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Vegetation cover and management factor(C) derivation through digital photographs

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***Abstract* — Vegetation cover and management factor (C) of the Universal Soil Loss Equation (USLE) is usually can be found from guideline. However, the value would actually bias for small scale area. This study was therefore aimed to use digital photograph to obtain the vegetation cover and management factor (C) at small scale. A total of 8 photographs were taken at the centre of the 8 experimental plots location. These photographs were processed using ArcGIS 10.1 whereby the vegetation cover and bared soil were identified using the maximum likelihood algorithm method. For validation purposes, the results obtained were compared with that of the previous studies. We found that the newly derived value of C is of comparable with that of the previous studies. This indicates the simple technique is beneficial for quantification of the vegetation ground cover for small scale and sloping topography as we applied to hilly area beside highway. The proposed technique is also applicable for large area but it is suggested to use unmanned aerial vehicle (UAV) in order to obtain overall picture of the area.**

***Keywords* — crop management factor (C), image analysis, Guthrie Corridor Expressway (GCE), vegetation ground cover**

I. Introduction

Vegetation cover is one of the most crucial factors in reducing soil erosion. In general, as the protective canopy of land cover increases, soil erosion decreases [1].Vegetation reduces soil erosion by protecting the soil against the action of falling raindrops, increasing the degree of infiltration of water into the soil, reducing the speed of the surface runoff, binding the soil mechanically, maintaining the roughness of the soil surface, and improving the physical chemical and biological properties of the soil [2].

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The C factor has been one of the most complicated Universal Soil Loss Equation (USLE) or Revised Universal Soil Loss Equation (RUSLE) coefficients to estimate over wide geographic areas.

Conventionally, spatial estimates of C factors have been done by just assigning C factor values from literature or field data into a classified land cover map (cover classification method) [3, 4]. This technique, however, resulted in C factor estimates that are unvarying for relatively large areas, and do not adequately reflect the variation in vegetation that exists within large geographic areas [5]. To increase the spatial variability and decrease the influence of classification errors, direct linear regression has been performed between image bands or ratios and C values determined in the field [6, 7]. [8] used joint sequential co-simulation with Landsat TM images for mapping the C factor from point values. However, this technique is expensive and obtaining the suitable number of sampling points for interpolation is quite difficult. Vegetation indices such as normalized difference vegetation index (NDVI) have also been explored for mapping the C factor by linking it directly to USLE and RUSLE-C factor by regression analysis. The correlation between satellite driven vegetation indices and C factor were not satisfactory enough [9, 10] explained that the low correlation is owing to the sensitivity of vegetation to vitality, as the condition of the vegetation is not always related to its soil protective function. In spite of these issues, the NDVI is one of the usually used methods to calculate the C factor using remote sensing for soil erosion assessment over regional or large geographic area [11-18]. Spectral Mixture Analysis (SMA) of Landsat ETM is another alternative method to estimate C factor. The advantageous feature of SMA is that it estimates the fractional abundance of ground cover and bare soils concurrently which is suitable for soil erosion analysis.

The objective of this study is to derive the vegetation cover and management factor (C) for USLE model at plot scale using digital images.

II. Methods

A portable camera was used to take digital photographs of the experimental site. Photographs from approximately at 2.0 meters high, perpendicular to the ground, were taken at the centre of the experimental plot area in April of 2013, in a sunny day (without clouds), from 10 to 12 am. Determination of C factors has been done from images of the experimental plots. Then the images were classified using ArcGIS10.1 through the maximum likelihood algorithm following the same procedures applied to process the satellites scenes. In each scene, few representative pixels of the two classes were used - bared soil and vegetation cover selected as a reference for the algorithm classification.

A. *Description of the study area*

The study was conducted at slope, Guthrie Corridor Expressway (GCE) in Kuala Selangor, Malaysia (latitude 3°13'12.40"N to 3°13'27.30"N; longitude 101°30'29.30"E to 101°30'50.21"E. The annual average precipitation is 1570 mm. The average elevation of the study areas (consist of eight plots) ranging from 45 m to 75 m and the percentage of slope is from 50% to 100%. On the basis of the slope values, the study area can therefore be relatively classified as prone to soil erosion [19]. Eight micro plots were chosen whereby these plots are located at two different locations. Figure 1 illustrates the location of all plots. There are six micro plots with microbe and coverage treatments, classified as NBM, NBNM, PLDM and PLDNM (8m x 8m) and NDNM and NLDNM (5m x 5m) located at location 1. At location 2, there are two plots classified as NDM & NLDM (8m x 8m). All the plots are covered with the vegetation of varying density from dense (D) to less dense (LD). In terms of soil classification, all of them are categorized under Soil Hydrologic Group B, whose water infiltration rates varies from 0.15 to 0.30 inch per hour. They are moderately well drained soils whereas the soil textures were categorized between structure category 2 & 3. The fine granular and coarse granular soils are represented by the structure categories 2 and 3, respectively.

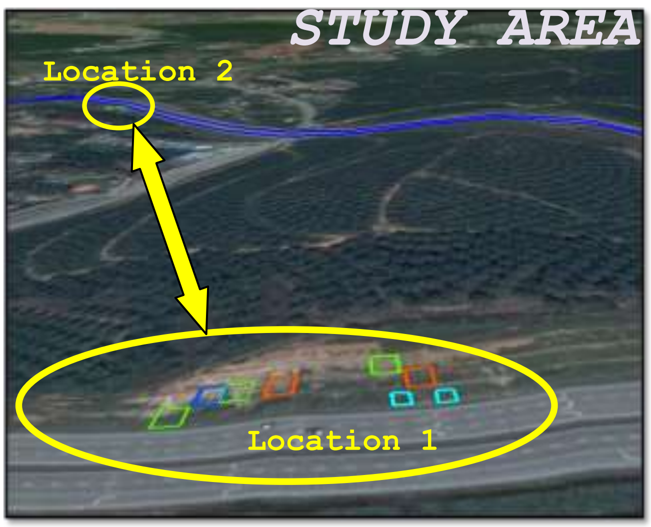


Figure 1. Aerial view of the study area

B. *Maximum likelihood (ML) classification*

Maximum likelihood (ML) is a supervised classification method derived from the Bayes theorem [20] which states that the posteriori distribution P(i|ω), i.e., the probability that a pixel with feature vector ω belongs to class i, is given by

$$P(i|\omega) = \frac{P(\omega|i)P(i)}{P(\omega)} \quad (1)$$

where P(ω|i) is the likelihood function, P(i) is the a priori information, i.e., the probability that class i occurs in the study area and P(ω) is the probability that ω is observed, which can be written as

$$P(\omega) = \sum_{i=1}^{M} (P(\omega|i)P(i)) \quad (2)$$

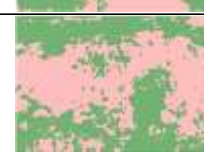
where M is the number of classes. P(ω) is often treated as a normalization constant to ensure the sums to 1. Pixel x is assigned to class i by the rule:$x \in i$ if $P(i|\omega) > P(j|\omega)$ for all $j \neq i$ Each pixel is assigned to the class with the highest likelihood or labelled as unclassified if the probability values are all below a threshold set by the user [21].

This is a method that calculates the median of the pixels taken as a reference. The probability of the pixels to belong to one of the two classes–bared soil or vegetation cover is determined based on statistical analysis by the algorithm. No limit of probability was selected which means that all pixels present in the scene processed were classified and included in one of the two classes.

C. *Ground vegetation covers calculation*

The different scenes contain the same number of pixels; areas of the two classes bared soil and vegetation cover were calculated. The percentage of the vegetation ground cover was calculated through the ratio between area of vegetation cover and total area (vegetation cover and bared soil). Despite the fact that photographs did not have scale, results were normalized as all photos were obtained in the same manner. The percentage of vegetation ground cover was then used to assess the crop management factor (C) for all the experimental plots.

TABLE I. GROUND AND CLASSIFIED IMAGE OF THE THREE PLOTS

Plots	Ground Images	Classified Images	Vegetation ground cover(%)
NBM (Natural Berm Microbs)			38.96
PLDNM (Planted Less Dense Non Microbes)			49.20
PLDM (Planted Less Dense Microbes)			76.42

D. Determination of crop management factor

In Malaysia, the C factor has been categorized into three groups [22]. Group one reflects the C factor for forested and undisturbed lands. The second group reflects the C factors for agricultural and urbanized areas whereby this group replicates the C factor for best management practices (BMPs) at construction sites. Whenever sufficient guidelines are not available to obtain the C factor values for a specific land use type or topography, the value is then suggested to be based on the correlation with other similar land use type or surface conditions. Sometimes, based on local condition, the C factor values from overseas were considered because of it similar field conditions [22]. Therefore, in this study the crop management factor is suggested to be on the basis of the similarity of land use. As the study area is at a plot scale, determination of C factor based on a similarity of the observations would be more effective and could provide accurate value than the other conventional remote sensing methods. The value of crop management factor for all the plots is shown in Table 2. Those values were calculated from the graph generated by [23] as well as following Cover Management, *C* factor for BMPs at construction sites [24-29]. As the different values of C factors are obtained from different sources for a certain category of land use type therefore, an average value is suggested if all the values are in reasonable range. According to [22], the average value of C factors for those plots will be considered as the more accurate one.

III. Results and discussion

The respective scenes of eight micro plots were classified with the ArcGIS10.1 using image classification tools. Table 1 illustrates three out of eight micro plots. In this research, the eight photographs are representative of the eight different plot scenario type subject to different vegetation coverage. The percentage of vegetation cover for the different plots shown in the second column of Table 2. The vegetation coverage varying from 38.96% to 99% plot basis whereas the plots NDM, NDNM and NLDNM have the higher amount of vegetation fraction.

A. Crop management factor by Wischmeier & Smith (1978)

The C factor values shown in Table 2 have been calculated following the techniques established by Wischmeier & Smith (1978). In 1978, they established a relationship between the percentage of ground vegetation and crop management factor. The C factors found for all the plots were ranging from 0.0125 to 0.15. The high density of vegetation cover delivered the lowest value of C factor at plot NLDNM, whereas the lowest dense delivered the highest value at NBM. To obtain the C factors, vegetation ground cover was measured at plot basis in 2013 mid of April and a relationship (3) has been derived between the C factor and the vegetation ground cover.

$$C = -0.13 \ln(VGC) + 0.626 \quad (3)$$

where C and VGC is crop management factor and vegetation ground cover, respectively.

B. Crop management factor (C) by Bubenzer (1980); ECTC (2003); Israelsen C.E. (1980); Kuenstler W (2009); Layfield (2009); Troeh F.R. (1999)

The C values shown in the fourth column of Table 2 were obtained from the available guideline established ever for Malaysian land use pattern [24-29]. The magnitude of C factors for all the plots were ranging from 0.025 to 0.1. The high density of vegetation cover delivered the lowest value of C factors at the plot NLDNM, whereas the lowest dense has delivered the highest value at the NBM. The relationship (4) between the C values and vegetation ground cover also produced good correlation value which is 0.941.

$$C = -0.083 \ln(VGC) + 0.417 \quad (4)$$

where C is crop management factor and VGC is vegetation ground cover. In case of vegetation species, Fern is dominated in most of the plots except plots NDNM and PLDNM. These two plots have contained shrubs species. But in this research, the role of species or how species variety set affect in determining C factor has not been taken into account.

C. Averaging of crop management factor (C) value

The previous calculated values give slightly differ value of C although the same characteristics of vegetation are considered. Therefore, final calculated C value was computed by averaging those two results shown in Table 2.

$$C = -0.11 \ln(VGC) + 0.521 \quad (5)$$

Equation (5) reflects the highest correlation between the C factors and Vegetation Ground Cover as compared to the others. In this study, three relationships were found using three alternative procedures to obtain C factors for identical spatiotemporal condition. The outcomes of these three methods are depicted in Table 2 and presented in Figure 2 clearly.

TABLE II. COMPARISON OF CROP MANAGEMENT FACTOR (C) OBTAINED FROM THREE METHODS

Plots	Vegetation Ground Cover (%)	Crop Management Factor (C) (Wischmeier& Smith, 1978)	Crop Management Factor (C) (Bubenzer, 1980; ECTC, 2003; Israelsen C.E., 1980; Layfield, 2009; Troeh F.R., 1999; W, 2009).	Average Crop management factor (C)
NBM	38.96	0.15	0.1	0.125
NBNM	57.59	0.1	0.05	0.075
NDM	80-99.61	0.05	0.02	0.035
NDNM	89.51	0.05	0.02	0.035
NLDM	59.18	0.067	0.05	0.0585
NLDNM	99.32	0.0125	0.02	0.0162
PLDM	76.42	0.067	0.035	0.051
PLDNM	49.20	0.117	0.075	0.096

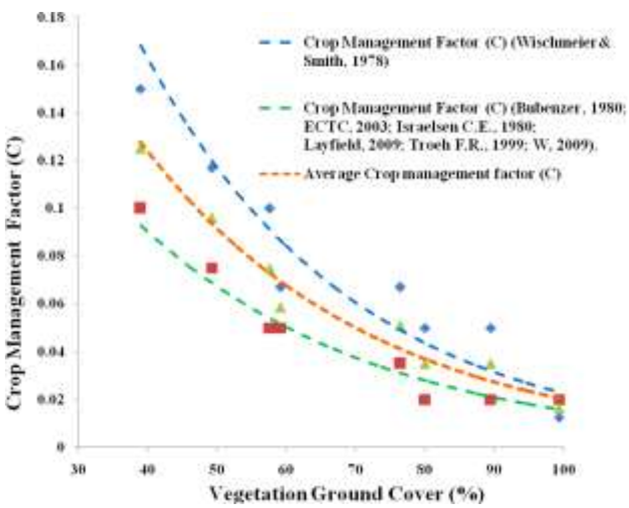


Figure 2. The relationship between Vegetation Ground cover and Crop management factors(C)

IV. Conclusions

The vegetation cover factor derived from the proposed method for all the plots seems more accurate as it is directly measured at site. The vegetation factor (C) ranges from 0.012 to 0.15 because of naturally developed dense cover. The proposed technique is proven to be useful for derivation of more accurate vegetation cover factor (C) value at small scale and sloping terrain. The technique also can be applied to a large area using unmanned aerial vehicle UAV. The presented method can be applied not only on the sloping area beside highway but also can be used in any topography and in everywhere. Due to its simplicity in operation, easy application and effectiveness in estimating vegetation ground cover, this technique can be beneficial for the government agencies who responsible for monitoring the relevant policies.

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