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Use of satellite imagery to determine the land use management factors of the USLE

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Abstract The Cameron Highlands, an idyllic highland resort in Malaysia, are now being threatened by landslips and flash floods due to numerous development projects as well as intensive agricultural activities being associated with tourism. A study of the land use management factor (Cover and Management factor, *C*, and Support Practice factor, *P*) of the Universal Soil Loss Equation (USLE) has been undertaken, as this parameter reflects the land cover in the study area and its effect on soil erosion. Using remote sensing satellite imagery, the Ringlet area in the Cameron Highlands has been identified as having the highest erosion risk/loss based on the *CP* factor and this is confirmed by its highest ranking for residential and construction areas compared to other locations. The results of this study highlight the important land uses associated with erosion risk, and provide guidance to ensure that development is carried out to ensure a quality environment for the future.

INTRODUCTION

The Cover and Management factor, *C* in the USLE represents the combined effect of all the interrelated cover and management variables and is defined as the ratio of soil loss from land cropped under the specified conditions to the corresponding loss from clean-tilled continuous fallow. In general, whenever sloping soil is to be cultivated and exposed to erosive rains, the protection offered by grass cover or close-growing crops needs to be supported by conservation practices that will slow the runoff and thus reduce the amount of soil that it can transport (Roslan, 1993). The most important of these supporting cropland practices are contour tillage, strip cropping on the contour, and terrace systems. The Support Practice factor, *P* in the USLE is defined as the ratio of soil loss with a specific support practice to the corresponding loss with up-and-down-slope cultivation (Wischmeier & Smith, 1978). Improved tillage practices, grass-based rotations, fertility treatments and the leaving of greater quantities of crop residues on the field can contribute significantly to erosion control.

With recent developments in remote sensing technology, colour infrared imagery can be used to determine the combined land use management factor, *C* and *P* of the USLE as shown in Table 1.

DATA

The data used for this study were derived from a Landsat Thematic Mapper image

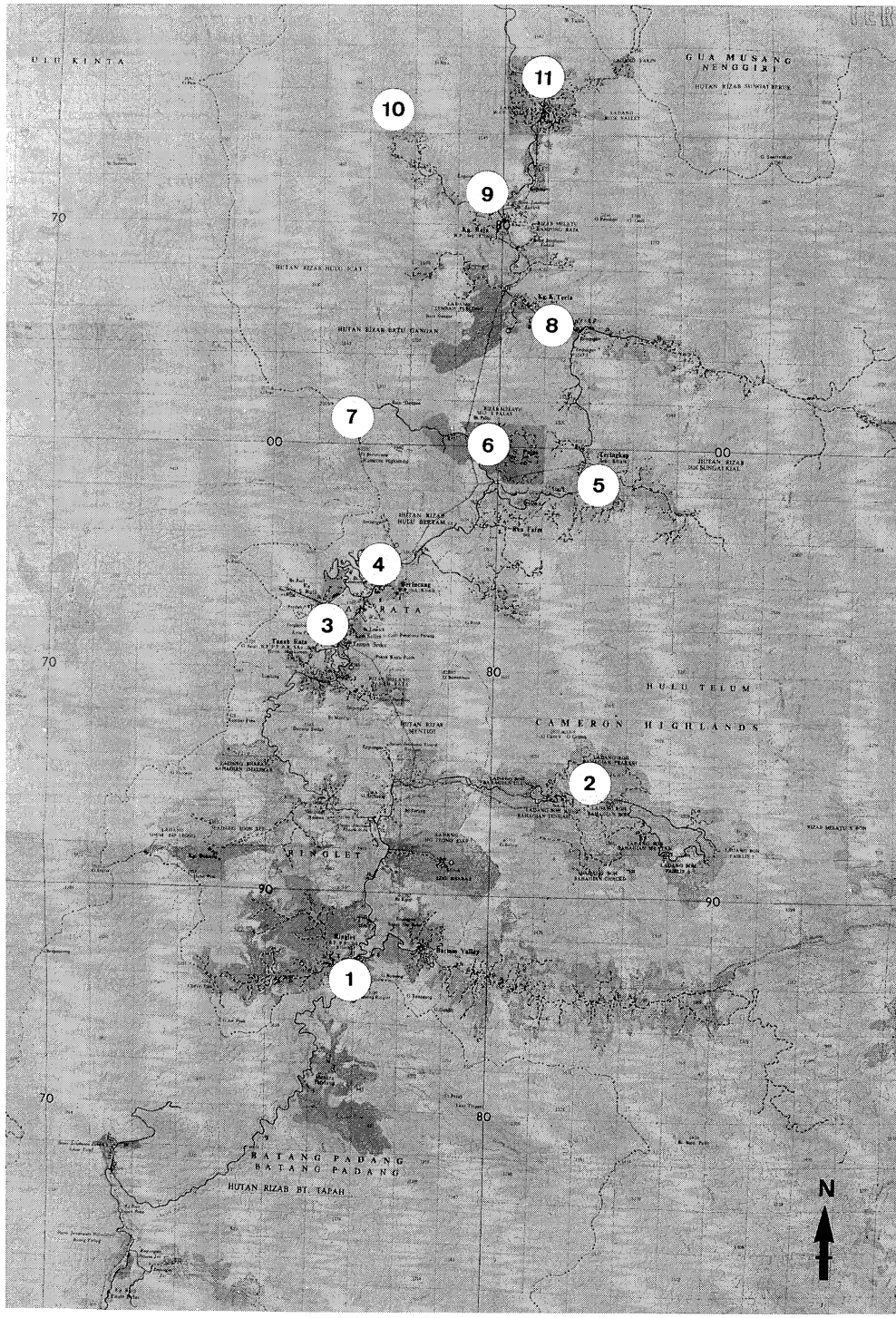

Fig. 1 The 11 locations in the Cameron Highlands with their respective zoning within a 5 km radius.

dated 23 April 1990, which was obtained from MACRES (Malaysian Center of Remote Sensing) for the area covering the Cameron Highlands catchment in the State of Pahang, Malaysia.

METHOD

Eleven locations have been identified in the Cameron Highlands as indicated in Fig. 1 and these are listed in Table 2. Attention has focused on a 5 km radius zone surrounding each of the locations. The satellite image covering the Cameron Highlands is shown in Fig. 2.

RESULTS

The Landsat Thematic Mapper image has been processed using the colour infrared interpretative key presented in Table 1 to obtain values of the *CP* factor for the 11 locations in the Cameron Highlands. Unclassified and water body areas are not included in the calculation of the *CP* factor since information on land use and cropping or land management was not available. As an example, the results for the

Table 1 The colour infrared interpretative key for the land use management factors *C* and *P* of the USLE.

Land use management	Photo characteristics	*CP* factor value
Grassland/hay	Pink tones, smooth texture	0.003
Residential	Pink tones, houses/streets	0.003
Forest	Red tones, coarse texture	0.003
Rangeland (grass and weeds)	Variable colours	0.007-0.450[a]
Cropland	Pink tones, cultivation	0.300-0.400[b]
Construction areas	White tones, coarse texture	1.000
Impervious areas	Bluish-white, smooth texture	0.005

[a] For rangeland, the average *CP* factor is taken as 0.229

[b] For cropland, the average *CP* factor is taken as 0.35

Table 2 The 11 locations in the Cameron Highlands with their respective 5 km radius zones.

Zone no.	Location
1	Ringlet
2	Ldg. Teh Boh
3	Tanah Rata
4	Brinchang
5	Tringkap
6	Ldg. Sg. Palas
7	Gunung Brinchang
8	Kuala Terla
9	Kg. Raja
10	Sg. Ikan
11	Blue Valley

Ringlet location (Zone 1), with its associates zoning within a 5 km radius, is shown in Fig. 3.

Appendix 1 provides further details concerning the procedure for ranking the various land use management factors C and P for the 11 locations and a typical result (residential areas) is shown in Table 3. The weighted CP factors for each location are as shown in Table 4.

Fig. 2 The Landsat Thematic Mapper image of the Cameron Highlands.

COMMENTS AND DISCUSSIONS

The observations carried out using the remote sensing image have a resolution of 30 m which means that each pixel inside the image will represent an area of 30 m $\times$ 30 m. Although this image will provide a greater accuracy compared to land use maps, roads and other buildings with a width of less than 30 m will not be able to be identified. Further work using a higher resolution image could be carried out in the future to provide improved representation of the *CP* factor. However, this study

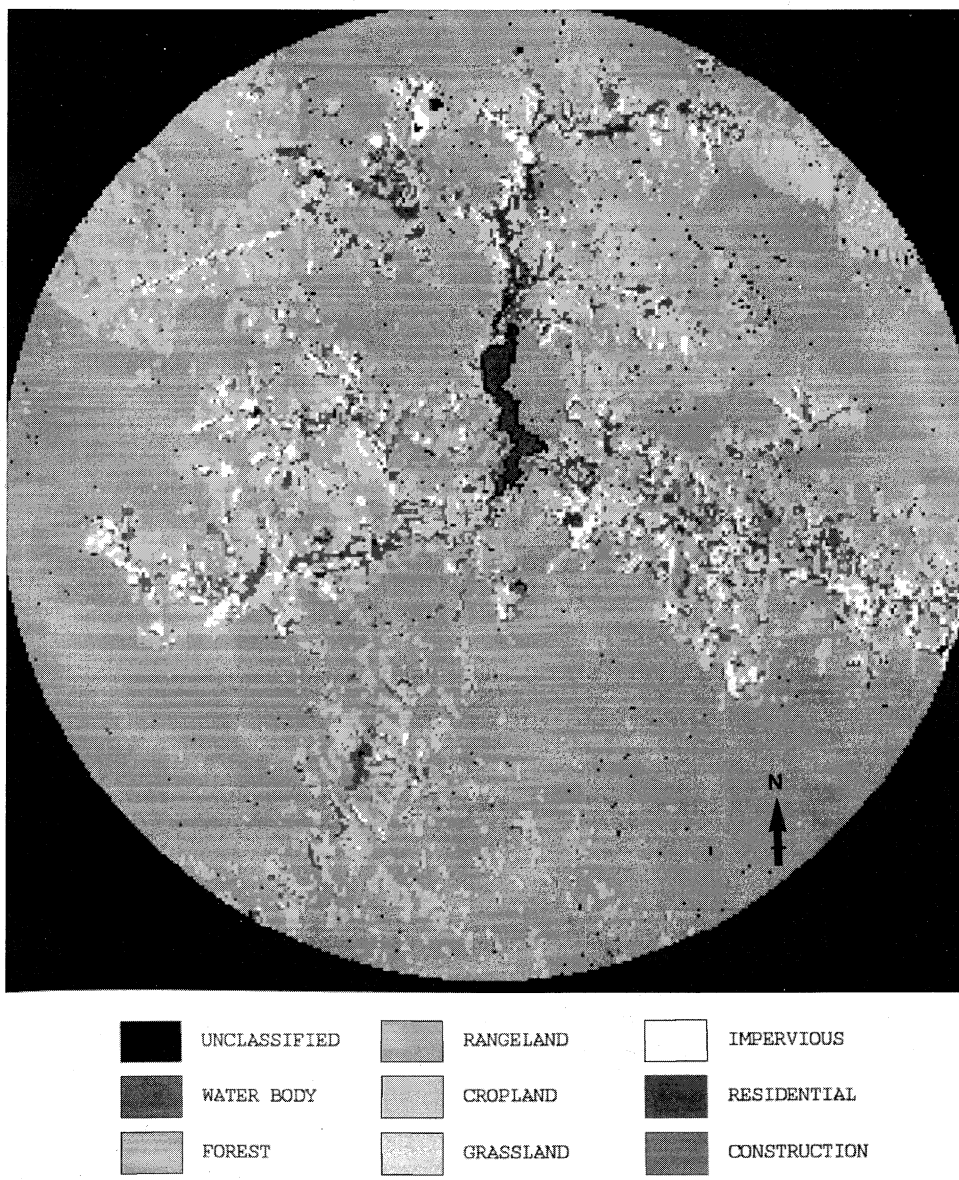

Fig. 3 Land use management within a 5 km radius of the Ringlet location (Zone 1).

Table 3 Ranking of the 11 locations in the Cameron Highlands in terms of the area of residential development.

Rank	Location	Area (ha)	% Image
1	Ringlet	0.46	5.39
2	Kuala Terla	0.46	5.34
3	Ldg. Sg. Palas	0.44	5.15
4	Tringkap	0.42	4.87
5	Ldg. Teh Boh	0.26	3.00
6	Brinchang	0.26	3.00
7	Tanah Rata	0.25	2.90
8	Gunung Brinchang	0.24	2.78
9	Kg. Raja	0.24	2.76
10	Blue Valley	0.18	2.13
11	Sg. Ikan	0.15	1.71

Table 4 Ranking of the weighted *CP* factor for the 11 locations in the Cameron Highlands.

Rank	Location	*CP* factor
1	Ringlet	0.0875
2	Kuala Terla	0.0830
3	Ldg. Sg. Palas	0.0795
4	Tringkap	0.0763
5	Ldg. Teh Boh	0.0762
6	Gunung Brinchang	0.0543
7	Brinchang	0.0540
8	Tanah Rata	0.0504
9	Kg. Raja	0.0501
10	Blue Valley	0.0471
11	Sg. Ikan	0.0355

highlights the dominant land use at various locations in the Cameron Highlands and provides some indication of the possibility of reducing future erosion risk/loss, based on the *CP* factor of the USLE.

CONCLUSION

From the analysis undertaken, it has been found that the Ringlet location has the highest erosion risk/loss based on the *CP* factor of the USLE with a value of 0.0875. This result is supported and justified by the fact that this location produced the highest ranking for residential (5.39%) and construction (2.07%) areas compared to other locations.

Conversely, the location at Sg. Ikan has the lowest erosion risk/loss, as the *CP* factor is only 0.0355. This result is again supported and justified by the fact that this location has the largest area covered by forest (84.21%). This area has yet to be developed and therefore has a lower erosion risk/loss. In terms of other land use categories, Sg. Ikan recorded the lowest value for residential (1.71%) and

construction (0.73%) areas which further justifies the results obtained.

Knowledge of the ranking of the *CP* factor at various locations in the Cameron Highlands, will ensure that the development of any new projects will be well planned and designed to ensure that the quality environment is maintained. Further work with a higher resolution image should be carried out in order to provide the best representation of the land use in the Cameron Highlands and liaison with the State Government is required to implement stricter laws in developing particular areas, in order to ensure sound and sustainable development in the future.

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APPENDIX

Sample calculation of the land use management factors *C* and *P* of the USLE for the Ringlet location (Zone 1)

No.	Land use management	% Image (1)	*CP* factor from Table 1 (2)	*CP* factor (1)×(2)
1.	Water body	0.34	-	-
2.	Forest	62.06	0.003	0.0019
3.	Rangeland	9.43	0.229	0.0216
4.	Cropland	12.27	0.350	0.0429
5.	Grassland	5.10	0.003	0.0002
6.	Impervious	2.37	0.005	0.0001
7.	Residential	5.39	0.003	0.0002
8.	Construction	2.07	1.000	0.0207
9.	Unclassified	0.97	-	-
	Total	100.00		0.0875

Weighted *CP* factor,

$$[(0.003) \times 62.06\%] + [(0.229) \times 9.43\%] + [(0.350) \times 12.27\%] + [(0.003) \times 5.10\%] + [(0.005) \times 2.37\%] + [(0.003) \times 5.39\%] + [(1.000) \times 2.07\%]$$

$$= 0.0875$$