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.

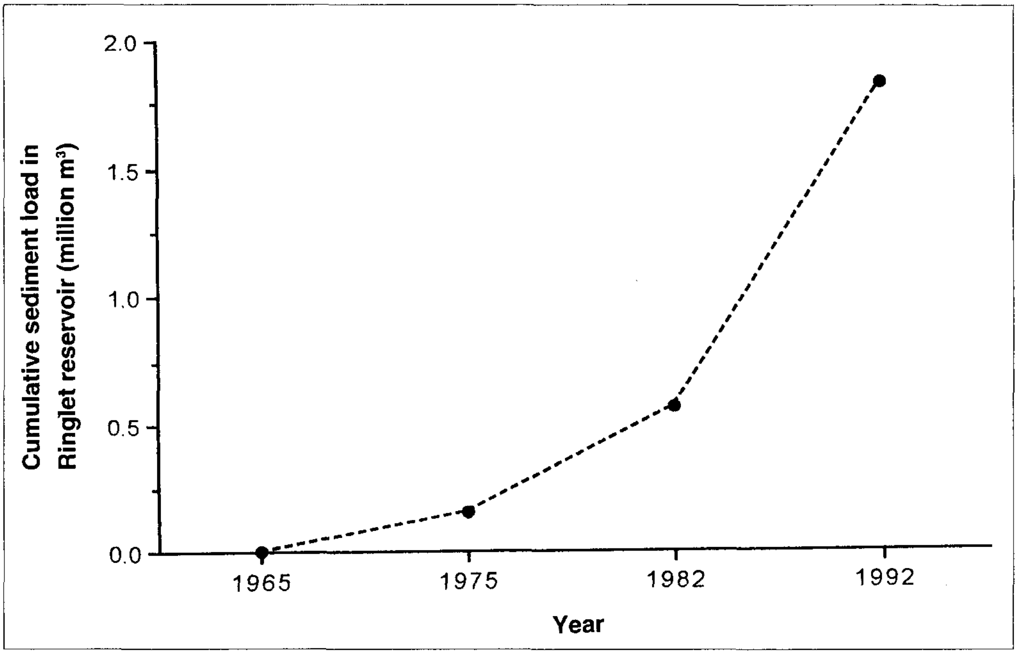

Fig. 16.
Cumulative sedimentation in the Ringlet reservoir, including some removal of sediment ***(Sources: Bin Omar 1988 and Bin Omar personal communication)***

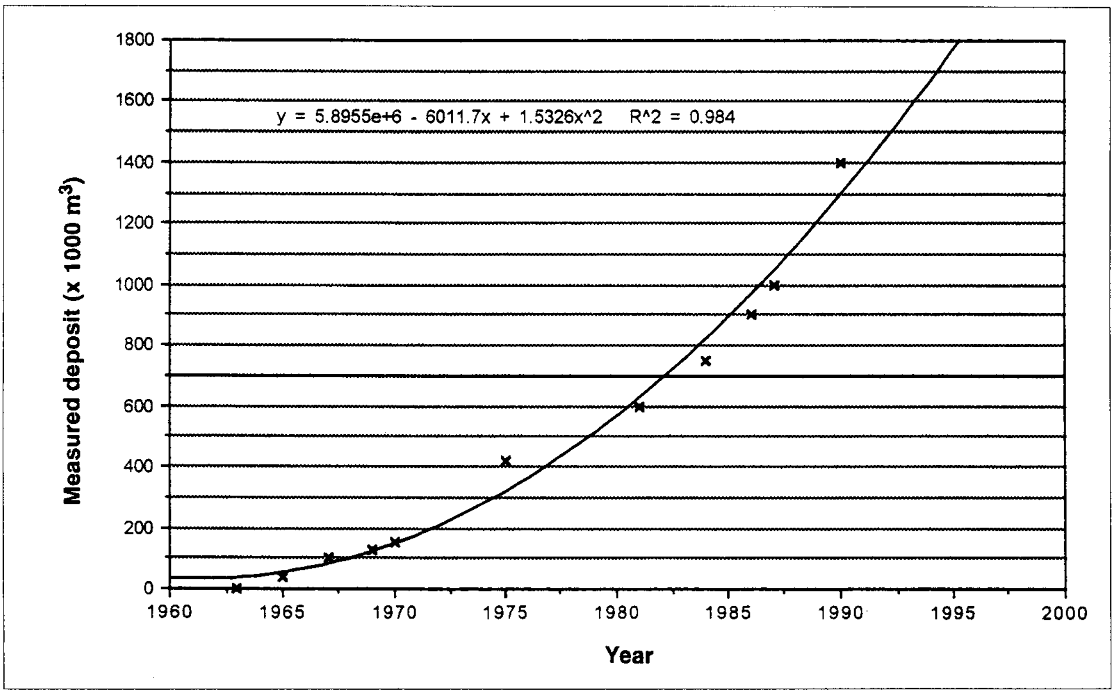

Fig. 17.
Ringlet reservoir sedimentation curve (Habu and Ringlet ends only)
(Sources: Choy Fook Kun and Mohamad Fuad bin Omar)

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.