Technical Bulletin No. 23

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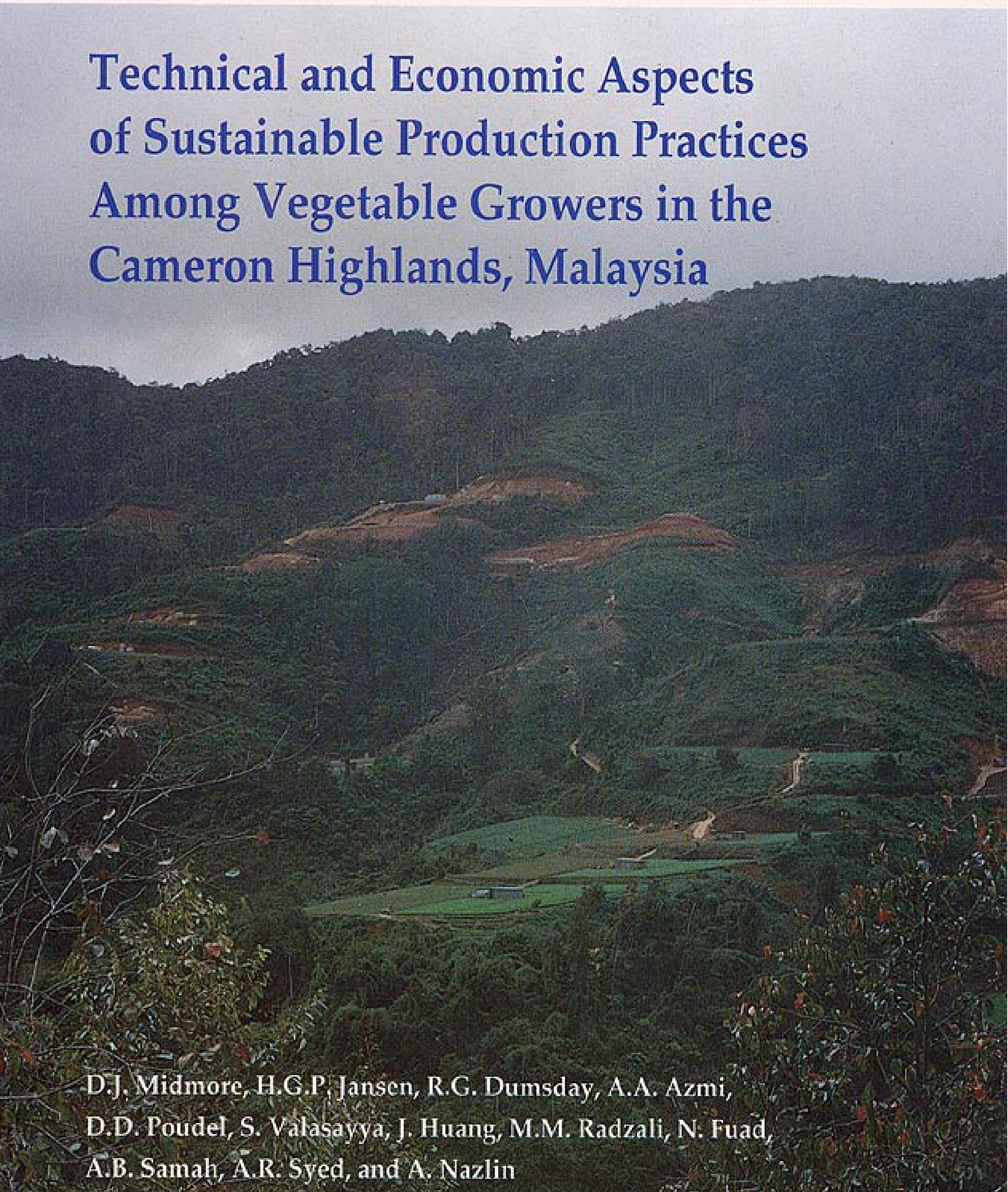

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1. Introduction

1.1 Background and justification

In Malaysia, the relative importance of agriculture has declined as a result of diversification and industrialization of the economy. The share of agriculture in GDP, employment, and exports has gradually declined and since 1984 the manufacturing sector has overtaken agriculture as the main engine of growth. Malaysia has recently declared its vision of becoming a fully developed nation by the year 2020. Realizing this vision involves a doubling of real GDP every 10 years over the next three decades and a balanced growth in all sectors of the economy. Within this context, accelerated efforts are needed to ensure a reasonably balanced rate of growth in agriculture in relation to other sectors of the economy.

The future performance of the Malaysian agriculture sector will continue to be influenced by the direction of the global economy and the national economy, as well as by the ability to comprehend the issues and challenges facing the agriculture sector itself. Currently the major issues being highlighted are resource and environmental issues, concerns for food safety and personal health, sustainable development, trade policy and international agreements, and poverty. Among the challenges, that of technological advancement appears to be the most prominent. In the Malaysian context technological development must be directed towards labor saving, land augmenting, and be environmentally friendly. With the shrinkage in land available for agriculture due to urbanization and industrialization, greater competition across sectors for other resources including labor and capital, and greater concern for preserving the environment, and different strategies to enhance agricultural development are needed.

Agriculture in the highlands offers one of several alternatives which address these issues and could help to improve the overall performance of the sector. A large part of the mountainous steep lands in Malaysia is kept under forest. However, in Peninsular Malaysia about 5000 ha of steep mountainous land in the Cameron Highlands (CH) have been developed for tea, temperate vegetables, floriculture, and fruits. In East Malaysia, cocoa and pepper are planted on steep lands. Another landuse type in steep areas is shifting cultivation, mainly found in East Malaysia. In Sarawak this amounts to about 2.7 million ha of which 0.1 million ha are cleared annually for the cultivation of hill rice and other food crops. The other East Malaysian state, Sabah, is dominated by a landscape of hilly and steep land which accounts for over 60% of its total area. The vegetable growing area of

Kundasang has a landscape characterized by steep slopes. Primary jungle is being replaced through clearing operations and vegetable production on steep land is gaining popularity.

The remaining portion of this introductory section focuses on the economics of Malaysian vegetables and the objectives of the study.

1.1.1 Vegetable economics in Malaysia

The Malaysian National Agricultural Policy (NAP), 1992-2010, states that the production of vegetables will be promoted to attain a targeted self-sufficiency level of 125% by the year 2010. Production is expected to increase at 9% and 7% per annum during 1991-2000 and 2001-2010 respectively, reaching 2.7 million metric tons by the year 2010 (Government of Malaysia 1993). There will be substantial expansion of area under vegetables involving both lowlands and highlands. Specific areas, including highlands, will be identified and zoned as vegetable growing areas. However, vegetable farming in the highlands will be rationalized to allow only the production of high valued vegetables with greater regard for conservation measures.

The area under vegetables in Malaysia (currently only about 1% of total arable land) is relatively minimal (Jansen 1992), and has fluctuated around 10,000 ha throughout the past decade [Government of Malaysia, Fifth Malaysia Plan, cited in Anang (1989)]. Data from the Ministry of Agriculture present a somewhat different picture, suggesting large year-to-year fluctuations in vegetable area which, after an increasing trend in the 1970s peaked at nearly 28,000 ha in 1980 and substantially declined after 2 years to around 12,000 ha (table 1). In 1989, the area under vegetables rose by approximately 60% compared to the previous 7-year mean. However, while the reliability of these official data may be questioned, figures supplied by Anang (1989) and FAO (1990) seem to agree on an annual production of some 500,000 t/year, as opposed to official estimates made by the Ministry of Agriculture of less than 200,000 and 296,000 t, and 100,000 and 120,000 t, respectively (Ahmad et al. 1992). Thus, even though a sizable proportion of Malaysia's total vegetable production is exported (mostly to Singapore) at about US$20 million per year, vegetable exports (tomato, peppers, cabbage, and a wide range of other vegetables) are rather minor in absolute terms. Malaysia is even a substantial net vegetable importer (mostly potatoes, garlic, and onion) with the total vegetable import bill exceeding US$80 million.

In addition to this negative trade balance in fresh vegetables, imports of processed vegetables by Malaysia exceed corresponding exports by about US$45 million annually. Recently it was reported that Singapore has refused some shipments of vegetables because of their high levels of pesticide residues. Integrated pest management practices have been promoted in the Cameron Highlands (Syed n.d.) to stem the overuse of pesticides, with hoped-for concomitant reductions in pesticide residues, favoring both the consumer and producer of vegetables.

Table 1. Vegetable area in Peninsular Malaysia, 1970-89

Year	Land area (ha)
1970	7,724
1971	7,247
1972	8,651
1973	6,224
1974	5,354
1975	6,368
1976	5,667
1977	6,243
1978	9,595
1979	8,975
1980	27,929
1981	23,628
1982	12,540
1983	12,513
1984	12,808
1985	9,340
1986	17,234
1987	12,412
1988	16,719
1989	26,165

Source: Ministry of Agriculture. Area under miscellaneous crops. Kuala Lumpur, selected issues

The most recent FAO figures for vegetable availability refer to the 1984-86 average and indicate a per capita daily supply of just over 100 g (FAO 1991). The figures for domestic production and trade for 1985-90 supplied by Anang (1989) and FAO (1990) suggest that vegetable availability has changed very little and significantly falls short of the FAO/WHO recommendation of 200 g/capita per day. More seriously, if historical supply growth patterns of the past two decades would continue in the future, per capita domestic supply of vegetables has been projected to decrease over the next two decades while the gap between demand and domestic supply can be expected to increase considerably, mainly fueled by strong growth in per capita income of about 6% per year and urbanization of about 5% per year (Ahmad et al. 1992, Jansen 1992).

In contrast, estimates of vegetable consumption based on consumption surveys carried out by the Federal Agricultural Marketing Authority (FAMA) paint a picture in which the consumption of vegetables increased from 118 g per capita per day in 1982 to 153 g in 1985 (Ahmad et al. 1992). The most popular vegetables include (figures in parentheses refer to 1991 per capita annual consumption in kilograms) mustard (5.8), English cabbage (4.7), long beans (4.2), cucumber (3.3), water convolvulus (2.9), and spinach (2.5). In 1991, onion was the most consumed vegetable (4.5 kg) followed by red chili (1.3 kg), garlic (1.0 kg), and ginger (0.3 kg). The FAMA survey also included the vegetables consumed by institutions and factories. The 1985-91 surveys indicated that total consumption of vegetables in Malaysia has almost doubled from 573,477 t (1985) to 1097 million t (1991).

It was estimated that current production of vegetables is about 680,000 t against the estimated demand of 830,000 t (Ahmad et al. 1992). The domestic demand for vegetables is projected to grow at 3% annually and export demand at 3.3% reaching 134,000 t by 1995. Given the projected volume of domestic production and domestic and export demand, the shortage of vegetables is likely to reach 250,000 t with the total import bill reaching M$447 million by 1995. Imports of fresh and chilled vegetables increased from 90,000 t valued at M$25 million (1970) to 296,400 t valued at M$228 million (1990). Potatoes, garlic, and onions accounted for 54% of the total import value of vegetables in 1990. Table 2 shows the import values of potatoes, garlic, and onions during 1970-90. Currently it is neither technically feasible nor economically viable to produce these vegetables under local conditions due to lack of suitable production technologies (Vimala et al. 1994).

Table 2. Import values and percentage of vegetable import value for potato, garlic, and onion, 1970-1990

Year	Value of import ('000 M$)	% of total import value
1970	17,363	80.0
1972	19,718	83.6
1974	29,946	86.4
1976	38,479	64.7
1978	47,872	87.1
1980	63,566	81.6
1982	104,670	84.3
1984	98,43	75.4
1986	110,220	75.2
1988	153,540	56.1
1990	163,597	53.5

Source: Statistical Department, Kuala Lumpur (in Fuad 1993)

It is apparent, despite the muddled statistics, that demand is increasing while production lags behind. The consumption figures still suggest that average daily consumption in Malaysia, a net importer, is less than that recommended by FAO.

Despite consistent attempts to adapt temperate vegetables to lowland tropical climates, a large proportion of temperate vegetables consumed in tropical countries is produced under more favorable highland climates. The Cameron Highlands is one of Malaysia's most important vegetable growing areas, with currently an estimated 2140 ha under vegetables (Fuad 1993). A considerable portion of the production is exported, earning valuable foreign exchange. However, there is mounting concern about the long-term environmental impact of vegetable production in general, and that in highland areas in particular. The concern is focused not only on the heavy use of pesticides (with health hazards presented by pesticide residues, the build-up of resistance, and contamination of soil), but particularly on the already highly visible erosion from vegetable production areas in the CH (with sedimentation of infrastructure, loss of soil structure and nutrients). The area is one of inherent national beauty, with a cool climate, and as such favored by local and foreign tourists. Concerns are mounting as to the detrimental effect of soil exposure following land clearing on the beauty of the area. Many proposals for reducing these problems have ignored economic factors and have consequently not been adopted by farmers. An additional source of soil exposure and soil erosion is that related to the construction of hotels, housing, and infrastructure for the tourist industry. Although not considered here in detail, other reports suggest a not insignificant impact on soil erosion (Cheng and Chen 1995). This report attempted to integrate the various disciplines engaged in research on sustainable management of vegetable production systems, with the ultimate aim to develop profitable vegetable growing practices for the CH while maintaining or enhancing its natural resource base.

The philosophies, concepts, and courses of action for sustainable agricultural development have, to some extent, been internalized in the development of highland agriculture in Malaysia. In the process of diversification and commercialization of upland agriculture, various efforts towards sustainability had been undertaken, either through government enforcement, private sector initiatives or international development agencies. The salient features of the efforts made and their degrees of effectiveness are discussed below.

As noted earlier, vegetable production in the highland areas of Southeast Asia (e.g., Bandung in Indonesia, Baguio in the Philippines, Nuwara Eliya in Sri Lanka, Dalat in Vietnam, Cameron Highlands in Malaysia) is highly lucrative and it is unlikely that a shift towards lowland vegetable production will deter highland farmers from continuing with the production of vegetables. Indeed with the greater demand for high quality vegetables, new land areas (inevitably with steeper slopes than presently under cultivation) are being opened in all the above regions despite government restrictions to the contrary. The dissected geomorphology of the highlands, often with cultivated slopes of up to 30°, and intense rainfall (2500-3000 mm) largely confined to the rainy season, are conducive to serious soil erosion leading to loss of soil fertility, silting of irrigation and hydroelectricity dams, and at times causing landslides.

The Cameron Highlands of Malaysia are no exception, and starting in 1979 the World Bank funded a program to test various technical facets of soil conservation (e.g., terracing, counter slopes, ponds, dams, toe drains, sandbags, wood retainers, plant species to retain soil). This culminated in the establishment of an 8-acre demonstration farm, now managed by the Department of Agriculture. Limited acceptance of these cultural practices can be observed in the 2000 ha under vegetable production in the Cameron Highlands. However, if terracing does take place it is with wide terraces, 0.125-1.0 acre, cut into slopes (plate 1), and not the narrow 1.0-2.0 m bench terraces advocated by the World Bank research program (plate 2).

Plate 1.
Most popular wide terraces in the Cameron Highlands
Note the sharp slope on the batter (right side) and the flat wide terrace with Chinese cabbage (to the center)

Plate 2.
Narrow bench terraces in an experimental site established by the World Bank
Note some slippage and reinforcement with sandbags

1.2 Study objectives

In 1991, the Asian Vegetable Research and Development Center commenced research on soil erosion in vegetable areas in the Cameron Highlands of Malaysia, funded by the Australian International Development Assistance Bureau (AIDAB) and executed jointly by the Malaysian Agricultural Research and Development Institute (MARDI) and AVRDC. The major objective of the study was to determine the extent of adoption of erosion control practices in relation to the economic resources of vegetable farmers and to critically assess the reasons why adoption has or has not taken place. These were related to the existing cropping system, soil type, slope, size of holding and land ownership, and history of cultivation.

Given the importance of producing vegetables with minimum pesticide use, both for the health of the producer and consumer, the extent of integrated pest management (IPM) practices adopted by farmers within the survey was also quantified to ascertain the need for further research and promotion along those lines. Besides the detailed farm survey, the project involved the use of Geographical Information Systems (GIS) and measurement of physical soil properties, the latter as a simple indicator of past erosion and erosion control practices.

Other specific objectives of the farm survey were to determine the methods, profitability, and input-output coefficients of vegetable cultivation systems in the CH; and to determine the physical extent of the soil erosion problem.

2. Materials and Methods

2.1 Study area

The survey was carried out among vegetable growers in the district of Cameron Highlands, which is Malaysia's oldest and single most important area involved in upland agriculture. Extending over an area of 71,255 ha, the CH is located in the state of Pahang, 250 km from the capital Kuala Lumpur (fig. 1). After Johor state, Pahang, with some 2500 ha under vegetables, is the second most important vegetable growing state in Malaysia. The total area under vegetable cultivation in CH is half of the total highland vegetable area in Malaysia. Daily vegetable production in CH amounts to some 180 t with a value of [1]M$50-60 million/year (Dumsday et al. 1991).

Most vegetable cultivation in the CH takes place at altitudes of between 900 and 1400 m asl within the mountainous area which rises to 2000 m above sea level (asl). The area is highly dissected, with few pockets of broad mountain valleys.

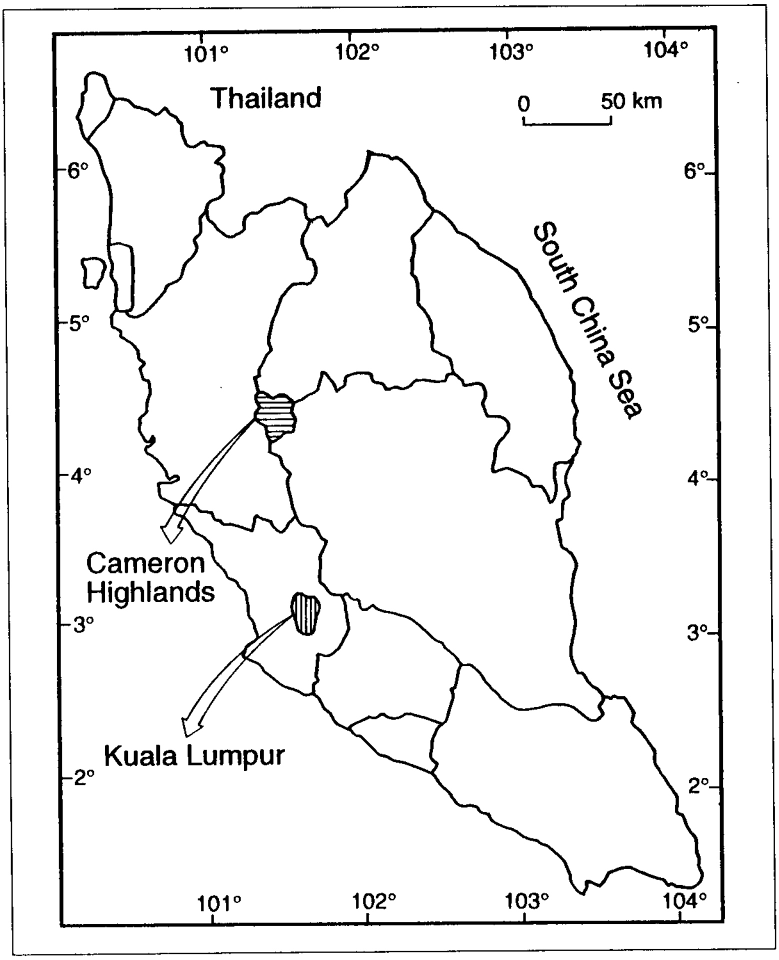

Fig. 1.
Map of Malaysia showing location of Cameron Highlands

[1] M$ stands for Malaysian dollar (or ringgit); the current (1992) exchange rate is about 2.6 to the US$.

Soils are mainly derived from granite, with sandy to sandy clay loam textures, and are classified as paleudults (Paramananthan 1977). Humus in virgin soils in the north of the CH reaches 80-100 cm in depth (Gunung Brinchang series), falling to 40 cm in the Central Tanah Rata Series and to a negligible layer of humus in the Ringlet Series of the south where altitude is less and temperatures higher. The virgin soil 0-10 cm beneath the organic or humus layer is comprised of 40% sand, 16% silt, 44% clay, with EC 0.13 mS/cm and pH 4.2 (MARDI 1993). Vegetable production is rarely practiced on natural slopes, with the exception of valley floors. Generally, small bench terraces (1-2 m wide) or more often platform terraces (10-100 m wide) are cut out of the natural slope without concern for repositioning of topsoil or humus. Farmers, therefore, even on newly opened land, require heavy inputs of nutrients to sustain crop growth. For most of the study area, natural or diverted drainage is to a reservoir constructed in 1965 for the purpose of generation of hydroelectric power.

Despite recommendations by the Malaysian Department of Agriculture (DOA) and the World Bank which encouraged the construction of bench terraces, almost all new land for vegetable and flowers is of the platform terrace type. Nevertheless, the cool temperate climate of the CH ideally suits production of temperate vegetables, with maximum monthly mean temperatures ranging from 21 to 24°C and minimum from 11 to 14°C (fig. 2). Average rainfall data for 1981-1991 show a bimodal annual pattern, with peaks in April/May and October/November (fig. 3). No month is without rainfall, although least rainfall is experienced in the months of December and June. Local perception is that air temperature has risen and rainfall diminished over the past four decades, to some extent borne out by data from the Malaysian Meteorological Service (fig. 2 and 3). Forest clearing has been commonly suggested as a cause of climatic change in the area.

2.2 Landuse and satellite data

The study utilized the digital landsat TM data (scene no. 127/57) acquired on 23 April 1990; the 1:50000 topographic map (sheet no. 36662 - plate 3); and the landuse map for 1986 produced by the Department of Agriculture. Color photographs were also used in identifying landuse types in the study area, and ground truthing was also undertaken.

First, the GIS database was created. This was done on a PC ARC-INFO system available at AVRDC using the topographic map as a base feature. The original map projection was Rectified Skew Orthomorphic (RSO). Using the geographic coordinate, this map was then converted to Universal Transverse Mercator (UTM) projection system.

Second, the landuse map of 1986 was registered to the created base map and all the features digitized. However, for this specific exercise only major cover types were inputted into the system: forest land, developed land, water bodies, and urban and associated areas.

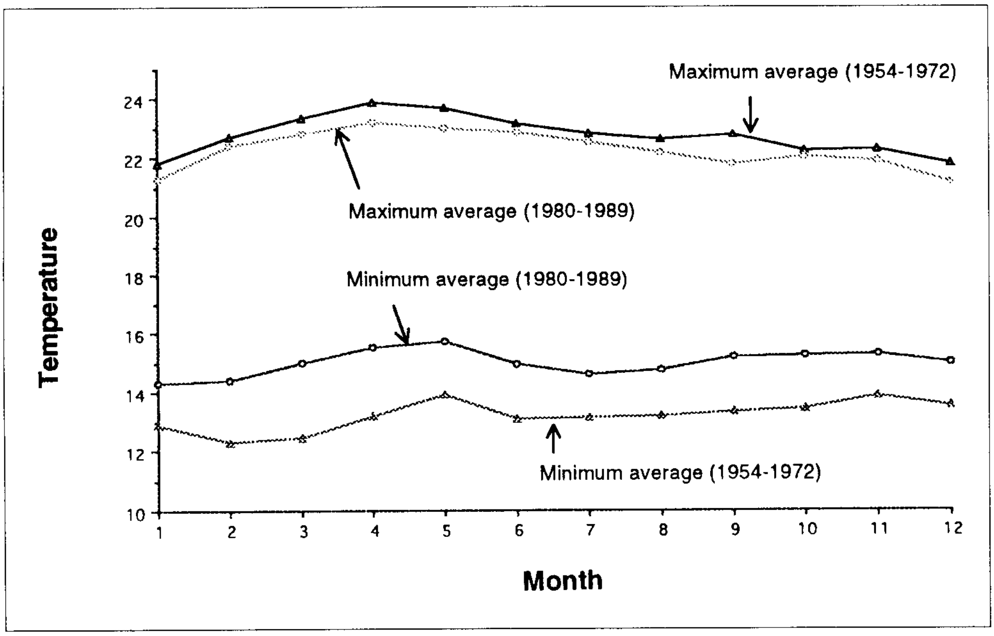

Fig. 2.
Average temperatures in the Cameron Highlands, Malaysia, 1954–1972/1980–1989

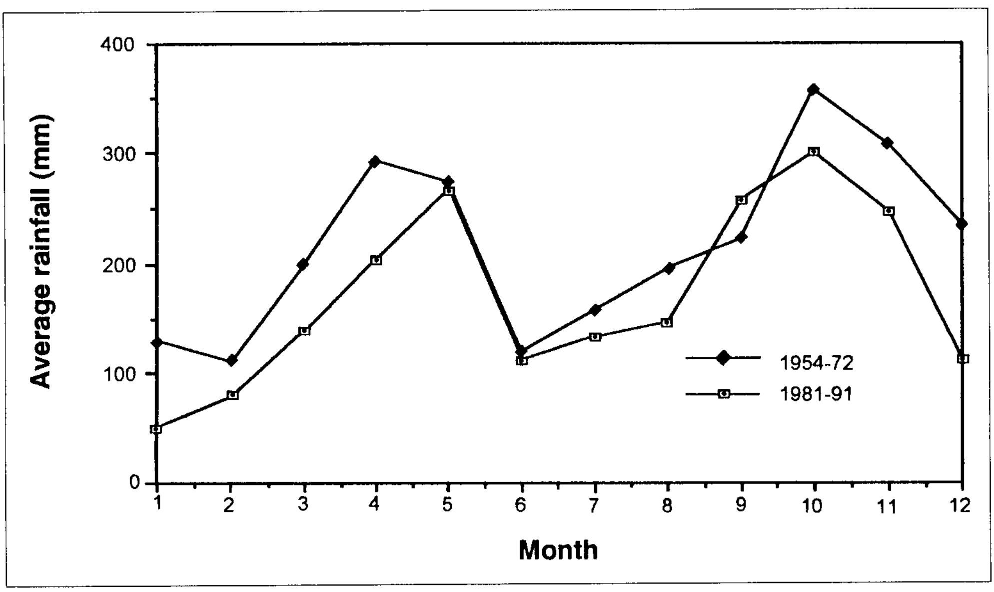

Fig. 3.
Average rainfall in the Cameron Highlands, Malaysia, 1954–1972/1980–1989

Plate 3.
Landsat image (Scene no. 127/57) of Cameron Highlands for 23 April 1990

The next step was to input the present landuse map to the system. The digital Landsoil TM data were processed and analyzed using image processing facilities available at MARDI. The data were classified into major landuse types and inputted into the ARC-INFO database.

Overlay analysis was then performed to both landuse data of 1986 and 1990 to detect landuse changes over time and to identify their extent and location. The coverage of the changes was then calculated and checked by ground truthing.

A digital elevation model (DEM) of the study area was also developed. One hundred meter contour lines and peaks of the topographic map (1: 50,000) of CH were digitized with PC ARC-INFO GIS. These contour files were then taken to a UNI Workstation with 6.1.1 version ARC/INFO TIN/capabilities and converted to TIN. Both line and point convergences were used in a TIN. The lattice option was used for vertical exaggeration of the model. A 100 by

100 m grid size (1 ha) was used to build a DEM. The DEM was vertically exaggerated five times. Landuse information from 1986 and 1990 were drafted on to the model (plate 4), and a slope map of several slope classes (in degrees) was prepared: <2, 2-5, 5-10, 10-20, 20-30, 30-40, >40°.

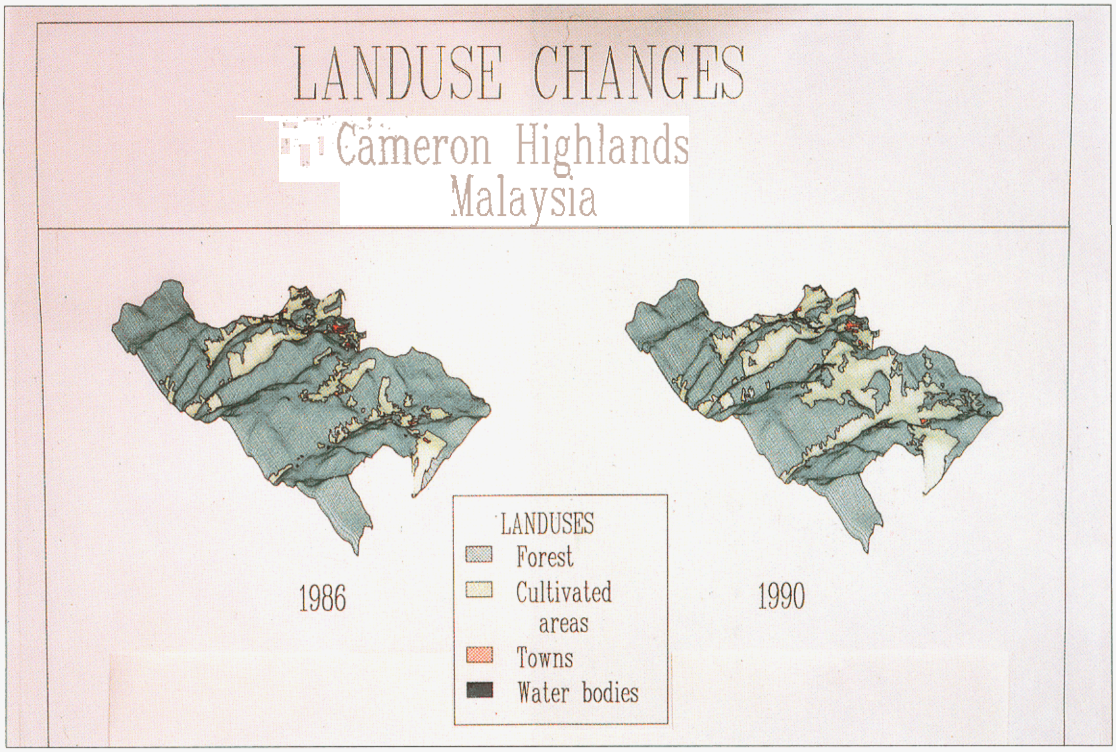

Plate 4.
Landuse changes from 1986 to 1990 superimposed on a digital elevation model of the Cameron Highlands

2.3 Rainfall and erosivity

Pluviographic charts for 1981-1991 were surveyed and the kinetic energy of rainstorms was calculated as

$$KE = 210 + 89 \log_{10} I$$ (Wischmeier and Smith 1978)

where KE = Kinetic energy (m - metric t/ha - cm)

I = Intensity (cm/h)

KE and erosivity indices (ET) were calculated for storms > 10 mm (Dumsday and Huang 1992).

2.4 Sampling methodology

A stratified random sample consisting of 206 farmers in 13 different locations (between 9 and 28 farmers per location) in the CH was interviewed[2] during January 1992; the survey data referred to the 1991 calendar year. The subenvironments, representing sections of the main north-south road running through the Cameron Highlands and certain east-west valleys were as follows:

1. Blue Valley
2. Kampong Raja
3. Sungai Ikan
4. Kuala Terla
5. Ipoh Road
6. Batu 49
7. Tering Kap
8. Sungai Palas
9. Kea Farm
10. Brinchang
11. Boh Road
12. Bertam Valley
13. Ringlet

Consolidated representative soil samples were collected from each farm and analyzed for physical composition, pH, and electrical conductivity. Measurements taken with a clinometer enabled assessment of natural land slopes on each farm, and slopes of terraces and beds. During the formal interview, casual observations on the degree of soil erosion on each farm were recorded. Locations representing all the recognized vegetable producing regions within the CH were chosen. Individual farms were chosen with the help of detailed maps of individual farm location, size, vegetable type and area and household size, obtained from FAMA in Brinchang. From the sample, 193 farms for which complete data sets were available were retained for analysis, representing approximately 10% of all vegetable farms in the CH.

2.5 Data analysis

The survey data were all stored in individual spreadsheets in Apple Macintosh Excel, one for each farm household interviewed. However, for statistical data analysis the Statistical Analysis System (SAS) was employed. Information in the individual spreadsheets was merged into a single SAS data set. Customized SAS programs were developed for statistical analysis of the data on an IBM PC-compatible 386 computer with 80 MB hard disk and 16 MB of RAM. The following procedures in SAS were used: MEAN, MAX, MIN, CV, CORR, GLM, PLOT. In addition to SAS, Word 5, and Cricket Graph for Apple Macintosh were used, respectively, for report writing and the production of graphs.

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[2] The survey sample and questionnaire are described in Dumsday et al. (1992).

3. Results and Discussion

3.1 Land, farm, and household statistics

3.1.1 Landuse statistics

Based upon the digital landsat TM data and the landuse map for 1986 produced by the Malaysian Department of Agriculture, an analysis was made of all the landuses, other than forest, within the CH. The summary statistics (table 3) indicate that > 3000 ha were used in vegetable and flower production in 1990. This is 50% greater than that reported in the most recent landuse statistics by Ko et al. (1990).

Analysis of land distribution in the designated slope classes (table 4) indicates that two-fifths of vegetable production in 1990 (landsat data) was on land with natural slopes < 5°, compared to > one-fifth for tea lands. The correspondence between natural slopes measured from the DEM across the 13 vegetable production subenvironments and those collected on sample farms was quite reasonable for the proportion of landuse in the 0-20, 20-30, 30-40 and > 40° classes (table 5). However, distribution of land within the 0-2° class was not well correlated. Data from the study by Macken and Ong (1979) are consistent with the field survey rather than the DEM. Another field survey (GOM/ADB 1988) of 83 land portions in eight subenvironments gave values for slope classes similar to that of the 1992 survey (<10° = 40%; 11-20° = 30.6%; 21-30° = 17.1%; >30° = 12.2%). Due to the large vertical interval used (100 m) it is likely that the DEM incorrectly interpreted land in the low slope category. In subenvironments where there was very little land in the class 0-5° (e.g., Batu 49), the relationship between slopes on sample farms and the DEM was very close ($r^2 = 0.967$, $P \leq 0.001$). The natural surrounding slope of sample farms ranged from 0 to 30°, and explained 28% of the variation in the recorded slopes for arable lands ($y = 1.20 + 0.37 \pm 0.04\ x$, $P \leq 0.01$). However, the slope of cultivated beds bore no relation to the natural slope ($r^2 = 0.03$) with a maximum slope of beds of 10° and an average of 2.6°. Although the greatest proportion of farmers cultivated vegetables on land with a natural slope of 10-20° (fig. 4), more than one half used beds with a slope of ≤ 2° and only 10% had beds with a slope of > 5° (fig. 4). Only 16% of all newly opened areas have slopes > 20°, which is not excessive considering that most new lands are up slope to those already opened within each valley in the CH (tables 6 and 7, and plate 5).

Table 3. Landuse statistics (hectares) for 1990 (by satellite imagery) and for 1986 (landuse map of MARDI) for the Cameron Highlands

Landuse types	1990	1986
Vegetables and flowers	3,236.8[a]	1,453
Tea estate	2,821	2,942
Cleared tea area	209.5	n.d.[d]
Newly opened forest	1,452.5[b]	n.d.
Scrub and scattered farms	1,859.7[c]	1,702
Town	179.0	194
Total	9,758.5	6,291

[a] includes farm roads, farmhouses, rainshelters, farmyards, and channels

[b] includes dead ferns, cleared forests, barren lands, and even landslides

[c] includes fruit orchards

[d] no data included

Table 4. Distribution of landuse classes (in hectares), by slope category, for 1990 satellite data and the digital elevation model

	Slope							
Landuses	0-2°	2-5°	5-10°	10-20°	20-30°	30-40°	>40°	Total
Vegetable and flowers	968.3	298.6	593.1	897.9	354.4	85.7	10.1	3,208.3
Tea	267.7	189.1	362.4	825.3	441.0	82.8	1.9	2,209.3
Scrub and scattered farms	377.4	164.5	336.4	635.4	340.6	103.4	5.7	1,859.7
Cleared tea	7.4	10.0	44.7	82.9	63.3	19.1	0.0	209.5
Opened up area	368.5	100.0	228.6	509.8	181.8	36.5	9.8	1,452.5
Town	51.9	70.3	15.8	27.2	8.7	1.1	0.0	179.0

Table 5. Distribution of vegetable production land (%) in the Cameron Highlands by slope classes, according to the digital elevation model (1990 data) and survey analyses (1992 data)

	Slope class						
	0-2°	2-5°	5-10°	10-20°	20-30°	30-40°	>40°
Survey	2.1	12.0	29.3	46.1	11.5	0	0
DEM	30.2	9.3	18.4	28.0	11.1	2.7	0.3

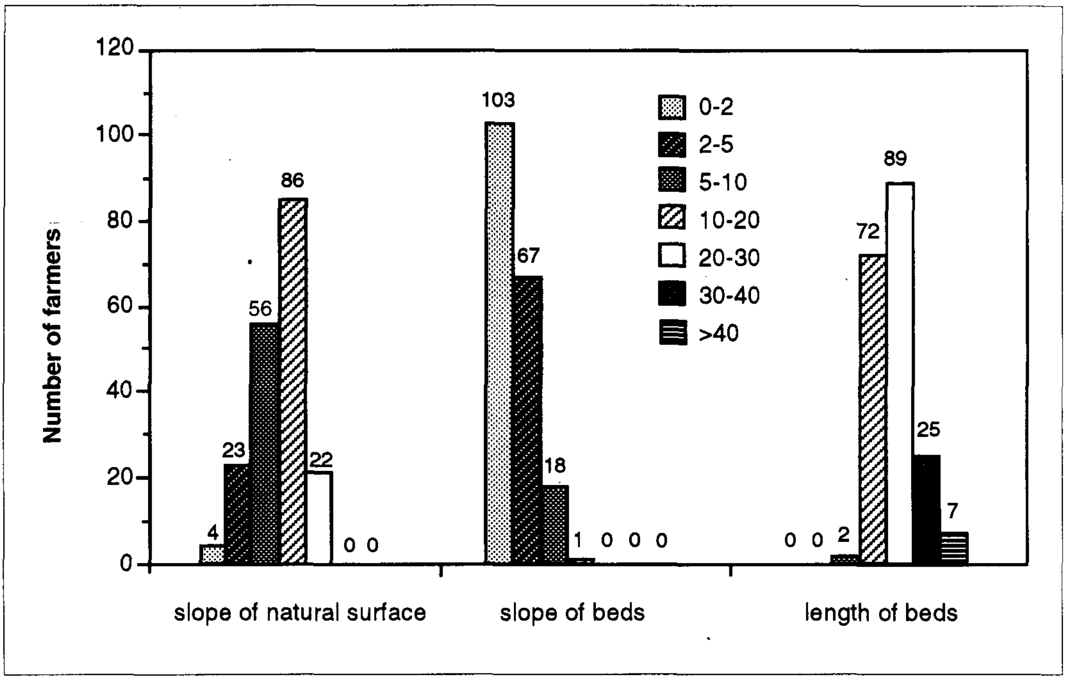

Fig. 4.
Distribution of natural slope, slope of beds, and length of beds in sample farms in the Cameron Highlands

Table 6. Vegetable areas (in hectares) by slope classes in the Cameron Highlands, 1986

	Slope class							
Subenvironment	0-2°	2-5°	5-10°	10-20°	20-30°	30-40°	>40°	Total
1. Blue Valley	29.1	27.1	8.8	13.9	11.5	1.9	1.8	94.1
2. Kampong Raja	49.7	2.8	15.1	24.5	3.5	1.1	-	96.7
3. Sungai Ikan	44.5	32.4	6.5	4.4	5	3.9	-	96.7
4. Kuala Terla	53.4	11.7	26.7	62.6	14.3	3	-	171.7
5. Ipoh Road	9.1	10.7	21.5	5.7	2.7	1.5	-	51.2
6. Batu 49	0.3	-	13.3	19.3	2.3	-	-	35.2
7. Tering Kap	115.6	7.7	6.3	16.9	7.2	0.7	-	154.4
8. Sungai Palas	21.9	1.2	3.5	9	8.4	4.3	-	48.3
9. Kea Farm	42.4	6.9	29.3	36.8	10.1	1.4	-	126.9
10. Brinchang	2.4	18.7	36.3	31.7	7.1	3.2	1.4	100.8
12. Boh Road	15.2	1.1	8.9	12.8	8.1	3.6	0.3	50.0
13. Bertam Valley	53.5	9.2	54.7	137.6	76.9	24.9	1.8	358.6
14. Ringlet	0.9	0.3	4.0	21.6	8.1	0.5	-	35.4
Total	438	129.8	234.9	396.8	165.2	50	5.3	1,420.0

Table 7. Additional vegetable area (hectares) by slope classes opened during 1986 to 1990 in the Cameron Highlands

	Slope							
Subenvironment	0-2°	2-5°	5-10°	10-20°	20-30°	30-40°	>40°	Total
1. Blue Valley	26.7	4.1	22.3	18.3	7.5	0.0	2.9	81.8
2. Kampong Raja	1.2	1.7	7.8	33.1	6.3	0.5	0.0	50.6
3. Sungai Ikan	35.1	25.4	24.9	14.0	5.8	0.2	0.0	105.4
4. Kuala Terla	21.6	7.8	18.8	37.4	17.2	5.8	0.7	109.3
5. Ipoh Road	12.5	31.1	59.7	57.2	17.2	0.3	0.0	178.0
6. Batu 49	1.5	0.4	2.3	9.8	7.1	0.5	0.0	21.6
7. Tering Kap	99.2	2.3	7.4	7.7	5.9	1.6	0.0	124.1
8. Sungai Palas	21.5	2.4	31.3	43.4	13.2	4.0	0.4	116.2
9. Kea Farm	63.6	12.9	69.9	113.7	37.0	3.9	0.0	301.0
10. Brinchang	85.2	45.8	9.4	15.4	3.9	0.0	0.0	159.7
12. Boh Road	14.6	0.6	2.7	24.5	17.6	10.7	0.7	71.4
13. Bertam Valley	71.8	7.2	22.2	62.3	30.3	5.0	0.0	198.6
14. Ringlet	75.8	27.1	75.2	64.3	20.2	3.2	0.1	265.9
Total	530.3	168.8	353.9	501.1	189.2	35.7	4.8	1,783.8

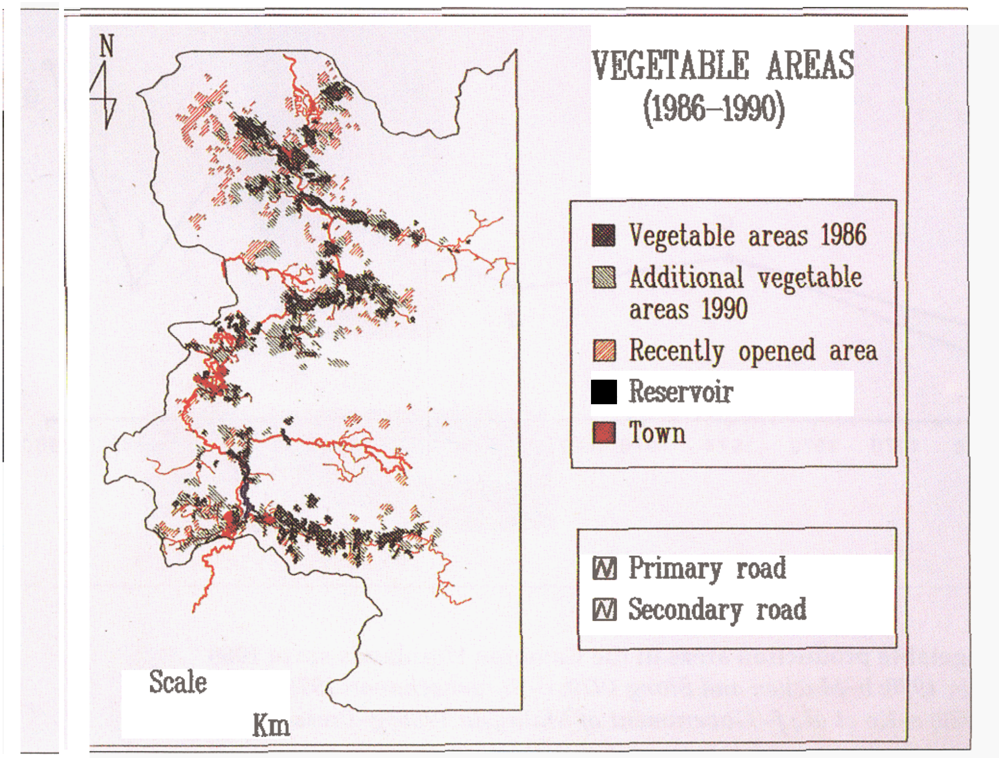

Plate 5.
Changes in vegetable production areas, 1986–1990, and extent of newly opened areas in 1990

Various estimates for the rate of forest clearing are possible from the data (table 3). From 1986 until 1990 (the most reliable data sets) the total developed land area increased from 6291 to 9758 ha, at an average annual rate of 693 ha. This figure includes land opened in 1986 but not included in the census of that year, up until and including land identified as being cleared on the landsat image. From the late 1960s the area with vegetable crops ranged from 535 to 769 ha, but in the 70s and 80s estimates often varied by a factor of two for the same year, with the Government of Malaysia apparently underestimating the extent of vegetable production (fig. 5).

Major expansion of vegetable area between 1986 and 1990 took place in Ringlet, Bertram Valley, Kea Farm, and Ipoh Road subenvironments (table 7), while new land clearing in 1990 concentrated on Blue Valley, Kuala Terla, Ipoh Road, Ringlet, and particularly Sungai Ikan (table 8). As long as access is feasible, it seems that expansion of new areas will concentrate on lower angle slopes further up each valley (plate 5).

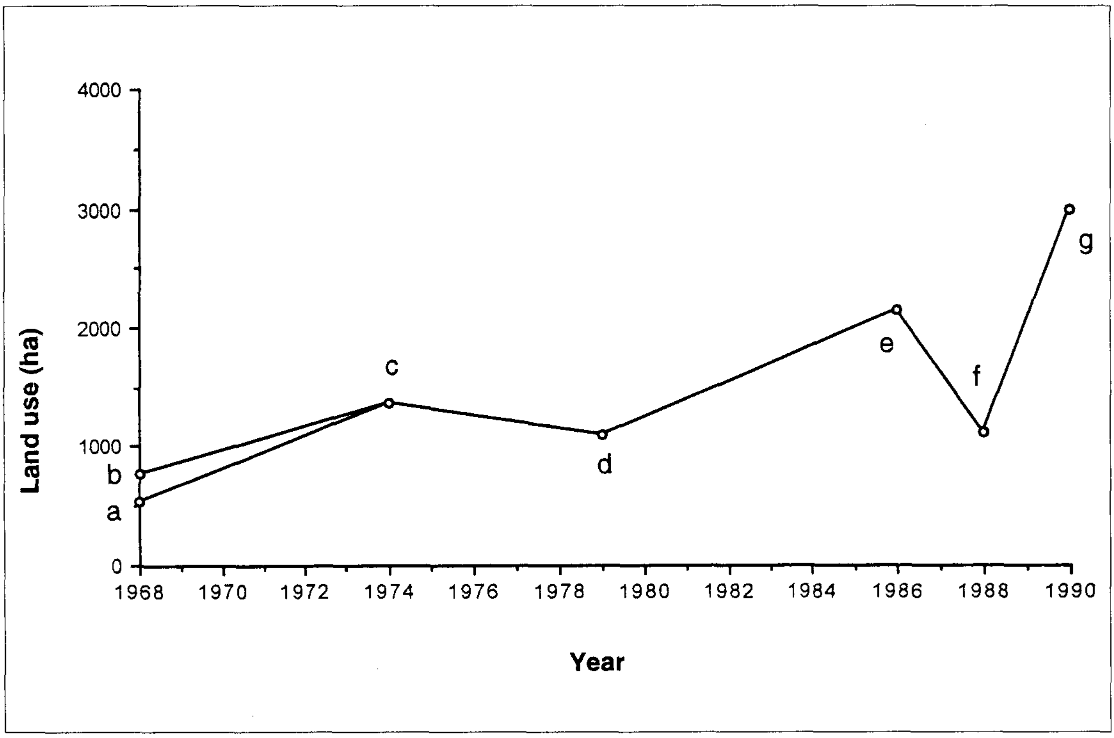

Fig. 5.
Reported vegetable production areas in the Cameron Highlands since 1968
(Source: a–Lin 1970; b–Macken and Siong 1979; c–Purushothanan 1976; d–Macken and Siang 1979; e–Ko et al.; f– Government of Malaysia 1988; g–Present satellite study)

Table 8. Distribution of landuses (in hectares) by slope category for the Cameron Highlands in 1990

Subenvironment/Landuses	Slope 0-2°	2-5°	5-10°	10-20°	20-30°	30-40°	>40°	Total
1. Blue Valley								
Vegetable and flowers	55.8	31.2	31.1	32.2	19.0	1.9	4.7	175.9
Tea	71.8	119.4	29.8	32.1	12.2	3.6	0.8	269.7
Scrub and scattered farms	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cleared tea	0.0	6.7	0.0	0.0	0.0	0.0	0.0	6.7
Opened up area	52.6	14.8	28.8	58.3	9.7	4.5	5.3	174.0
Town	0.0	10.7	0.0	0.4	0.0	0.0	0.0	11.1
2. Kampong Raja								
Vegetable and flowers	50.9	4.5	22.9	57.6	9.8	1.6	0.0	147.3
Tea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scrub and scattered farms	34.4	0.3	10.2	11.9	1.5	0.0	0.0	58.3
Cleared tea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Opened up area	11.7	2.7	8.5	18.1	1.8	0.2	0.1	43.1
Town	6.0	0.0	2.8	2.6	1.2	0.0	0.0	12.6
3. Sungai Ikan								
Vegetable and flowers	79.6	57.8	31.4	18.4	10.8	4.1	0.0	202.1
Tea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scrub and scattered farms	34.4	15.2	14.2	16.5	1.1	1.0	0.0	82.4
Cleared tea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Opened up area	165.6	52.7	57.9	56.1	14.4	3.4	3.7	353.8
Town	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4. Kuala Terla								
Vegetable and flowers	75.0	19.5	45.5	100.0	31.5	8.8	0.7	281.0
Tea	6.8	2.2	4.9	3.9	1.1	0.6	0.0	19.5
Scrub and scattered farms	16.6	6.8	27.0	46.9	13.0	2.8	0.0	113.1
Cleared tea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Opened up area	19.7	3.0	22.0	44.2	17.7	2.3	0.0	108.9
Town	0.0	1.8	1.2	2.9	0.1	0.0	0.0	6.0
5. Ipoh Road								
Vegetable and flowers	21.6	41.8	81.2	62.9	19.9	1.8	0.0	229.2
Tea	20.0	22.7	38.3	65.5	19.9	5.1	0.0	171.5
Scrub and scattered farms	18.9	3.0	13.6	31.0	16.4	0.2	0.4	83.5
Cleared tea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Opened up area	9.6	8.3	34.3	74.8	21.7	2.1	0.0	150.8
Town	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6. Batu 49								
Vegetable and flowers	1.8	0.4	15.6	29.1	9.4	0.5	0.0	56.8
Tea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scrub and scattered farms	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cleared tea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Opened up area	8.2	1.1	16.5	58.2	15.7	0.5	0.0	100.2
Town	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7. Tering Kap								
Vegetable and flowers	214.8	10.0	13.7	24.6	13.1	2.3	0.0	278.5
Tea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scrub and scattered farms	48.4	1.1	2.2	0.4	0.0	0.0	0.0	52.1

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Table 8. Distribution of landuses (in hectares) ...continued

Subenvironment/Landuses	Slope							Total
	0-2°	2-5°	5-10°	10-20°	20-30°	30-40°	>40°	
Cleared tea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Opened up area	56.5	0.4	6.8	10.9	3.1	0.4	0.0	78.1
Town	0.0	1.8	4.0	2.4	1.2	0.3	0.0	9.7
8. Sungai Palas								
Vegetable and flowers	43.4	3.6	34.8	52.4	21.6	8.3	0.4	164.5
Tea	53.4	4.0	39.1	144.3	43.8	8.1	0.0	292.7
Scrub and scattered farms	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cleared tea	3.5	0.2	3.6	1.8	2.1	0.3	0.0	11.5
Opened up area	18.5	1.8	14.7	43.7	11.4	0.7	0.0	90.8
Town	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9. Kea farm								
Vegetable and flowers	106.0	19.8	99.2	150.5	47.1	5.3	0.0	427.9
Tea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scrub and scattered farms	31.3	13.2	54.0	108.2	23.9	4.3	0.4	235.3
Cleared tea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Opened up area	0.2	0.0	1.0	9.6	7.9	0.3	0.0	19.0
Town	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10. Brinchang								
Vegetable and flowers	87.6	64.5	45.7	47.1	11.0	3.2	1.4	260.5
Tea	0.3	1.4	32.8	3.2	0.0	0.0	0.0	37.7
Scrub and scattered farms	67.8	80.5	74.4	48.3	11.3	4.7	0.0	287.0
Cleared tea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Opened up area	0.0	0.7	4.5	14.1	1.3	1.2	0.0	21.8
Town	9.8	56.0	7.7	8.0	2.3	0.2	0.0	84.0
11. Boh Road								
Vegetable and flowers	29.8	1.7	11.6	37.3	25.7	14.3	1.0	121.4
Tea	109.5	38.4	251.5	572.3	361.1	61.0	0.8	1,394.6
Scrub and scattered farms	18.9	5.0	19.7	49.0	37.0	11.1	1.1	141.8
Cleared tea	1.9	1.6	14.7	51.5	48.1	14.1	0.0	131.9
Opened up area	11.0	1.1	11.7	41.2	29.0	8.9	0.5	103.4
Town	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12. Bertam Valley								
Vegetable and flowers	125.3	16.4	76.9	199.9	107.2	29.9	1.8	557.4
Tea	5.9	1.0	5.1	4.0	2.9	4.4	0.3	23.6
Scrub and scattered farms	59.8	7.5	59.8	223.6	204.4	69.4	2.2	626.7
Cleared tea	2.0	1.5	8.5	29.6	13.1	4.7	0.0	59.4
Opened up area	1.4	4.9	14.3	34.8	31.0	10.3	0.0	96.7
Town	21.9	0.0	0.0	0.0	0.0	0.0	0.0	21.9
13. Ringlet								
Vegetable and flowers	76.7	27.4	79.2	85.9	28.3	3.7	0.1	301.3
Tea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scrub and scattered farms	46.9	31.9	57.7	99.6	45.0	9.9	1.6	292.6
Cleared tea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Opened up area	13.5	8.5	25.1	45.8	17.1	1.7	0.2	111.9
Town	14.2	0.0	4.1	10.9	3.9	0.6	0.0	33.7

3.1.2 *Erosivity*

Although a close linear fit was observed between monthly rainfall erosivity and rainfall (fig. 6), the datum for the month of May, 1991 was an important outlier, when erosivity was much greater than expected based upon data for the monthly rainfall. It is probable that a large proportion of the erosion for the 11-year period would be accounted for by that month's KEt. A visit to the area in September 1991 provided visual evidence of severe gully erosion and landslips, and suggests that erosion control practices, to be effective, should be implemented in anticipation of extraordinary rainfall events. The low likelihood of such rare events does not encourage farmers to adopt preventative measures. During the survey, 10% of farms still had visual signs of severe landslip.

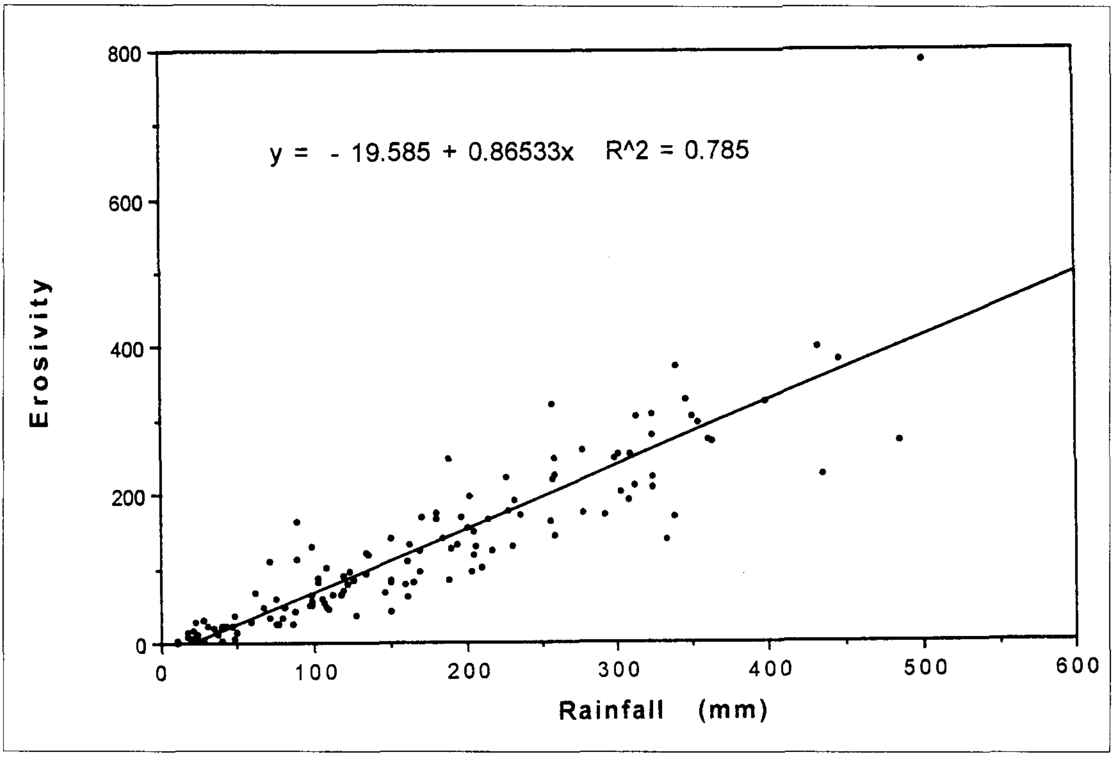

Fig. 6.
Relationship between monthly erosivity and rainfall for the Cameron Highlands, 1981–1991 (*Source: Dumsday and Huang 1992*)

3.1.3 *Farm sizes, land ownership, and investment in infrastructure*

At just over 0.8 ha (table 9), average farm size among sample farmers exceeded the average of 0.55 ha in the CH (Dumsday et al. 1991) and is about double the national average for vegetable growers reported by Anang (1989). A recent survey in the CH (Taylor et al. 1993) reported 0.85 ha as the average farm size, hence, previous estimates may need to be adjusted upwards. In fact, if farm numbers have not markedly increased in the recent past, the recorded increase in individual farm size is in line with the observed increase in total area under vegetables in the CH.

Table 9. Land statistics (hectares) for individual farms surveyed in the Cameron Highlands

	N	Mean	Min.	Max.	CV
Total farm size	193	0.82	0.16	4.0	0.57
Cultivated land	193	0.75	0.16	4.0	0.58
Owned land	32	0.75	0.28	2.0	0.48
Temporarily occupied land	130	0.89	0.16	4.0	0.57
Rented-in land	32	0.56	0.20	1.6	0.60
Land rent paid (M$/ha/year)	32	7,314	750	15,000	0.54
Irrigated land					
- sprinkler	175	0.74	0.16	4	0.60
- other irrigation	26	0.53	0.10	1.2	0.68
Plastic shelter area	50	0.40	0.04	1.8	0.78
Platform terrace area	157	0.67	0.02	4.0	0.62
Bench terrace area	47	0.27	0.02	1.2	1.04

Most farmers' tenure arrangement consists of a Temporary Ownership Licence (TOL); 67% of farmers in our study and 75% in the study by Taylor et al. (1993) farmed TOL land. TOLs are a common form of land tenure where land is held for 5-15 years, with nominal fees (about M$250-350/ha/year) paid annually or periodically, accompanied by reviews of landuse and management practices. There have been few cases of TOLs being revoked. Only 16% of all sample farmers rent some of their land from others. Those who rent have an average rented-in area of less than 0.6 ha at an average rental cost of over M$7000/ha.

All farmers irrigate their vegetable land, mostly using sprinkler systems. All farms have some form of irrigation facility, 90% with sprinkler irrigation. Water is directed from stream flow higher in the watershed by way of small weirs and plastic pipes to provide sufficient head to operate sprinklers. Generally, farmers have sufficient facilities to irrigate their whole farm area (fig. 7). About one-quarter of all sample farmers make use of plastic shelters; on average, about 0.4 ha of land is covered by farmers who use shelters.

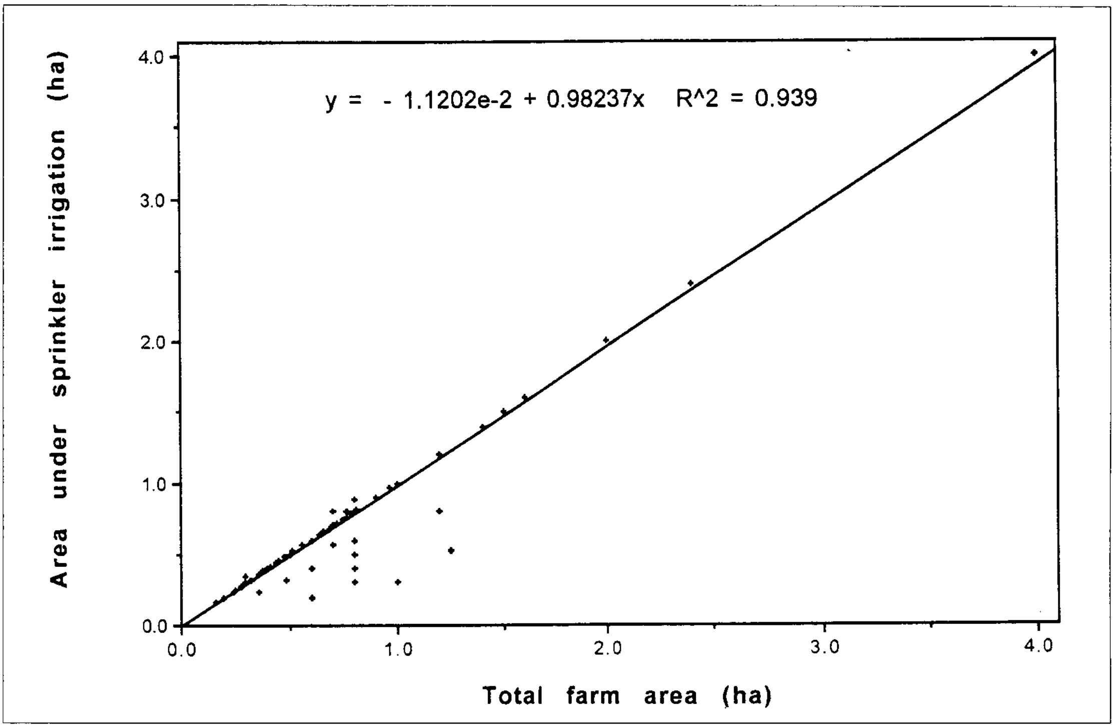

Fig. 7.
Area irrigated by sprinkler in relation to total farm area for each farm surveyed

3.1.4 Household composition and individual farmer characteristics

The number of persons living in the sample households ranged from 1 to 20, for a sample average of 5.8 members per household (table 10). On average, a sample household is comprised of 3.8 adults (defined as persons 17 years or older), 1.1 youngsters (between 10 and 17 years), and 0.9 children (less than 10 years old). Vegetable farming is the main occupation of all respondents, with farming as the sole source of income for 95% of them. Three respondents also worked as teachers, two as shopkeepers, and two as drivers.

Table 10. Household composition in survey farms in the Cameron Highlands

	N	Mean	Min.	Max.	CV
No. of males > 17 years	194	2.16	1	12	0.74
No. of females > 17 years	181	1.76	1	8	0.62
No. of male children 10-17 years	72	1.51	1	4	0.46
No. of female children 10-17 years	64	1.53	1	4	0.59
No. of male children < 10 years	66	1.56	1	5	0.57
No. of female children < 10 years	51	1.47	1	5	0.55
Total household size	194	5.79	1	20	0.51

The Chinese have been involved in vegetable production in the CH for many years, hence, the greater proportion of sample farmers had Chinese ethnic background; 39 farmers were Indian, and only two were Malay. Ninety-five percent of all sample farmers were males. Half of all sample farmers have had only primary education, while the majority of the others have had a secondary education. Only 1% of sample farms had no education whereas 7% had a college education. Respondent farmers were between 18 and 80 years old, with an average age of 41 years and an average of 16 years of vegetable farming experience. Generally, vegetable farmers in the CH enjoy a good standard of living, with most of them having either a saloon car or a four-wheel drive vehicle. The perception of the majority of the farmers is that their living standard has improved considerably, but that it may not improve much in the near future. The most successful Chinese vegetable growers are currently investing heavily in infrastructure for floriculture, which is viewed as an alternative source for capital growth.

3.2 Enterprises and cropping patterns

3.2.1 Livestock ownership

Livestock play a minor role in vegetable production systems in the CH. Only two farmers kept some livestock, in both cases small ruminants (i.e., goats and sheep, with one farmer keeping a total of 3, the other 30 head). Thus, virtually all organic fertilizer used on vegetables is purchased.

3.2.2 Nonvegetable crops

While most sample farmers exclusively grew vegetables, 14 also produced cut flowers. The annual value of flower production in the CH has been estimated at some M$20 million (Dumsday et al. 1991) or about 40% of the value of vegetable production. However, the data collected to calculate the profitability of flower cultivation (both in absolute terms and relative to that of vegetables) were unreliable. Nevertheless, flower cultivation is generally considered an increasingly important and profitable enterprise, and a comparison with vegetable production might be worthwhile in the future.

3.2.3 Cropping patterns for vegetables

Most farmers grow between two and five different vegetable species (fig. 8) while most grow three. The 13 most popular vegetable crops in the CH (fig. 9) include English cabbage (*Brassica oleracea* var. *capitata*), Chinese cabbage (*Brassica pekinensis*), tomato (*Lycopersicon esculentum*), lettuce (Indian *Lactuca indica* and head *L. sativum*), onion (*Allium cepa*), snow peas (*Pisum sativum* var. *macrocarpon*), celery (English *Apium graveolans* var. *dulce* and Chinese *A. graveolans* var. *secalinum*), spinach (*Spinacia oleracea*), tong ho (*Chrysanthemum coronarium*

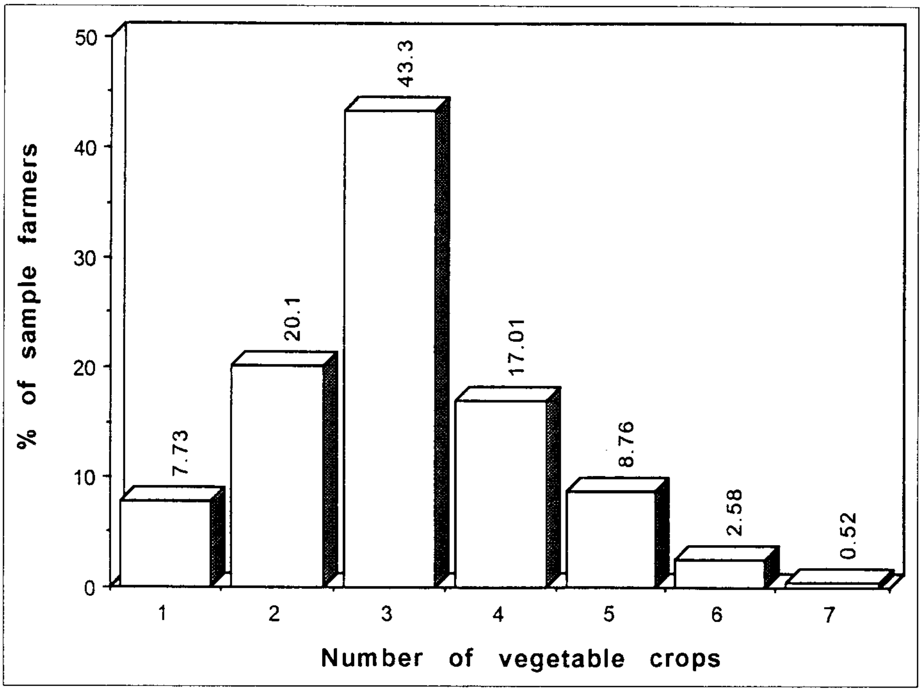

Fig. 8.
Number of different vegetable crops grown per farm per year

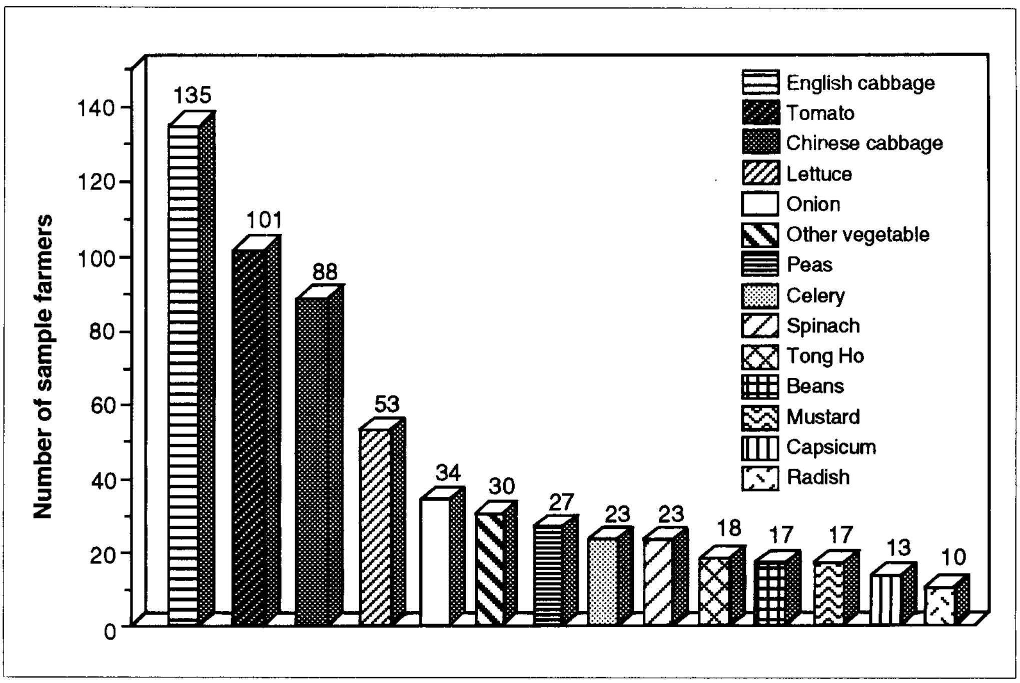

Fig. 9.
Vegetable crops most frequently grown by sample farmers

= garland chrysanth), beans (butter *Phaseolus lunatus*, green *Phaseolus vulgaris*, French *Phaseolus vulgaris*), mustard (Chinese *Brassica juncea* kaves, leaves), *Capsicum* sp., and radish (*Raphanus sativus*).

The heterogeneous category "other vegetables" includes (number of sample farmers in parentheses) asparagus [*Asparagus officinalis* (4)], carrot [*Daucus carota* (2)], cauliflower [*Brassica oleracea* var. *botrytis* (1)], Chinese matrimony [*Lycium chinense* (3)], pak choy [*Brassica chinensis* (6)], coriander [*Coriandrum sativum* (2)], leek [*Allium ampeloprasum* (4)], parsley [*Petroselinum crispum* (1)], potato [*Solanum tuberosum* (1)], and water cress [*Rorippa nasturtium-aquaticum* (3)].

As they are the most commonly grown vegetables, analysis of cropping patterns is presented separately for tong ho, spinach, onion, Chinese cabbage, English cabbage, and tomato (e.g., fig. 10). The other vegetables were grouped into two groups: Veg. 7 and Veg. 8, corresponding to the seventh and eighth crops grown on each farm after the major six vegetable species were accounted for.

Farmers' cropping patterns are determined by a variety of factors. For example, cabbage is relatively easy to grow, without the need for plastic shelters. On the other hand, crops such as spinach, tong ho, and lettuce need rain shelters for optimal yield performance. Tomato is a crop with a relatively high labor requirement.

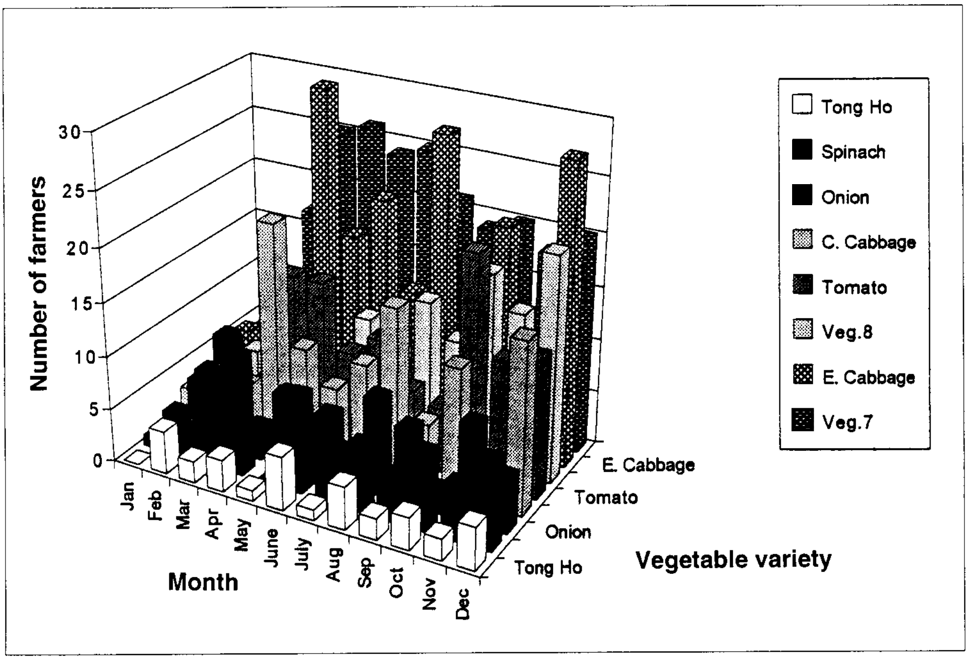

Fig. 10.
Distribution of major crops by harvest period

The popularity of intercropping depends on the species grown. Cabbage, tong ho, lettuce, celery, beans, mustard, and capsicum are usually grown as a sole crop, while intercropping is more common in onion, spinach, peas, and tomato. When intercropped, tomato is predominantly grown in association with cabbage [and cabbage also commonly with leek - Taylor et al. (1993)], but intercropping of most other vegetables involves a wide variety of different crops. A large proportion of respondents indicated that intercropping was often precluded due to labor shortages, and when practiced it was believed to reduce price risks and control some pests and diseases (Taylor et al. 1993).

3.2.4 Cropping systems

Vegetables are grown year-round, although some seasonality is encountered among species. Consideration of harvest time is important in relation to soil exposure and erosion during pre-sowing cultivation, and before complete ground cover by the succeeding crop. Peak transplanting of English cabbage occurs in February/March and May, with November and December as the only months with relatively little transplanting of this crop (table 11). Peak transplanting of tomato, another crop which is commonly transplanted, is in February, April, and July to September with very little transplanting occurring from October to December. Directly sown crops such as onion and spinach tend to be sown more in the driest month of January, to reduce washout of small seed if not protected, with few farmers sowing during the peak rain periods (April/May and October/November).

Harvest of English cabbage is less predominant during dry than wet periods [with the exception of December (fig. 10)] with peaks in April and August [(when prices are low, although the farmer price of cabbage only varies by a factor of two throughout the year (GOM/ADB 1988 and table 12)]. Harvest of Chinese cabbage follows a pattern similar to that of English cabbage (fig. 10) while onion is more commonly harvested prior to peak rains (March and August), with spinach and tomato slightly later.

Table 11. Number of survey farmers who sow, transplant, and harvest the six principal crops, plus the two subgroups of crops, during a calendar year in the Cameron Highlands

Sow	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
English cabbage	29	19	14	28	15	16	15	22	19	8	7	2	194
Chinese cabbage	24	10	10	8	10	7	11	4	14	5	4	1	108
Onion	14	3	7	4	2	6	8	4	8	8	2	4	70
Spinach	11	8	7	3	9	6	6	5	8	4	6	3	76
Tong ho	5	2	2	6	5	0	3	3	3	1	5	1	36
Tomato	16	8	17	7	10	10	16	13	9	8	4	1	119
Veg.7	18	25	15	15	18	12	17	14	10	12	3	9	168
Veg.8	10	3	5	9	2	9	8	11	11	9	5	4	86
Total	127	78	77	80	71	66	84	76	82	55	36	25	857
Transplant	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Chinese cabbage	1	12	2	9	5	4	4	7	1	5	2	0	52
Onion	0	0	1	0	0	0	1	0	0	1	1	0	4
Spinach	0	0	1	1	0	0	0	0	0	0	0	0	2
Tong ho	0	0	0	0	1	2	0	0	1	0	1	1	6
Tomato	7	15	6	14	3	8	10	10	10	5	5	4	97
Veg. 7	0	7	3	6	5	8	2	7	6	3	1	3	51
Veg. 8	0	1	1	0	1	0	4	4	3	4	4	1	23
Total	23	63	34	42	41	35	39	44	41	36	21	15	434
Harvest	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Chinese cabbage	3	4	5	21	10	7	10	16	6	12	2	16	112
Onion	2	6	11	3	7	3	3	9	7	2	9	5	67
Spinach	1	3	9	11	0	9	8	6	4	7	5	8	71
Tong ho	0	4	2	3	1	5	1	4	2	3	2	4	31
Tomato	2	4	4	15	15	9	11	7	6	21	12	13	119
Veg. 7	4	9	17	25	26	24	25	21	19	20	18	20	228
Veg. 8	5	5	11	8	6	11	11	14	11	18	15	21	136
Total	22	46	70	116	82	89	82	105	67	104	73	115	971

Table 12. Prices and annual production value of vegetable crops by survey farmers in the Cameron Highlands

Vegetable	Price (M$/kg)			Total prod'n value ('000 M$) based on		
	average	high	low	avg. price	high price	low price
English cabbage	0.64	0.84	0.46	1,799	2,424	1,086
Chinese cabbage	0.53	0.67	0.38	669	854	477
Mustard	0.83	1.07	0.61	85	111	60
Spinach	1.19	1.64	0.73	202	279	118
Tong ho	1.39	1.85	0.90	131	174	81
Lettuce	1.04	1.30	0.77	291	368	207
Celery	1.06	1.42	0.67	96	126	57
Onion	0.82	1.13	0.48	232	359	102
Beans	1.54	1.81	1.29	112	135	89
Peas	4.66	5.86	3.47	339	435	242
Tomato	0.92	1.23	0.64	976	1330	644
Capsicum	1.97	3.00	1.13	193	289	117
Radish	0.45	0.61	0.28	26	35	16
Other vegetables	1.73	2.05	1.20	491	634	313
Total all vegetables				5,642	7,553	3,609

3.3 Volume of vegetable production and profitability

3.3.1 Area, production, yields, prices, and production value of vegetables in the CH

The total gross area cultivated with vegetables (i.e., taking account of multiple cropping and intercropping) by the sample farmers came to 318 ha with cabbage (Chinese and English), tomato, lettuce, and "other vegetables" accounting for respectively 47, 15, 7, and 5%. The average cropping intensity (area cropped/year per land area) equals 2.2, which is considerably less than the value of 3.2 four years earlier calculated from data of GOM/ADB (1988). Area, production, and yields of individual vegetable species show wide variation between sample farmers (table 13). On average, cabbage, tomato, and capsicum are the highest yielding species in the CH, with per hectare yields in the neighborhood of 27 t, although some farmers reported yields as high as 70 t/ha. Most other vegetable species have average yields of between 10 and 15 t/ha, with the exception of snow peas which yield on average less than 6 t/ha. Given that the sample represents 10% of all vegetable farmers in the CH, the figures in table 13 suggest a total daily vegetable production of 179 t, confirming the MARDI estimate cited in Dumsday et al. (1991).

Table 13. Area, production, and yields of vegetable crops by survey farmers per annum in the Cameron Highlands

Vegetable	Gross area (ha)					Gross production (t)				Yield (/ha)			
	N	Mean	Min.	Max.	CV	Mean	Min.	Max.	CV	Mean	Min.	Max.	CV
English cabbage	135	0.73	0.12	4.8	86.7	18.7	1.8	108	99.4	27.1	6.3	84.4	59.3
Chinese cabbage	88	0.54	0.12	2.0	63.8	14.2	1.2	75	85.2	26.4	5.0	72.5	54.9
Mustard	17	0.57	0.12	2.4	105.7	6.4	0.7	30.0	104	12.9	4.5	27.5	56.5
Spinach	23	0.62	0.12	2.16	86.4	7.1	0.5	20.5	89.8	14.5	1.3	56.3	95.1
Tong ho	18	0.47	0.12	1.2	81.7	6.3	0.5	28.8	114	14.8	1.3	45	76.7
Lettuce	53	0.42	0.10	2.0	77.2	5.2	0.8	21.0	75.8	12.8	3.4	26.3	48.0
Celery	23	0.40	0.08	2.16	110.1	3.9	0.2	12.0	87.2	13.9	0.8	45.0	88.4
Onion	34	0.56	0.12	2.8	93.0	6.7	0.3	30	103.6	13.0	1.0	60	87.3
Beans	17	0.30	0.08	1.2	89.8	3.5	0.3	28.5	188.1	10.1	2.0	23.8	63.9
Peas	27	0.44	0.10	2.0	78.7	2.5	0.03	12.5	101.5	5.7	0.2	22.5	77.6
Tomato	101	0.46	0.08	2.0	71.5	11.2	0 [a]	75	91.4	26.0	0 [a]	75	60.0
Capsicum	13	0.33	0.13	0.7	55.3	7.7	0.9	22.5	90.0	27.1	3.3	68.8	89.7
Radish	10	0.43	0.10	1.2	77.3	5.6	2.8	12.6	53.2	16.1	7.0	30.0	43.0
Other vegetables	30	0.56	0.10	1.68	84.0	12.1	0.4	94	154.0	18.7	1.4	65.5	95.0

[a] one farmer experienced crop failure

The value of annual vegetable production by the sample farmers at average prices is M$5.642 million (table 12), giving an estimated total annual production value for the CH of M$56.42 million. This latter figure agrees with estimates made by MARDI, though it is significantly below the estimate of M$100 million provided by the Department of Agriculture (Dumsday et al. 1991).

Due to its large area and high yields, English cabbage is responsible for nearly one-third of the total value of vegetable production in the CH, despite its low price relative to most other vegetables. On the other hand, due to its high unit price, snow peas account for some 6% of total production value, despite its relatively low production volume. The fact that capsicum is responsible for 3.5% of total production value but less than 1.5% of total area reflects its high price, combined with relatively high yields.

On average, the difference between the highest and lowest prices received ranges from a factor of 1.4 (for beans) to 2.7 (for capsicum). Data presented in Ding et al. (1981 - table 11.6) allow a comparison between 1991 and 1981 vegetable prices (in nominal terms). Whereas, over the span of one decade, prices for spinach have nearly doubled and that for beans have increased by 50%, prices of English cabbage, capsicum, and radish have significantly decreased in the order of 40%. Nominal prices of lettuce, mustard, and tomato have largely remained the same, implying significant decreases in real prices. With the exception of spinach, capsicum, and radish, within-year price fluctuations (measured by the ratio of the highest and lowest average price received by farmers during a particular year) decreased between 1981 and 1991. This ratio had substantially exceeded 2.0 for almost all vegetables in 1981, but had dropped below 2.0 for most vegetables by 1991.

Practically the entire vegetable produce is sold, mostly to wholesalers. Together with other farmers and lorry operators, wholesalers are the most important sources of marketing information for farmers.

3.3.2 *Costs and returns of vegetable cultivation in the CH*

Costs and returns of vegetable cultivation were calculated at two levels. First, net returns per hectare per year were calculated for each individual vegetable species (i.e., totals for the year for all crops of each species grown during the year), defined as the difference between gross sales revenues and the sum of expenditures on seed, manure, chemical fertilizers, pesticides, and tractor use. Net returns calculated in this way can be interpreted as returns to labor (including management) plus money left over to pay for what mostly are fixed costs, including irrigation investment, plastic shelter costs, costs to make beds and terraces, land rent and taxes, electricity costs, and marketing costs.

Second, total net income per farm per year was calculated as the sum (over vegetable species) of net returns per hectare per year, multiplied by the actual area for each individual species, minus the sum of the cost items which could not be attributed to individual vegetable species. The latter include hired labor costs (including permanent labor, but excluding family labor); annualized costs of irrigation, plastic shelters and terrace construction; recurrent cost of beds (remaking) and terraces (resurfacing); other material costs; land rent and taxes; electricity costs; marketing costs; and any other costs not included elsewhere. Total net income per farm per year calculated in this way can be interpreted as net profits or returns to own land, family labor, and management.

Table 14 shows the mean costs and returns for the most commonly grown vegetables in the CH. Net returns throughout the year per hectare at average prices vary between M$9000 and 14,000 for most vegetable species with the exceptions of onion, radish, peas, tomato, capsicum, and "other vegetables". While onion and radish seem to generate relatively low returns (particularly at the lower end of the price range), peas, tomato, and (particularly) capsicum have above-average returns. However, for capsicum, the high returns may be offset by the high costs of constructing rain shelters. With the exception of capsicum for which our survey finds exceptionally high returns, these results are consistent with those from an earlier survey carried out by MARDI and reported by Ding et al. (1981).

Expenditures for manure (mostly chicken dung to improve soil fertility) account for the largest part of total material costs for every vegetable except celery and radish, and are particularly high for capsicum (table 15). Except for mustard, tomato and capsicum, expenditures for fertilizer usually exceed those for pesticides. However, a note of caution is in order here. Many farmers were reluctant to give full information about pesticides, with about half of the respondents supplying either no information at all or revealing only partial information. As a result, quantities used were certainly underreported, and the figures for pesticide expenditures in table 15 should be regarded as underestimates. A direct consequence of this situation is, of course, that net returns may have been overestimated.

While the share of tractor costs in total material costs is small for all vegetables, the share of seed costs differs widely among different vegetables, on average varying from only 1% for tomato (indicative of the fact that nearly all tomato farmers use their own seed) to nearly 50% for onion.

Table 16 summarizes the results for total net income per farm per year. Costs for semipermanent structures such as irrigation facilities, plastic shelters, and terraces need to be spread over several years and were annualized. On the basis of the survey data, the life span of irrigation structures was set at 10 years. A similar assumption was made for plastic shelter structures with a life span of 2 years. Terraces were assumed to last for 15 years.

Table 14. Mean costs and returns of vegetable crops in survey farms in the Cameron Highlands (M$/ha)

Type of vegetable	Average gross revenues at				Material costs[a]	Net returns at[b]		
	No.	mean price	high price	low price		mean price	high price	low price
Amaranthaceae								
Spinach	23	15,553	21,569	9,423	2,448	13,105	19,121	6,976
Compositae								
Tong ho	18	15,583	21,427	9,455	2,000	135,84	19,427	7,455
Lettuce	53	12,884	16,301	9,480	2,711	10,172	13,590	6,769
Umbelliferae								
Celery	23	13,484	19,217	7,558	2,013	11,471	17,204	5,545
Cruciferae								
English cabbage	135	17,166	22,625	12,114	3,598	13,567	19,027	8,516
Chinese cabbage	88	13,472	16,915	9,974	3,649	9,824	13,266	6,325
Mustard	17	11,446	14,410	8,665	2,129	9,316	12,280	6,,536
Radish	10	7,759	10,610	4,766	2,503	5,256	8,107	2,263
Alliaceae								
Onion	34	9,794	13,440	5,798	2,976	6,818	10,464	2,822
Leguminosae								
Beans	17	15,708	18,744	12,577	2,262	13,446	16,482	10,315
Peas	27	24,575	30,792	18,072	4,216	20,359	26,575	13,855
Solanaceae								
Tomato	101	22,997	31,675	15,240	4,111	18,887	27,564	11,129
Capsicum sp.	13	50,251	76,996	30,508	6,697	43,554	70,299	23,811
Other vegetables[c]	30	23,923	29,182	16,101	2,769	21,154	26,413	13,332

[a] Includes cost for seed, manure, fertilizer, pesticides, and tractor use

[b] Includes returns to labor plus money left over to pay for irrigation investment costs, plastic shelter costs, costs to make beds and terraces, land rent and taxes, electricity costs, vehicle, and marketing costs

[c] Consists of a wide range of vegetables grown by relatively few sample farmers, including asparagus, carrot, cauliflower, Chinese matrimon, choy, coriander, kau-ki, leek, parsley, potato, and water cress

Table 15. Breakdown of material costs by vegetable species as purchased by sample farmers in the Cameron Highlands

		Average amount (M$/ha) spent on				
Vegetable	N	seed	manure	fertilizer	pesticides	tractor use
English cabbage	135	335	1,755	958	491	60
Chinese cabbage	88	331	1,976	710	592	53
Mustard	17	93	952	467	578	40
Spinach	23	400	954	572	413	109
Tong ho	18	208	799	616	272	145
Lettuce	53	140	1,335	796	380	61
Celery	23	179	460	805	530	38
Onion	34	1,450	766	385	342	33
Beans	17	149	853	665	542	53
Peas	27	484	1,499	1,345	810	79
Tomato	101	56	1,948	1,027	1,039	51
Capsicum	13	212	3,436	1,478	1,541	30
Radish	10	302	775	931	101	91
Other vegetables	30	183	1,233	894	431	28

The calculations from which data in table 16 were derived indicate that about one-quarter of all sample farmers lose money. However, it should be noted that the results are only for 1 year, that it is normal for some farmers to make losses in some years, and that the income figures may be understated due to unreliable data collected on income other than that from vegetable production, for example income from flower production.

Net income was related by statistical correlation to various inputs, management practices, and environmental factors.

There was no increase in NFI (expressed per hectare) with scale of production, nor with annual volumes of manure, lime, or fertilizer application. Nor was NFI related to freehold ownership, slope of land (natural or manmade), nor directly to soil physical composition. However, with increasing proportion of bench terraces per farm the NFI appeared to increase ($r^2 = 0.07$, $p = 0.05$, $n = 54$) while with increasing proportion of land under plastic shelters NFI decreased ($r^2 = 0.25$, $p \leq 0.001$, $n = 41$, fig. 11). Average NFI within subenvironments was positive in subenvironments with less sand or greater EC (1:5).

Table 16. Mean annual costs and returns (M$) per farm for vegetable production by survey farmers in the Cameron Highlands for 1991

	N	Mean	Standard deviation
Total annual gross revenues			
from vegetable crops	193	27,702	26,919
Total annual material costs (vegetable-crop specific)			
- seed	190	519	591
- manure	188	2,510	2,519
- fertilizer	189	1,486	1,835
- pesticides	164	748	729
- tractor use	166	92	185
Total annual costs (nonvegetable specific)			
- hired labor costs	91	5771	8,447
- annualized costs of [a]			
- irrigation			
- sprinkler	172	1,682	2,432
- other	17	1,405	1,268
- plastic shelters	39	5,095	4,559
- terraces			
- bench	48[b]	374	395
- platform	158[b]	2,131	1,330
- bed costs	57	910	1,233
- cost of liming	117	306	360
- costs of other materials	188	2,357	1,608
- land rent	32	3,946	3,361
- land taxes	158	286	277
- electricity costs	80	337	218
- marketing costs	131	883	724
- other costs	2	4,500	707
Total input costs	193	16,729	12,925
Net annual income per farm	193	10,974	21,876

[a] Using the following formula: $A = P[r/1-(1+r)^{-t}]$ where A is the annualized capital cost of the structure; P is the current cost of the structure; t is the assumed life span of the structure; and r is the interest rate at which the farmer can obtain a loan (which is currently 8%)

[b] Does not include rented farm areas with terraces

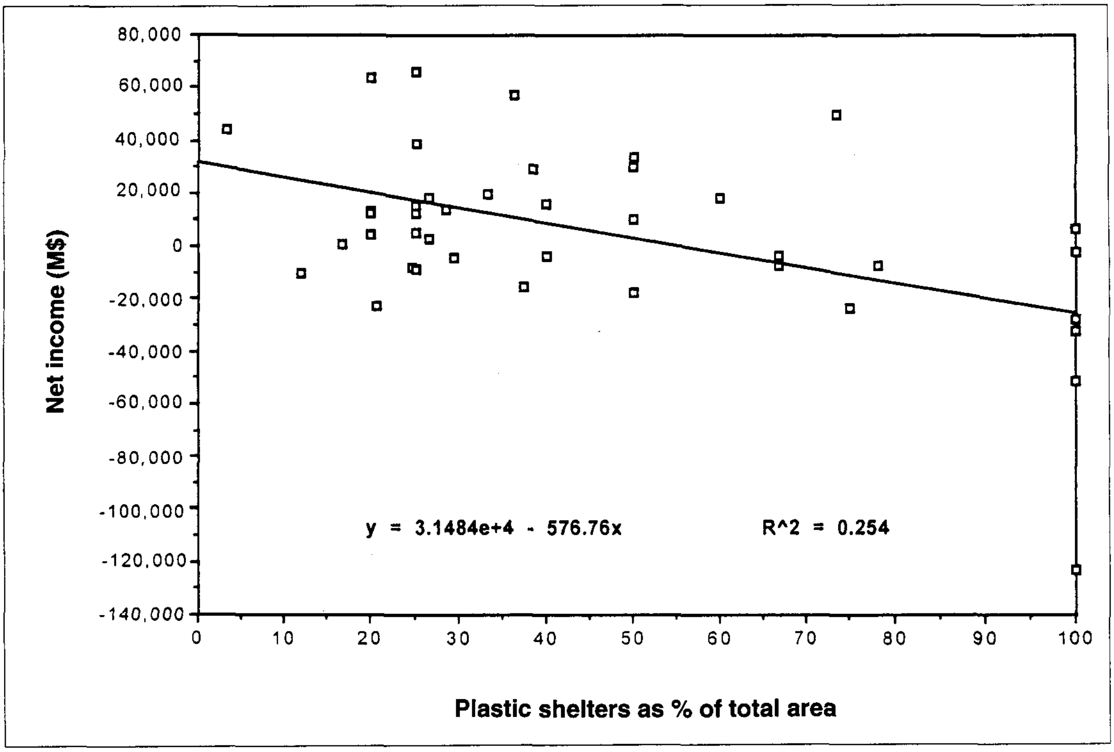

Fig. 11.
Net income per hectare as influenced by the proportion of land under plastic shelters

3.4 Sustainable production practices

3.4.1 *Use of pesticides and adoption of IPM practices*

In Malaysia, the presence of pesticide residues on market vegetables and fruits has long been a matter of serious concern and is often attributed to the failure of farmers to restrain application before harvesting. Aside from the effects on farmer (including pesticide poisoning during application) and consumer health and the environment, the presence of pesticide residues has significant trade implications as well[3] (Lim et al. 1988).

To make an adequate assessment of the extent of possible environmental damage caused by the overuse of pesticides in horticultural production, data are needed regarding the use of agro-pesticides by the production system. With the exception of data for highland vegetable production systems which are available from the present survey, such data are generally difficult to obtain, although some scattered secondary information is available. Agro-pesticides were a US$297 million industry in Malaysia during 1989, 81% of which was spent on herbicides, 12% on insecticides, 4% on fungicides, and 3% on rodenticides.

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[3] For example, in 1987 vegetables exported to Singapore were rejected because of fungicidal residues.

Orchards and vegetables accounted for only 7% and 3% of the herbicides used, whereas rubber and oil plantations accounted for more than 60%. Cocoa areas took 10%, and the remaining 11% was used in forestry and nonagricultural use. The use of nonliquid herbicides in Malaysian agriculture has declined by about 35% between 1985 and 1989, but the use of liquid herbicides has increased by 21%, resulting in an overall increase of about 4.5% (Anon. 1991). While the total proportion of herbicide use in Malaysia on vegetables is minimal, fungicide and insecticide use on vegetables represent 38% and 25%, respectively of total use in Malaysia.

In general, most vegetable farmers in Malaysia rely solely on chemicals which are often used indiscriminately to control pests, and the use of IPM methods is minimal (Lim et al. 1988). Ninety-seven percent of all survey respondents regarded pesticides as a necessary input without which production of vegetables would be impossible, even though about half of them had heard about IPM.

The question "Do you use MARDI's IPM package?" was included as a late suggestion in the survey, and was only asked in subenvironments 12 (Bertam Valley, 29 farms) and 13 (Ringlet, 10 farms). Five of the 39 farmers (13%) actually claimed to use MARDI's IPM package which is comprised of a combination of counting of diamondback moth (DBM) larvae and the degree of parasitism, and basing sprays with *B. thuringiensis* or synthetic insecticides upon predetermined economic threshold levels (Loke et al. 1991).

Cultural methods are used to control diseases such as clubroot (mostly crop rotations) and were claimed to be implemented by 111 (or 55%) of all sample farmers. Even though over 50% of all farmers were aware of natural enemies (e.g., *Apanteles plutellae*) of DBM, one of the most common and serious insect pests which particularly affect cabbage, only 16 (8%) farmers promoted biological control methods (mostly wasps). Of these, 12 were in the cooler central portion of the CH, confirming the thesis of Taylor et al. (1993) that farmers in the central zone show a greater tendency to follow IPM for DBM. Analysis of awareness of IPM strategies for pest control across subenvironments (fig. 12) showed a greater preponderance in the cooler subenvironments such as Kuala Terla, Ipoh Road, Tering Kap, Kea Farm, and Brinchang. Whether this is due to the greater emphasis MARDI, following research in the CH, has placed on extension of their package[4] in that region or the more favorable climatic conditions for parasitism of DBM larvae is unclear. A worrying concern for the continued success and expansion of IPM is the view of 31% of sample farmers that pesticides offer the best solution to their farming problems, compared to 26% who considered curtailment of vegetable imports and a policy of stabilized prices as solutions to their major farming problems!

[4] The MARDI package has included the release of four more parasitoids, of which only *Diadegma semiclausum* and *Diadromus collaris* became established (Syed n.d.).

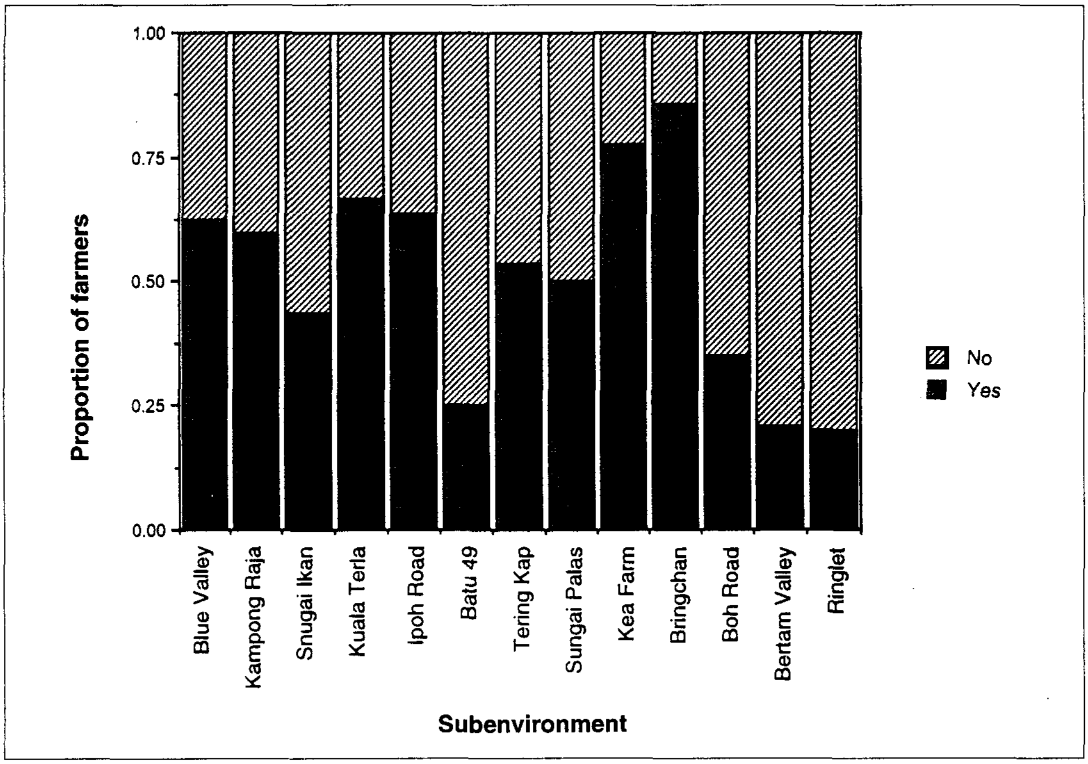

Fig. 12.
Proportion of farmers who have heard of IPM within each environment

Given the importance of cabbage in farmers' cropping patterns, it is no surprise that DBM is the most common insect pest on vegetables in the CH (fig. 13). Other pests frequently mentioned by farmers included armyworms, aphids, snails, and leaf miners. As far as diseases are concerned, the most frequently mentioned diseases include black rot, leaf spot, and soft rot (fig. 14).

Forty-two percent of all sample farmers claimed to use smaller amounts of insecticides than in the past while 34% claimed to be using more; 25% used similar quantities as those in the past. These figures are in line with those reported by Taylor et al. (1993) for English cabbage as 39% less, 24% similar, and 38% more insecticide use compared to 5 years ago. A switch in types of pesticide was reported by 77% over recent years, nearly exclusively because of increased resistance of insects to previously used chemicals. Of the 50 farmers who use plastic shelters, 27 claimed a reduction in the incidence of pests, with 14 farmers using less insecticides as a result.

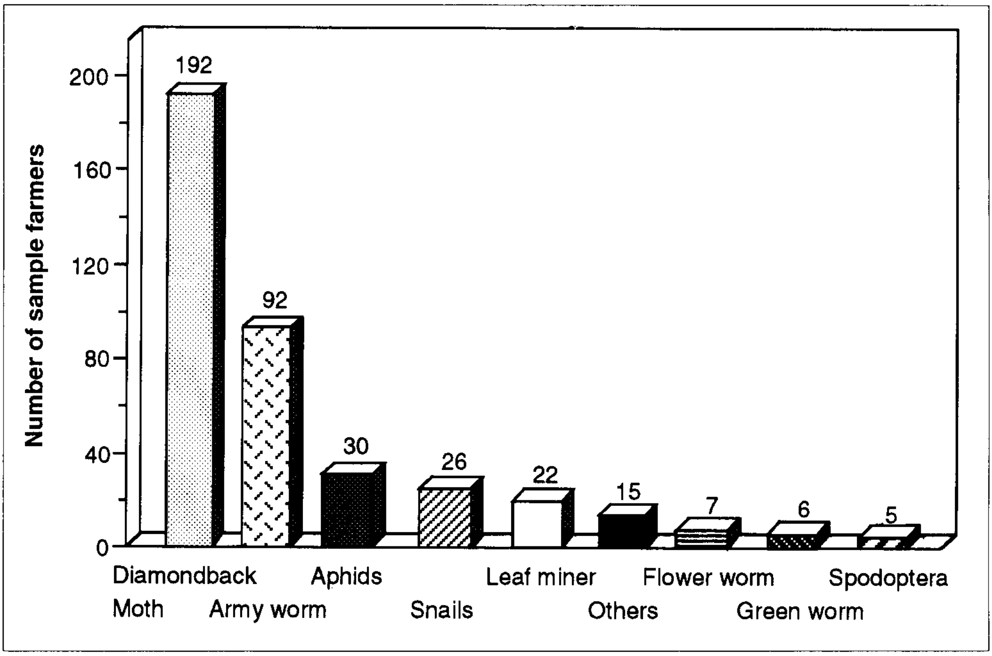

Fig. 13.
Number of farmers who mentioned various pests

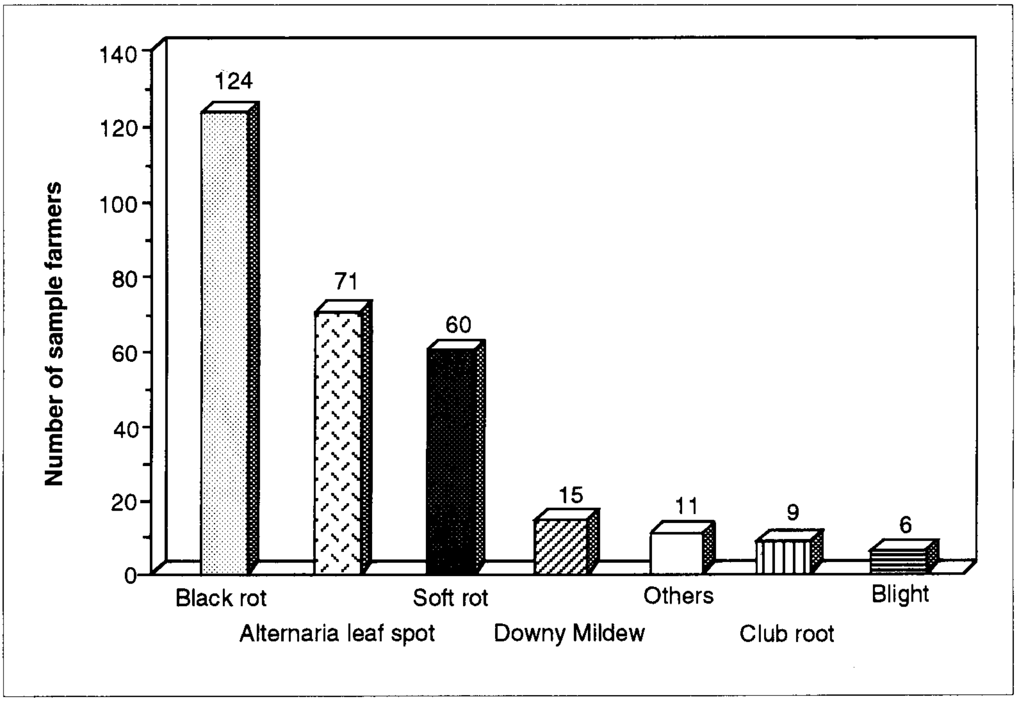

Fig. 14.
Number of farmers who mentioned various diseases

3.4.2 *Soil erosion*

When questioned on the ranking of main farming problems, 46 farmers (24%) mentioned soil erosion or soil fertility as one of the constraints. Amounts of soil erosion will depend upon a range of factors; from natural and farmer-created slope angles, lengths of fields and beds; soil cover by crop, weed, vegetative or manmade materials; soil type and composition, and rainfall erosivity, etc. A number of these factors were quantified in the CH survey and are reported here.

3.4.2.1 Incidence of bare soil

In the CH, soil becomes exposed following forest clearing, clearing and pruning of tea, and crop harvest (in addition to leveling for roads and buildings which is not considered here). Given the extent of forest clearing, as indicated by landsat imagery and landuse maps over the 4-year period 1986-1990, the estimated amount of soil exposed, including newly opened forest, is approximately 880 ha/year which can be assumed to have been exposed at least once (table 3).

Rejuvenation of tea estates, whether by complete uprooting and replanting or by drastic pruning, is a routine procedure in the CH, and a proportion of production areas undergoes rejuvenation on an annual basis. Based on satellite imagery, about 7.5% of tea land is subject to this situation, and therefore liable to erosion (i.e., is exposed at any particular time).

With common cabbage occupying the major proportion of vegetable land in the CH, seasonality in its harvest has the greatest influence on exposed cultivated land area. Major harvest activity is in April and August, months with some of the highest rainfall erosivities recorded (fig. 6).

The physical composition of topsoil was quantified on the assumption that more eroded soils would have lower clay fractions and higher sand fractions. Data on the percentage of clay in soil from farms with plastic shelters, assumed to have least soil erosion, showed a significant positive increase as the proportion of land under plastic increased (fig. 15), and to some extent supported the abovementioned assumption. The clay fraction in soil from farms with all land covered by plastic shelters was also greater than that from farms without plastic shelters (18.0 vs. 15.6%, $t = 2.319$ df 4 to 153). Undisturbed soil (collected at 1080 m asl under the forest) had the following physical and chemical composition: % sand - 40%; silt - 16%; clay - 44%; EC - 0.130 mmho/cm; pH - 4.2. From the data for cultivated soils it appears that much silt and clay have been washed away compared to the virgin soil, and, as will be seen later the extent of alteration of composition was not greatly affected by agronomic management practices, other than by the use of plastic rainshelters.

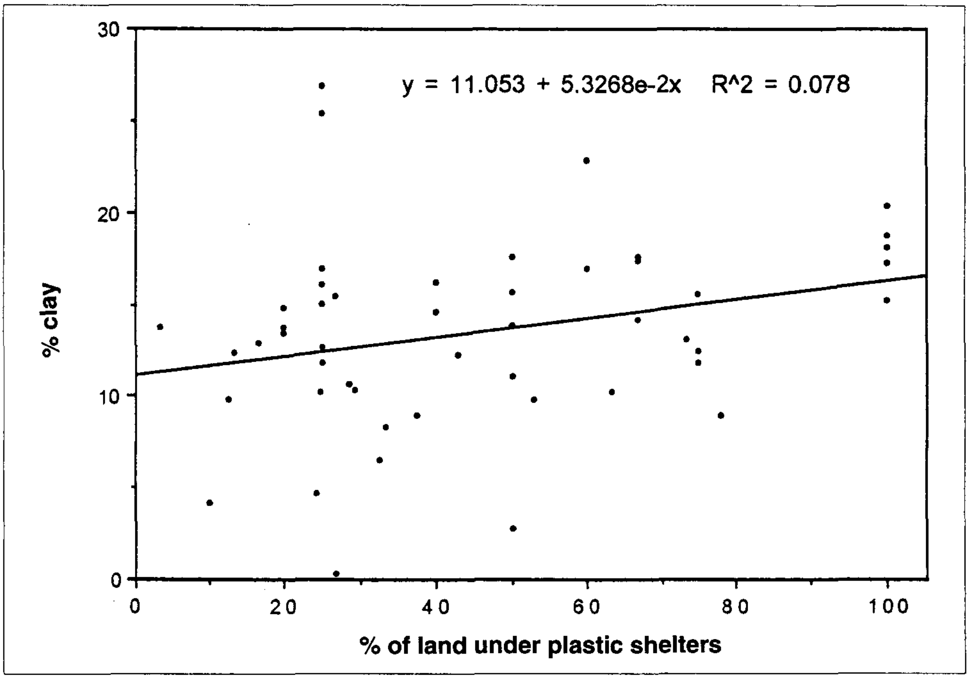

Fig. 15.
Relationship between % clay in soil samples and % of land under plastic shelters

There were no significant relationships between % sand, silt, or clay and the natural slope, the arable slope nor the slope nor length of beds. Apparently factors other than slope classes were of overriding importance.

Organic manures, particularly chicken dung, are spread on the surface of beds, and only rarely incorporated before planting, hence, they should serve a dual purpose: provide nutrients and act as a mulch. There was, however, no evidence to suggest that the loss of silt or clay particles was restricted to greater application rates of manure.

Seventy percent of the survey farmers resurface their soil periodically for a variety of reasons, due primarily to poor yields (43%) and poor soil (29%), but also because of weeds (16%), diseases (7%), and flooding (3%). Resurfacing is done by either scraping off topsoil to a depth of 10-15 cm or cutting the batter face and leveling that soil uniformly over the terrace. Among farmers who resurface, 65% resurface between 4 to 10 years after construction of terraces. Average costs for resurfacing, apart from labor (30 man days/ha), are M$17,500/ha. The time between opening platform terraces and resurfacing was expected to relate to soil physical composition, but no such evidence was found. A possible reason for this is that the time duration between opening and resurfacing might not relate to the actual age of the topsoil on the platform terraces. Additionally, well-managed farms may in fact have longer-life terraces. There was also no relationship between the ranking of poor soil as a reason for resurfacing terraces and the current soil physical composition.

Sediment samples from the Ringlet reservoir (east end) were analyzed for % sand, silt, clay composition, and pH and EC (table 17). Sand content in surface layers ranged from 48.5 to 93.6% along transects and from 75.1 to 51.8% within a 0-3 m profile. Variability along transects might reflect various point sources for deposition from stream or river flow, whereas within a transect variation could represent a shift in composition of depositions with time. The profile beneath the bridge (the main river entry to the reservoir) indicated a possible change from early splash erosion (dislodging the clay fraction) to a more all-encompassing stream erosion, where the composition of deposits more closely reflected the in situ soil in the CH. The higher predominance of sand (or lower predominance of silt and clay) in the sediment samples probably reflects the loss of silt and clay as suspended sediment with water evacuation from the reservoir through the turbines.

3.4.2.2 Beds and terraces

Growing vegetables on beds is common in the CH for all vegetable crops. Beds are on average 1 m wide, approximately 7-15 cm high, and are built out of soil from previous beds, where used lime may be incorporated during bed-making. On average, beds need to be remade every 22 weeks, often because of poor soil (33% of respondents) and low vegetable yields (30%). However, the time between forming raised beds and breaking them down can be as long as 2.5 years. On average, the per hectare labor and nonlabor costs of making beds amount to about M$200 and M$500, respectively. However, the sample exhibited large variation across farmers, as evidenced by corresponding maxima of M$1700 and M$5000. These values may reflect manual labor for bed construction, compared to lower figures for mechanized bed construction.

Fifty-four and 187 farmers have constructed bench and wide (i.e., platform) terraces, respectively. The percentage of land under wide terraces greatly exceeds that under bench terraces, with an average 36% of the land of the 54 farmers under bench terraces (the rest of their land being in wide terraces). Wide terraces on average occupy 92% of farm land. Bench terraces were also reported to be used by less than one-third of CH farmers in the study of Taylor et al. (1993). Bench terraces have a number of disadvantages relative to platform terraces. Their construction is entirely done by hand (platform terraces are constructed largely by machine), their cultivation is more intensive, they are relatively difficult to irrigate, and it is impractical to protect them with plastic shelters. The per hectare costs of terrace construction amount to about M$11,700 and MS$27,200 for bench and wide terraces respectively, which translate into corresponding annual costs of M$1365 and M$3177 (assuming a 15-year life span for bench and wide terraces and an interest rate of 8% for 1992). Resurfacing is mostly done (71% of respondents) by covering the terrace with new

Table 17. Soil physical composition, pH and EC for samples collected at the east end of the Ringlet reservoir, 10 September 1991 (P1-P3 - cross-sectional samples at surface; F1-F3 - profile samples at 1, 2, and 3 m, respectively)

Sample no.	Sample location		% Sand	% Silt	% Clay	pH (H_2O)	EC (mS/cm)
L1P1	Cross-section, under bridge		90.4	9.4	0.2	6.4	0.027
L1P2			82	1.9	16.1	6.0	0.042
L1P3	Surface samples		79.5	17.2	3.3	6.0	0.024
L1P4			57.3	36	6.7	6.2	0.082
L1F1	Profile, under bridge	1 m	75.1	6.2	18.8	6.0	0.077
L1F2	"	2 m	55.5	38.5	6	5.7	0.098
L1F3	"	3 m	51.8	34.5	13.7	6.2	0.143
L2P1	SBR/17 survey line		63.8	14.6	21.8	6.0	0.186
L2P2	Surface samples		79.9	4.7	15.4	6.1	0.021
L2P3	"		52.8	23.5	23.7	6.4	0.112
L4P1	SBR/16 survey line		48.5	27.5	24.1	6.2	0.164
L4P2	Surface samples		57.7	35.1	7.4	6.2	0.027
L4P3	"		93.6	4.3	2.1	6.0	0.104
L6P1	Between SBR/14 & SBR/15		56.3	29.8	13.9	5.9	0.063
L6P2	"		70.6	27.9	1.4	6.2	0.076
L6P3	"		80.9	1.6	17.5	6.3	0.031
L6P4	"		82.1	0.7	17.2	6.1	0.028
L6F1	Profile between SBR/14 & SBR/15	1 m	79.7	8.9	11.4	6.2	0.057
L6F2	"	2 m	82.2	5.2	12.6	6.2	0.049
L6F3	"	3 m	81.2	16.3	2.4	6.0	0.030

soil (plate 6). The other one-third of farmers scraped off topsoil to expose soil beneath. In spite of the greater difficulty associated with the construction and management of bench terraces, they did not seem to have a benefit in terms of retained silt and less sand as the proportion of bench terrace per farm increased.

About one-third of all respondents claimed that their farms suffer from water runoff from higher altitude farms, and that the amount of water that can be effectively used on their own farms is reduced by farms higher in the watersheds.

Plate 6.
First stage in resurfacing wide terraces: cutting back batter to cover old terrace with new soil

3.4.2.3 Weeding

Weeding in vegetables is nearly exclusively done by hand. The number of weedings varies between zero and four, with an average of between one and two for most vegetable crops (table 18). Weeding operations are performed most often for tomato and celery, and least frequently for radish and onion. Weeding patterns in vegetables (i.e., none, one, two, three, or four times per season) were also not in general related to soil physical composition (exceptions were Chinese cabbage vs. % clay, and onion vs. % silt); i.e., there was no reduction in finer particle size with greater degree of weeding. However, the incorporation of weeds and crop stubble into beds had an apparently significant negative effect on the proportion of clay in soil. The number of farmers who routinely incorporate stubble or composted crop remains was low, as was reported by Taylor et al. (1993) who found only 2 out of 80 farmers practicing this, and may reflect a reluctance on account of phytopathological concern, or, less likely (see below) because incorporation of weed and crop stubble represented extra opportunity for erosion to take place.

Table 18. Number of weedings per crop by sample farmers in the Cameron Highlands

Vegetable	N	Number of weedings 0	1	2	3	4	Average
		(number of sample farmers)					
English cabbage	135	0	25	73	33	4	2.1
Chinese cabbage	88	3	10	52	21	2	2.1
Mustard	17	0	8	7	2	0	1.6
Spinach	23	0	11	6	4	2	1.9
Tong ho	18	0	10	5	3	0	1.6
Lettuce	53	1	12	32	8	0	1.9
Celery	23	1	4	8	7	3	2.3
Onion	34	4	13	12	5	0	1.5
Beans	17	1	4	7	5	0	1.9
Peas	27	3	1	15	8	0	2.0
Tomato	101	2	12	58	24	5	2.2
Capsicum	13	5	1	3	1	3	1.7
Radish	10	2	3	5	0	0	1.3
Other vegetables	30	7	10	7	5	1	1.4

3.4.2.4 Adoption of soil conservation and management practices

Seventy-five percent of all farmers do not practice mulching and dispose of their crop stubble and weeds into gullies or other non-arable areas. The majority of the remaining 25% put their crop stubble and weeds on terrace batters. Generally, mulching is considered as too labor-intensive and too expensive.

Liming, on the other hand, is practiced by 62% of all sample farmers, half of who apply lime once, 34% twice, and 15% three times per year, mostly using rock (rather than powdered) forms; only four farmers apply lime more than three times. The average annual quantity applied per hectare (total of all applications) is 1200 kg, with large variations between individual farmers. The cost of lime in the survey varied between M$0.10 and M$0.50/kg; however, MARDI estimates for lime range from M$0.10 to M$0.12/kg. The discrepancies in lime prices may be related to the form of lime used; powdered lime costs more than rock forms.

The majority (i.e., about 75%) of all sample farmers make beds across the slope, with most of the remaining farmers constructing them up and down the slope. Very few farmers plant along the contours which is generally viewed as making most farming operations too difficult, particularly irrigation and transportation of inputs and harvested produce. Stagnant rain water and flooding close to the batters are major problems during the heavy rain season in both bench and platform terraces. The current cultivation practices are employed because 26% of farmers believe that they create better water flow off the land and 36% are convinced that drainage is improved. Nearly 80% of all farmers grow lichens, mosses, or other small plants on the side of the beds. However, soil physical characteristics were not related to the presence or absence of short-stature bryophytes (liverworts).

Direction of beds in relation to the manmade slope had no influence on soil physical composition (table 19), nor on EC or pH. This is not surprising since the slopes on beds were predominantly less than 5°.

Table 19. Influence of direction of beds on various soil parameters measured for each sample farm in the Cameron Highlands

Direction of beds	No.[a]	% Sand	% Silt	% Clay	EC 1:1	pH
Up/Down	61	60.8 ± 9.5	23.7 ± 10.4	15.1 ± 6.3	0.57 ± 0.56	6.31 ± 0.38
Across	157	62.8 ± 8.5	22.0 ± 8.0	15.3 ± 6.8	0.45 ± 0.44	6.32 ± 0.39
Contour	8	64.2 ± 4.1	21.2 ± 2.4	12.7 ± 4.0	0.29 ± 0.10	6.25 ± 0.25
No pattern	1	67.5	22.9	9.6	0.19	6.1

[a] Number of farmers using each direction

Generally, farmers seem to be well aware of the environmental problems in the CH and expect a future deterioration in most indicators of sustainability such as soil quality, crop yields, and pest and weed infestation. Farmers' perceptions of soil erosion differ depending on the context, i.e., own fields, local district, or the CH as a whole. Generally, they perceive soil erosion to be an increasingly serious problem the farther away from their own farms. Thus, while only 28% of the farmers view soil erosion as serious or very serious on their own farm, 61% and 80% indicated similar concerns for their local district and the CH, respectively (table 20). While the available data clearly show a significant decline in forest area in the CH between 1986 and 1990 (table 3), farmers' opinions about the forest situation in the CH were divided, with 48% recognizing the decline, 38% denying it, and 14% not sure. On the other hand, farmers believed that soil erosion was less of a problem in the past.

Table 20. Farmers' perceptions of erosion in their own fields, in their local district, and within the Cameron Highlands in general, in the past, present, and future

		None	Moderate	Serious	Very serious
Own fields	Past	27	53	12	9
(n = 150)	Present	27	45	21	7
	Future	23	48	22	7
Local district	Past	8	60	26	6
	Present	6	33	49	12
	Future	8	32	40	21
Cameron Highlands	Past	5	49	36	10
	Present	2	19	56	24
	Future	4	20	48	29

There was a shift in perceived soil quality by sample farmers. Through time, the proportion of farms with very good soil declined while the categories of good and fair soil quality increased (table 21). Many farmers expected their soil quality to decline further in the future, with > 30% of farmers expecting poor or very poor soil compared to ~ 15% in the past and present. Expectations for crop yields, pests, and to a less marked extent, weeds were similar to those for soil quality, but nevertheless, a significant proportion of farmers expected standards of living to increase over the same time frame (table 21). Farmers presumably considered that their current practices were 'sustainable'; it is difficult to appreciate how living standards will continue to improve while the natural resource base deteriorates.

Table 21. Farmers' perceptions of soil quality, crop yields, pests, weeds, and standard of living in the past, present, and future in the Cameron Highlands

		Very good	Good	Fair	Poor	Very poor
Soil quality	Past	10	33	42	14	2
(n = 165)	Present	2	38	48	12	2
	Future	3	25	41	19	11
Crop yields	Past	8	37	37	17	1
(n = 165)	Present	2	37	51	11	1
	Future	6	29	39	21	6
Pests	Past	5	26	28	34	9
(n = 158)	Present	0	21	44	30	6
	Future	1	20	40	22	16
Weeds	Past	6	28	32	24	10
(n = 162)	Present	1	17	44	33	6
	Future	1	19	29	38	14
Standard of	Past	0	17	62	17	3
living	Present	1	45	47	7	1
(n = 159)	Future	17	38	36	9	1

Besides farmers' perceptions on soil erosion, the survey also asked for the enumerators' field assessment of the extent of soil erosion on each individual farm (table 22). Rill erosion is clearly the most serious, with 73% of all sample farms already experiencing at least moderate rill erosion, followed by gully erosion which is a reason for concern on nearly half of all sample farms. Even though two-thirds of all sample farms have not yet had landslips, and nearly 60% have thus far been saved from sheet erosion, the situation is expected to worsen in the future. During the survey, severe landslips were observed on 10% of the farms, most likely following the heavy rains of May in 1991. No meaningful relationships existed between visual assessments of erosion (rill, sheet, gully) and texture of soil samples collected at each farm. Rill erosion was more likely to occur when the natural and arable slope was high, but neither bed length nor slope were related to visual estimates of rill erosion. No such relationships were evident for gully, sheet, nor landslip erosion.

Table 22. Enumerators' assessment of soil erosion on sample farms in the Cameron Highlands

Type	Degree of occurrence			
	None	Moderate	Severe	Very severe
		(% of sample farmers)		
Sheet	59	38	3	0
Rill	27	61	11	1
Gully	55	34	9	2
Landslip	64	20	7	9

Though farmers seemed to be well aware of the soil erosion problems in their area, two-thirds blamed the weather (particularly the heavy rains in 1991) for the increase in erosion problems. About one-quarter of all respondents recognized deforestation and opening up of new land for vegetable cultivation as important contributors to soil erosion, but 74% of all sample farmers were unwilling to plant trees on their farm (mainly due to the limited area of land available), with most of the remaining farmers showing an interest in fruit trees. Only 7% of farmers explicitly mentioned low adoption of soil conservation methods by vegetable farmers as an important reason for increased soil erosion problems. At the same time, when asked about ways in which farming methods affect soil erosion, farmers seemed well aware of the fact that a well drained (i.e., established drains to ensure disposal of runoff) farm causes less erosion. About half of all sample farmers mentioned lack of proper drainage facilities on their farm as a major contributing factor to soil runoff from their farms. Some farmers also admitted that the natural slope of their land was too steep for farming, and that the necessary construction of terraces and beds caused a lot of erosion. When asked about possible solutions to soil erosion, majority of the farmers mentioned the use of sandbags, plastic mulches, wooden planks, etc., as well as improved drainage facilities.

When questioned about the implementation of erosion control practices, 27% claimed not to use any, saying either that soil erosion is not a serious problem on their farms or that it is so serious that nothing can be done about it, while 44% used sandbags, 23% constructed clay or cement drains, 12% used cover crops, 3% protected batters with vegetation, and 1% used mulches. However, several farmers expressed concern about the costs involved with these measures. Relatively few farmers mentioned cultivation and other management practices (i.e., relay or intercropping, rotation, contour farming, cover crops and trees, plastic shelters, etc.) as possible ways to overcome soil erosion problems. A moratorium on further opening up of new farming areas was mentioned by only 12 farmers.

Table 23 summarizes farmers' perceptions regarding the effectiveness and suitability of a wide range of soil conservation measures. Consistent with earlier findings, farmers are generally not enthusiastic about contour farming and the use of cover crops or trees. The same holds for alley and relay cropping methods which are considered rather ineffective in combating soil erosion. The contrary is true for sandbags, the use of which is widespread. The practice of mulching in its various forms is not widespread and farmers are divided about its effects on soil erosion. The use of plastic mulches was, however, favored by farmers over organic mulches. Plastic shelters are considered by most farmers to reduce soil erosion, even though concerns were expressed about their large investment costs.

Table 23. Farmers' perceptions of soil conservation methods in the Cameron Highlands

	Capability to reduce erosion			Suitability for own farm		
	A lot	Some	None	Yes	No	Maybe
	(% of farmers)					
Contour farming	25	42	33	25	59	16
Cover crops/trees	42	38	20	18	72	10
Terraces/banks	22	51	27	40	44	16
Intercropping	20	35	45	64	19	17
Alley cropping	5	25	70	6	74	20
Relay cropping	33	24	43	54	38	8
Logs/rocks	35	38	27	34	60	6
Sandbags	55	38	7	69	23	8
Mulches on beds	39	28	33	19	62	19
Protection between beds	42	45	13	19	69	12
Mulches on batters	39	27	35	29	47	24
Plastic mulches	48	22	30	27	47	26
Plastic shelters	57	17	26	77	16	7

3.5 Constraints in vegetable cultivation

Farmers' perceptions regarding main problems experienced in farming in general and in the cultivation of vegetables in particular were elicited by asking them to rank their main constraints. Farmers were also asked about their opinions regarding possible solutions to their farming problems.

Eighty-seven percent of all respondents mentioned price-related factors (high variability and low unit prices – which are mainly blamed on relatively cheap imports from Thailand and Indonesia) as a problem, with over half of the total sample ranking variability in prices as the most important constraint. Factors which reduced potential yield (weeds, pests, and diseases) were also considered an important problem for vegetable production, with 39, 71, and 25 farmers assigning first, second, or third ranking, respectively, to the combination of these factors. Soil erosion and fertility were not perceived as major production constraints; only five and nine farmers assigned a first or second ranking to soil-related problems. With the exception of labor, input availability (including that of information) does not generally seem to present a problem for vegetable farmers in the CH either. Sixty-eight farmers mentioned labor shortages, with 6, 13, 23, and 19 farmers giving this constraint a first, second, third, or fourth ranking, respectively.

When asked a similar question ("What do you believe are the main obstacles to achieving your farming aspirations?") later in the survey, 62% of all farmers again mentioned price-related factors (i.e., imports and variability), 21% expressed a lack of sufficient capital, 13% were concerned with land shortages or a lack of tenure, and 7% blamed the weather. Only 6% mentioned biotic problems and only four farmers were concerned with labor shortages or lack of information. Regarding tenure, 31 farmers said that they would start planting flowers if they owned the land, and 25 farmers said that they would build plastic shelters as land owners. However, the proportion of farmers using plastic shelters at present (25%) is similar to that having freehold ownership (6 out of 32), hence, the propensity to use plastic shelter cannot be related to freehold ownership.

Solutions to their main farming problems, as suggested by farmers, can be grouped into eight major categories (table 24). Increased use of chemicals in general, and insecticides in particular, was the most frequently mentioned solution (62 farmers), suggesting that there is still a long way to go before the merits of IPM are widely recognized and corresponding practices adopted on a significant scale by vegetable farmers in the CH. The solutions next most frequently mentioned by farmers were all geared towards improving incomes obtained from vegetable farming, by being allowed to bring more land under cultivation (24 farmers), and by controlling the levels and variability of vegetable prices. Thirty farmers felt that the Malaysian government should either ban or limit the imports of vegetables, while 22 farmers were in favor of the government (FAMA) directly controlling vegetable prices. A number of farmers experienced labor shortages and argued for a relaxation of Malaysia's immigration laws. Only eight farmers saw a need for soil erosion reduction measures on their own farm (e.g., by reconstructing terraces, using sandbags, building cement drains, etc.). The availability of credit seems to constitute a problem for only relatively few farmers.

Table 24. Perceived solutions to farming problems proposed by sample farmers in the Cameron Highlands

Solution	Number of farmers
Increased use of insecticides	62
Reduction or ban in vegetable imports	30
Permit to cultivate more land	24
Price control by the government	22
Increased labor availability	14
Improved access to credit facilities	11
Soil conservation measures	8
Other	19

Although clear plastic shelters result in less pesticide usage (Taylor et al. 1993), better quality produce (Chang and Liao 1989), and reduced erosion (fig. 15), their long-term use may create new problems related to an increase in soil EC. Of the farms surveyed, all five farms with EC > 1.5 mS/cm had a proportion of their production under plastic. On average, farms with plastic shelters had an EC of 0.47 mS/cm compared to 0.27 ($t = 2.49$, $P \leq 0.05$) for farms without shelters ($t = 2.49$, $P \leq 0.05$). Rain shelters also funnel runoff rainfall and could lead to serious stream erosion due to greater volumes and velocity of water flow. However, casual observation during the survey revealed that many farmers had developed safe water disposal methods such as grassed waterways or chutes, or step-down drains. There was no relationship between either the rate of manure or fertilizer application and EC across farms nor between those application rates and soil pH.

4. Synthesis and Conclusions

Management of the CH watersheds illustrates a classical imbalance between short and long-term expectations of the stakeholders within and outside the watershed. The loss of revenue through reduced generation of electricity, the increased costs associated with routine maintenance (shut down) and replacement of parts with shorter than expected useful life span, the runoff of chemicals (both fertilizer and pesticides) and associated implications for human and wildlife health, and the potential loss of tourism must be weighed against the livelihood of vegetable, flower, tea and fruit producers, the service industries which supply inputs and transport, and the net gain in foreign exchange due to exports.

That substantial soil erosion is occurring within the CH is undeniable, and averaged over cleared and managed lands (i.e., other than forest) the annual loss amounts to an estimated 16.8 t/ha (see below). Naturally the electricity board (TNB) is concerned with reducing the erosion at the source rather than sustaining a continuous maintenance program on its reservoirs and generating equipment. The tourist board is also concerned with the upsurge of eyesores in the form of exposed lands and plastic shelters for crops, and the loss of natural forest ecosystems.

Reliable figures for the loss or potential loss of revenue by the TNB are difficult to acquire. Both quantity and quality of downstream water are inferior to those of the past (Omar 1988). By July 1986 one-third of the capacity of Ringlet Reservoir was taken up by silt (1.15 million m^3, compared to an expected 1.6 million m^3 over a 70-year life span until 2045) and in 1992 an estimated 2 million m^3 of sediment occupied the reservoir (fig. 16), in spite of removal of 382,000 m^3 over the years 1980 to 1988 at a cost of M$1.3 million. At M$5/m^3, the cost to dredge the reservoir will amount to M$10 million, to which can be added the dredging costs from 1980 to 1988 (M$1.3 million), another M$1.5 million to clear intakes and tunnels on two occasions, and an estimated M$1 million annual loss due to partial operation (closing of intakes during turbid periods, spillage and the like - Omar 1988; Syed 1993). The total costs (including lost revenue) from 1980 to present to clear the reservoir amount to M$25.8 million.

The total estimated volume of deposited sediment (an unknown amount is carried in a suspended form to lower reaches of the waterways) amounts to 2.4 million m^3 to 1992. With a bulk density of approximately 1.4, this amounts to 3.3 million t of soil. Assuming a linear rate of increase in opening up of new land, starting with 750 ha in 1965 to 9758 ha in

1992, the average accountable soil loss from all opened lands, assuming negligible loss from the natural forest ecosystem, was 23.5 t/ha per year. This is most likely an underestimate since the early rate of opening was probably less than linear for the earlier mentioned reasons of an expanding periphery of cleared forest. The rate of filling of the reservoir with sediment has not been linear (fig. 17). The estimate of average soil loss per year at 23 t/ha is in line with that observed by Shallow (1956) for vegetables in the CH (14.6 t/ha per year). However, land at one time in the CH was once newly opened and liable to serious erosion. Hence, taking the total opened area (minus 750/ha as the vegetable area in 1965), and assuming that erosion seriously took place at that time, and at one-off periods of high erosivity (one in 1992 on > 9700 ha and the other in the 70s on approximately 3000 ha) plus serious erosion at the time of land opening, then erosion could have amounted to 155 t/ha per event since 1965 based upon the sedimentation figures calculated above. In reality, the truth most likely lies between these two extremes, tending towards a lower rate of erosion after farms have been opened. If rates of soil erosion were consistently high due to poor field management, in line with rates reported for slopes and soils of a similar nature, then the reservoir would have filled at a far faster rate. However, the filling of the reservoir was more or less in line with the rate of opening new land, further evidence that the major source of sediment was due to the initial soil loss at breaking of new land.

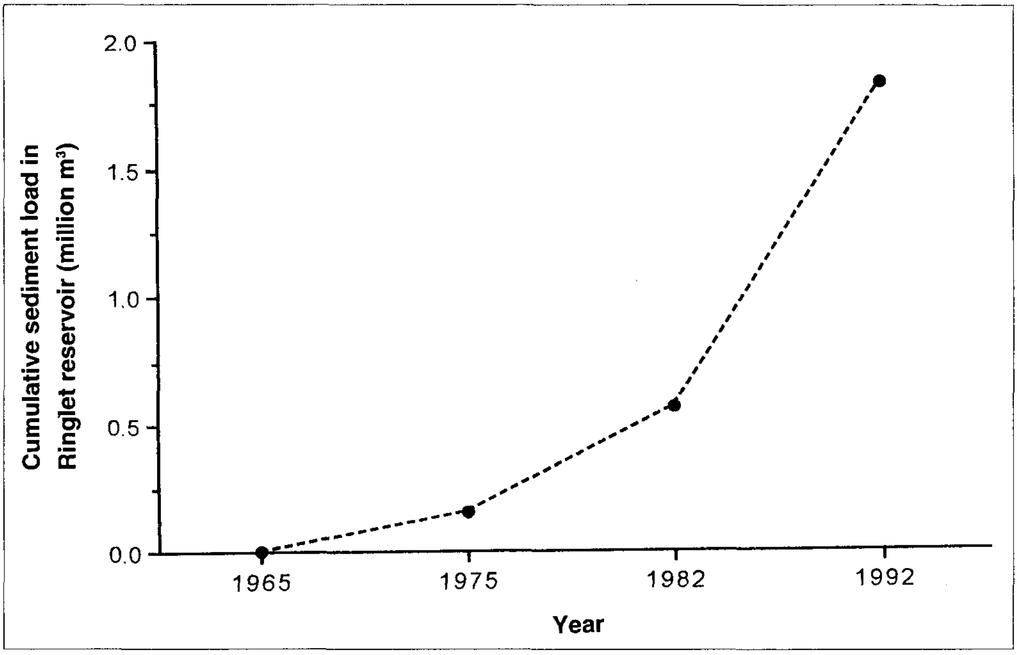

Fig. 16.
Cumulative sedimentation in the Ringlet reservoir, including some removal of sediment ***(Sources: Bin Omar 1988 and Bin Omar personal communication)***

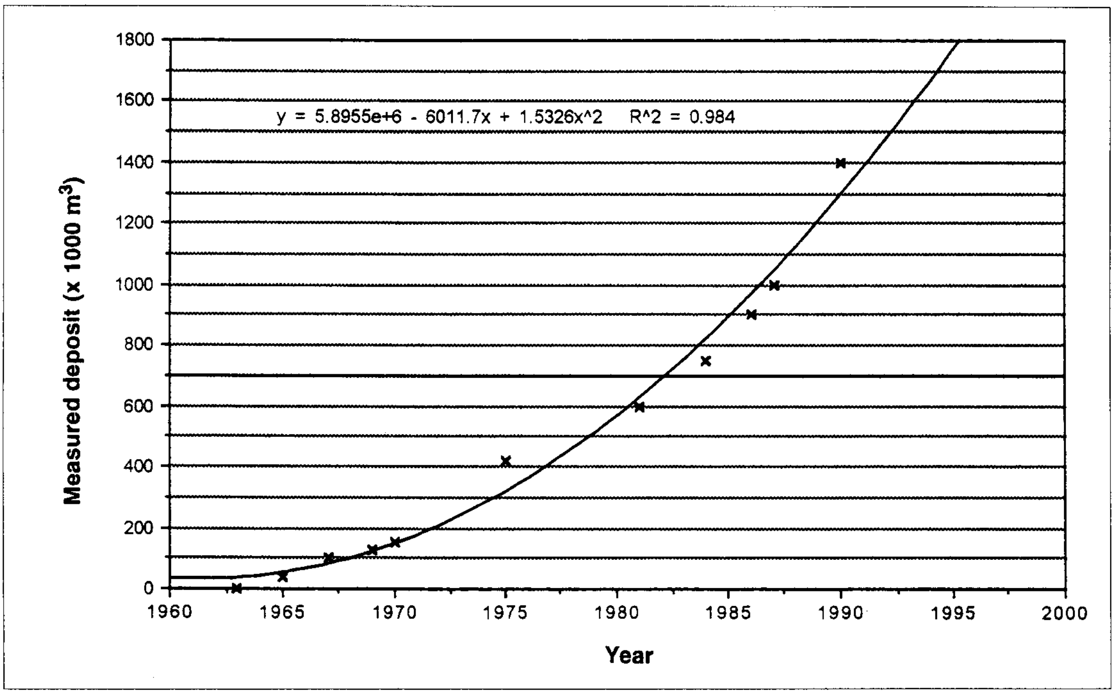

Fig. 17.
Ringlet reservoir sedimentation curve (Habu and Ringlet ends only)
(Sources: Choy Fook Kun and Mohamad Fuad bin Omar)

Analysis of the farming system within the CH suggests that vegetable farmers apply practices which ameliorate the effects of erosion once crops are in the ground. Major factors involve limiting the slope of manmade terraces to < 10°, a predominance of across the slope as opposed to up-down alignment of beds, minimum tillage through reuse of production beds with reasonably long periods between reconstruction of beds, the adoption of bryophytes to counteract erosion from sides of beds (and as a weed suppressor), a degree of intercropping, and emphasis on adequate drainage. None of these practices alone were able to maintain clay/silt: sand ratios compared to those of virgin soil. The practice which did conserve that ratio to some extent, the use of plastic shelters, did not substantially prevent loss of silt and clay in absolute terms compared with unprotected farmlands, and incidentally, led to higher soil EC values and were associated with negative net incomes ($r = -0.504$, $n = 41$, $P \leq 0.001$).

The adoption of soil conservation measures and other production practices was not apparently constrained by land tenure arrangements of individual farmers. Almost all farmers have overhead sprinkler irrigation systems installed, and the distribution of plastic shelters was not biased towards farms with freehold land access. In this respect, therefore, the financial position of farmers in the CH does not appear to limit their ability to implement sound erosion control practices.

Farmers are accustomed to applying large quantities of lime and organic manure with a naturally low pH and negligible amounts of organic matter right from the time the land is brought into cultivation, as a consequence of the inversion and burying of the natural humus and organic matter during terrace formation. Many farmers believe that this practice is rational in terms of controlling weeds, pests, and diseases.

Our analysis of the physical, social, and biotic circumstances surrounding the CH vegetable production systems suggests that the major sources/causes of soil erosion from vegetable fields are chronologically as follows:

- at land clearing, before vegetable crops are planted, when soil is bare and rapid sheet erosion takes place. Silt and clay levels fall well below virgin soil levels, and later application of conservation practices has little impact since much damage and loss has already occurred;
- from backslopes and rises of terraces especially if not protected with mulches or lower crops;
- following harvest of vegetables, when residues are collected and removed from the field and soil is once again exposed;
- at resurfacing of terraces, when poor topsoil is either scraped away or covered with fresh soil taken from a new cut face from the batter of the natural slope;
- when either or both of the above coincide with peak rainfall and erosivity; and
- when a combination of conditions occurs such that the soil is heavily charged with water and is followed by long continuous heavy rain causing landslips.

Solutions to preventing soil erosion could take the following form:

- conservation of organic humus and repositioning over newly formed terraces;
- use of organic mulches on soil immediately after terracing, before crop is (trans) planted.
- use of organic mulches, and/or relay cropping practices during production, to continue to cover soil after harvest (particularly of cabbage where harvesting in April and October coincides with heavy rainfall, fig. 3 and 9);
- avoiding preparation of new land and resurfacing of old ones during peak rainfall months;
- reinforcing the retaining structure for platform terraces to reduce the incidence of landslip; and
- revegetation of exposed batters of newly constructed terraces.

However, the observation that farmers attach low priority to controlling soil erosion implies that these measures will not be adopted unless the current system of incentives is changed. In addition, agriculture is most likely not the only cause of soil erosion in the CH, and attempts to quantify soil lost from the construction of roads, tourist developments, and housing will help validate the conclusions.

Given the serious nature of environmental degradation in the Cameron Highlands, as described in this report, it may be time to consider some further initiatives to improve catchment management:

- Bring the stakeholders–farmers, land developers, the tourist board, and the TNB–together to explore areas of negotiation and tradeoffs with regard to catchment management.
- Consider the establishment of a catchment authority with power to advise on or regulate land use practices.
- Exclude farming and infrastructure development from the more environmentally fragile areas or areas having a high impact on the reservoir system.
- Revitalize the relevant research and extension programs.

Without some of these more radical approaches to catchment management it is likely that the productive capacity and environmental quality of the Cameron Highlands will continue to decline.

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