burmese border, I was subjected to a tirade against former Chinese Nationalist soldiers, now turned farmers, for their alleged failure to control soil erosion. I therefore asked of several questions the senior Thai soil scientist who had given vent to this litany - How much soil was being lost? - How far did the sediments go? - Did the soldier-farmers own the land and what equally-paying alternatives to temperate vegetables did they have? The answers were, respectively - don't know - don't know - no - none. The second question I answered for myself within the hour, for the sediments were highly distinct in colour and most were being transported no more than a couple of hundred metres. If Douglas and his fellow workers on river basins in the region are right, possibly as much as 70 percent of eroded sediment ends up, for varying retention times, in various system "sinks" - aggrading valley floors, flood-plain terraces, point-bars and so forth. Many of these sinks are perfectly usuable for farming for longer or shorter, though unpredictable, periods. There is a second significance to this finding, namely that conservation farming at the point of sediment origin, on the middle and upper hill slopes, will probably take a very long time to be fully effective in controlling downstream sedimentation for the sediments are already in a system which may take considerable periods of time to re-equilibriate itself.

A further question is that of research strategy in erosion studies. Plot studies, despite problems in scaling up to whole catchments and regions, are relatively simple but are expensive for poverty-stricken hill regions. If we do not yet know enough, and this is not certain, should there not be many more simple experiments such as those using cooking-oil tins as sediment traps and modified lunch-boxes to catch rain-splashed materials? Erosion is a highly variable phenemenon both spatially and temporally. Since there are real dangers in extrapolating widely from a few widely-separated and short-lived experiments, should not more attention be directed to exploring variability and the reasons for it?

Or do we now know enough to make the main thrust in the direction of on-farm conservation? For the moment the judgement must be that in the region, with a few notable exceptions, for example in Xishuangbanna, the linkages of research station and farmer in respect of experimentation and the active spread of proven conservation from station to farmer or farmer to farmer are weak. The collection of papers edited by Parham and his associates (1993) is extremely revealing in that with very few exceptions, the conservation methods described have no economic component. That is to say they have been shown to be technically feasible but their economic feasibility at farm level has been neither tested nor demonstrated. This is not surprising for many scientists working in this field would deny that economic analysis of the interventions they propose is their concern. (For an discussion of these concerns see Hill - (1994).

What can be said is that a number of interventions have not been successful and others cannot be. For example, attempts to oversow tree-seeds, mainly *Pinus massoniana* into scrub and grassland have been expensive failures with one-year survival rates mostly well below one percent. The support of village communities in headwaters of the Chiang Jiang to plant thousands of square kilometers of forest is showing considerable initial success. But the lands that are being planted are partly those from which communities gained their subsistence. For the moment, some intercropping of trees and food-crops is feasible and there is still income from the wage-labour in tree-planting. But as the tree canopies close what then? Some will find continued employment in silviculture; under Chinese conditions up to a maximum of about 30 persons per square kilometer can be supported. There are some prospects for increasing intensive cropping of valley floors and hillside terraces but most of that potential has already been realized. Transportation and marketing linkages are mostly very weak. Towns are distant. Townspeople are also poor and so demand is relatively weak. Yet population densities are not infrequently well over 30 persons per square kilometer. Where will the "surplus" people go? What will they do? In all probability they will fell the young trees to grow food - and erosion will roar away again.

The region is not noted as one in which herd animals, sometimes including pigs in their ranks, are important. But in the higher terrain such as the plateaux of Guizhou and Yunnan, herds are common. They graze common land, rough grass, herbs, fern and shrubs often at densities clearly in excess of the pastures to support them without deterioration of the vegetative cover. This leads, expectably, to erosion of various kinds which in the familiar vicious circle, in turn increases the pressure upon the remaining pasturage. Yet farmers may obtain soft loans to buy more animals, a benevolent central government wishing to be seen to be doing something for the poor. But local officials, well aware of the problem as they may be, are unable to divert any part of the funds to improving the pasture, to devising appropriate means of managing the commonage for the benefit of all. So erosion continues apace.

Engineering solutions to erosion problems have been used in necessarily - limited parts of the region, necessarily by reason of their high cost. As elsewhere, masonry check-dams and stone-faced terraces are initially very effective and their capacity to hold material can readily be established, a significant consideration to design engineers. But repeatedly it has been found that such structures are eventually overtopped, not infrequently creating basal and lateral scouring by concentrated flow, and ultimately necessitating yet further works to set matters to rights. By contrast, the use of biological solutions, contour strips, hedges such as those of the stiff Vetiver grass, quick-growing cover-crops such as *Pueraria* in tree-crop areas and in road and railway applications, is in its infancy, with widespread ignorance of their effectiveness amongst officials and farmers. Or where that ignorance has been dispelled, the social and economic means to implement effective interventions based upon biology often do not exist. Vested interests in engineering solutions may be strong. In connection with the "contest" between engineering and biology in erosion control the work of Dano and Siapno (1992) in mountain regions of the southern Philippines is instructive. On clay to clay loam soils, slopes 18°-36°, with annual crops of maize/peanuts and pineapples, potent generators of soil erosion, they found that terraces and rock barriers costing about U.S.$40 per (unstated) unit reduced erosion to within the range of

17-23 percent of the erosion levels on untreated control plots. By contrast, *kakawate* hedges, costing U.S.$5 per unit reduced erosion to 42 percent of the control level in the first year following planting and to 33 percent of the control level in the second year, not as effective as the "engineering" solutions but far superior in terms of cost effectiveness. In Thailand and Malaysia Vetiver (*Vetiveria zinzanioides*) contour hedges are proving to be extremely effective both technically and in terms of cost, not only in agricultural contexts but also in the context of road construction (United States, National Research Council, Board on Science and Technology for International Development, 1993). Southern China so far lags, though the residual authoritarianism of the society gives hope that once the bureaucracy is convinced of the utility of a biological approach then there is fair a chance of it being widely applied.

Conclusion

But what are the chances of any soil conservation strategy being widely applied? It is true that there now exists an increasing realization that the lack of adequate watershed protection has major costs, most notably in respect of the siltation of reservoirs and loss of storage capacity. This is now so serious that planned flood-control functions are seriously compromised and limited water storage is clearly leading to dry-season shortages. There are, of course, many other significant costs : downstream flooding, accelerated coastal sedimentation and the formation of invasive sand-dunes, desilting of irrigation and drainage systems. What the magnitude of these may be is anyone's guess for the socialist accounting system does not lend itself to the determination of the costs of inaction. The art of environmental economics is at its earliest stages in China with the merest handful of practitioners in the country, all, apparently, in Beijing.So far as I am aware, there is in China nothing comparable to the U.S. EPIC model which quantifies the relationship between erosion and soil productivity by calculating erosion-productivity index values as the ratio of annual crop yields with erosion to those without (Williams *et al.*, 1990). Nor has there been any attempt to develop or apply erosion productivity models such as THEPROM (Biot, 1990).

What is sure is that downstream costs of erosion and sedimentation are of no concern of upland farmers. Their battle is with poverty for in significant areas of southern China per-person annual incomes are still below U.S.$35. Many are in no position to finance conservation, especially if this means taking even a few tens of square metres of land out of production. The tenurial position of uplands is quite unclear. Under the responsibility system, now more than a decade old, rice-fields have been allocated to individual families. Individuals may also be permitted to "own" trees they may plant and maintain on the hillslopes. But the status of much of the hill land is very unclear, essentially being commonage. Yet with the demise of the communes there are now no effective structures to manage such lands. With the death of the commune, too, there is now no organizational means by which labour may be substituted for capital in the countryside where officials increasingly admit that the villages are "out of control". As successors to the commune administrations, the counties, in many instances are unable to secure satisfactory revenue, a situation that extends right up to the national level. At that level the realities of rates of return force government to allocate the bulk of its limited capital investment resources to the sectors which give the best returns, infrastructure development in the growth poles of the coastal provinces for example.

Such central government spending on erosion control as there is seems to be directed in three main directions. First is "big-project" spending mainly on anti-desertification measures in the south-west or on the Loess Plateau. Second is on headwater erosion control where there are major downstream dam projects such as the Three Gorges enterprise. Last is what may be described as "keep-the-peasants-happy" spending, alias "pork-barrel" projects whose objectives are basically political. The southern lands share in the two latter classes of expenditure only marginally for there seems to be a wide spread perception at the centre that the south is rich - and is thus well able to solve its own problems. This is not wholly so as Hill's study of the poverty-stricken southwestern province of Guizhou demonstrates (Hill, 1993).

Soil erosion, in the Chinese, context, is quite clearly a function of poverty. Farmers living at the margin have nothing to offer except their time. But the social basis by which their gifts of time may be mobilized has gone and is not replaced by effective alternatives. Ultimately, it may be supposed, the large structural change in the economy now under way, the shift from agriculture to manufacturing industry, will create wealth sufficient to encourage withdrawal from economically-marginal and environmentally-fragile hills and mountains. Or at least it will permit disintensification of land use, a process already under way in hill villages adjacent to the special economic zones of the south where fruit trees replace wet rice on hillside terraces. Increasing wealth will lead to the use of commercial fuels such as kerosene, natural gas, coal and electricity rather than phytomass which currently is about one-tenth the cost of such commercial fuels. Markets will enlarge and individual, local and regional self-sufficiency in food will tend to disappear, reducing pressure on the land. But that happy day is probably at least a century away. To live in the mountains in southern China is still to be desperately poor. Poverty will continue to promote soil erosion, as in turn soil erosion will continue to promote poverty.

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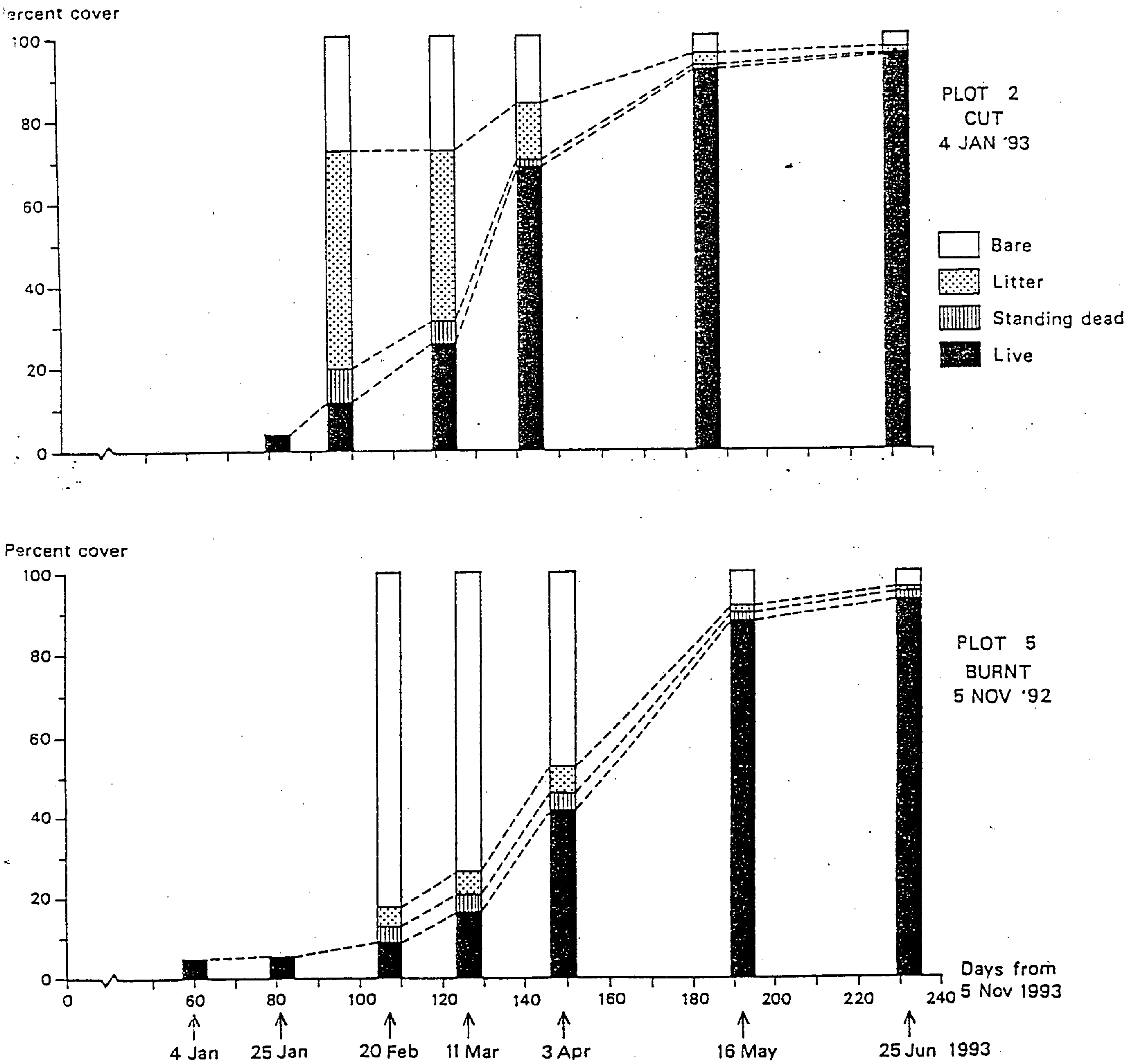
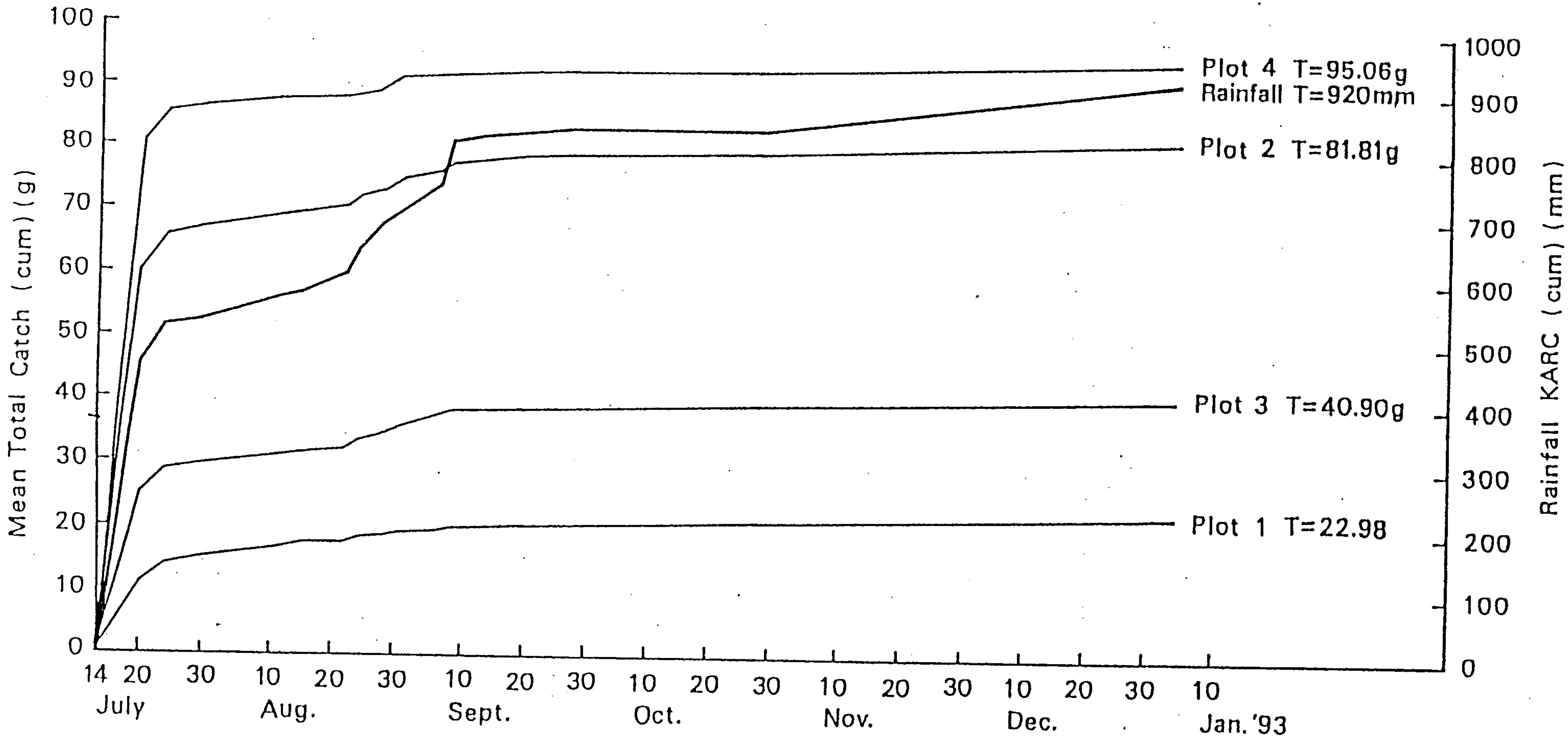


Fig. 1 Regeneration Diagram, 1993

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

JULY '92 - JAN. '93



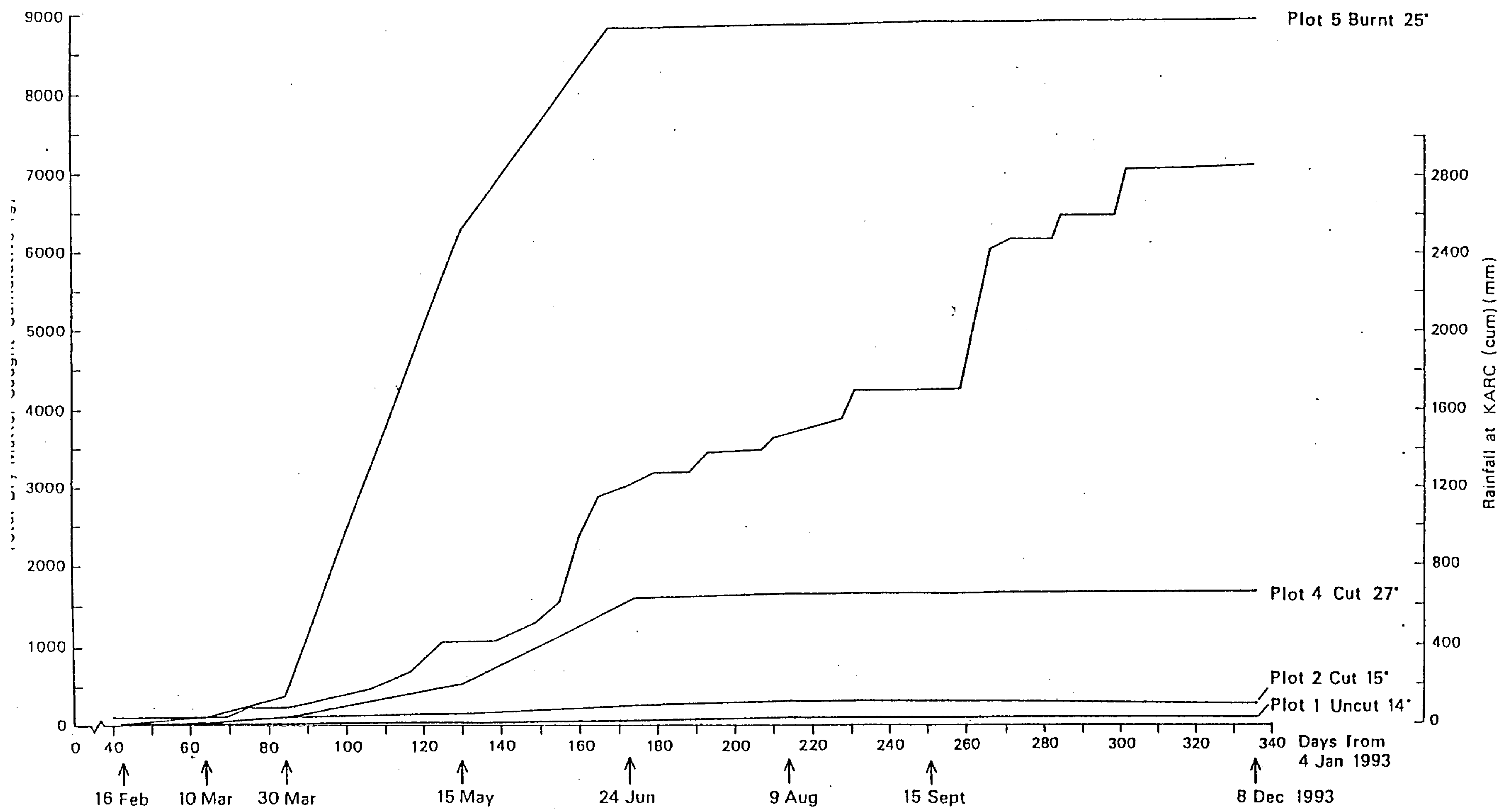


Fig. 3 Total Dry Matter Catch and Rainfall, 1993