SELECTION OF APPROPRIATE MODEL FOR TOPOGRAPHIC CORRECTION IN VIETNAM'S MOUNTAINOUS TERRAIN BY USING SPOT-5 SATELLITE IMAGERIES

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Abstract: Vietnam's forest mountainous areas account for three quarters of the whole country. Many local regions are in altitude over 1000m compared to sea level. Complex mountainous terrain is first related with high elevation differences described by slopes and their aspects, so the solar illumination over terrain is changeable very large and affecting the spectral radiance of optical satellite images; particularly those related to appearance shadows. To enhance image interpretation for the mountain terrain and improve accuracy in mapping land surface covers, we need to correct topographical factors affecting primarily to the difference of spectral radiance of optical satellite images. There are over 10 models of different algorithms such as cosine, Minnaert, C-correction, etc. used for topographical correction. This paper presents some algorithms widely applied in practice along with examined tests performed on ENVI system to choose suitable algorithm for Vietnam's mountainous terrain characteristics with the use of SPOT-5 satellite and DEM data.

INTRODUCTION

Illumination terrain effect in high terrain elevation areas impacts on changing reflection of objects' properties on the ground, regarding to misunderstanding on partitioning land surface cover because of different situation terrain. Impact of terrain illumination terrain effect (from the Sun) affects local angle incidence of each imagery pixel, wavelength of coming radiation, and own characteristic reflectance of land surface cover. Researches of the world from the 80s of the previous era until now have concluded illumination terrain effect to radiant image needs to correct each multi-spectral channel before image classification and study on changing land surface covers [1, 2, 6, 7].

In order to correct illumination terrain effect in high terrain elevation areas of each imagery pixel, we use DEM model that is also used for rectifying geometric imagery. DEM accuracy not only affects geometric rectification accuracy, but also affects accuracy correction of radiant image [3, 5]. For low terrain elevation of image, we use global DEM of SRTM with its grid resolution of 90ms, or DEM of ASTER – 30ms, or DEM covering at corresponding map scales 1: 50 000, 1: 25 000 for high image resolution.

A number of model for rectifying illumination terrain effect at high terrain elevation areas of each imagery pixel which scientists have proposed from the 80s of the previous era until now up to 10 models [1, 2, 6, 7, 8]. Selection of an appropriate model to rectify radiant image that are influenced illumination effect by high terrain elevation needs to study on each type of terrain in details.

This paper presents the scientific basis of four correction models of radiant image caused by high terrain elevation of Hoa Binh province. Research results show the third and the fourth model can be applied mountainous terrain in Viet Nam because of their coefficient of variation (CV) of the image after correcting using the third and the fourth models are less than CV of the original image. With the purpose for selecting suitable correction models to improve imagery quality, so we use an image at 1A level represented in DN (digital number – the original image) and skip other correction steps such as sensor radiation calibration and atmospheric effects.

METHODS AND EQUATION

In this section, we present 4 correction models that use for rectifying radiant image caused by high terrain elevation, which have considered by scientists in the World.

Cosine correction model

The Teillet model is a name of the proponent calling cosine correction model or the Lambert correction model. This is the simplest model to correct radiant image caused by high terrain elevation. This model was based on an assumption of coming radiation (from the Sun) reflecting equally in all directions. Naturally, the assumption was not appropriate to objective reality. The model used two angles which were solar zenith angle θ_S and angle of incidence i of light beam from the Sun to the terrain. The model has a form:

$$Rn = R.(\cos \theta_S / IL) \text{, với } IL = \cos i \qquad \textbf{(Equation M1)}$$

Where: R – Radiant image before correction (the origin); Rn – Radiant image after correction; IL – cosine function of i or illumination terrain function.

Minnaert's correction model

The Minnaert model supposed that a correction model in all directions was different or the terrain was non Lambert terrain. This assumption was close to reality. The Minnaert added a constant k that was an exponent for the ratio of ($\cos \theta_S$ /IL). Minnaert model has a form:

$$Rn = R.(\cos \theta_S / IL)^k \text{, with } k \text{ is constant} \qquad \textbf{(Equation M2)}$$

The constant k was called the constant characteristic of terrain. Some authors had modified the Minnaert model by adding cosine function of slopping terrain into the formula M2.

Teillet's correction model

Teillet added a constant C into numerator and denominator of the formula (1) or was called a correction model C. Where: C was a ratio between the 'additional compensation' (offset) and rate coefficients (slope) of linear regression line between the original image R and IL. The rectification model C is written as:

$$Rn = R.[(\cos \theta_S + C)/(IL + C)] \qquad \textbf{(Equation M3)}$$

Meyer's correction model

In fact, Meyer correction model was called a statistical modeling. Its form as:

$$Rn = R - m.IL - b + R_{mean} \qquad \textbf{(Equation M4)}$$

Where: m – slope coefficient; b – offset; R_{mean} – mean value of R. m and b coefficients were determined by linear regression function between R and IL, details as $R = m.IL+b$.
Experiment of all models presented above to select the one appropriate to the mountainous terrain with high terrain elevation in Hoa Binh province is carried out in the experimental section.

EXPERIMENT

Experimental area

Geography: The experimental area is located mountainous area belonging to Tan Lac district, Hoa Binh province. Its geography are latitude $20^0$30' - $20^0$45' North and longitude $105^0$30' - $105^0$45' East, far away from Ha Noi about 73kms.
Topography: Topography of the experimental area is a high mountain, split complex, high slope and its direction is North-West and South-East. The high mountain (North-East) has average height from 600-700ms, the greatest height is 1189ms, average slope is 30^0-35^0. The terrain is obstacle, difficulty in going and walking.

Data

The data is used in the report includes:

Digital elevation model (DEM).

DEM data of the experimental area is established by topographic maps at scale 1: 25 000 with accuracy 3ms (equally 1/3 of all about high of the basic contours of the topographic map 1: 25 000). DEM has magnitude values of pixels about 20ms, which are re-spitted samples with its resolution 10ms for appropriate to spatial resolution of multispectral satellite images SPOT 5. The DEM data is described in figure 1a.

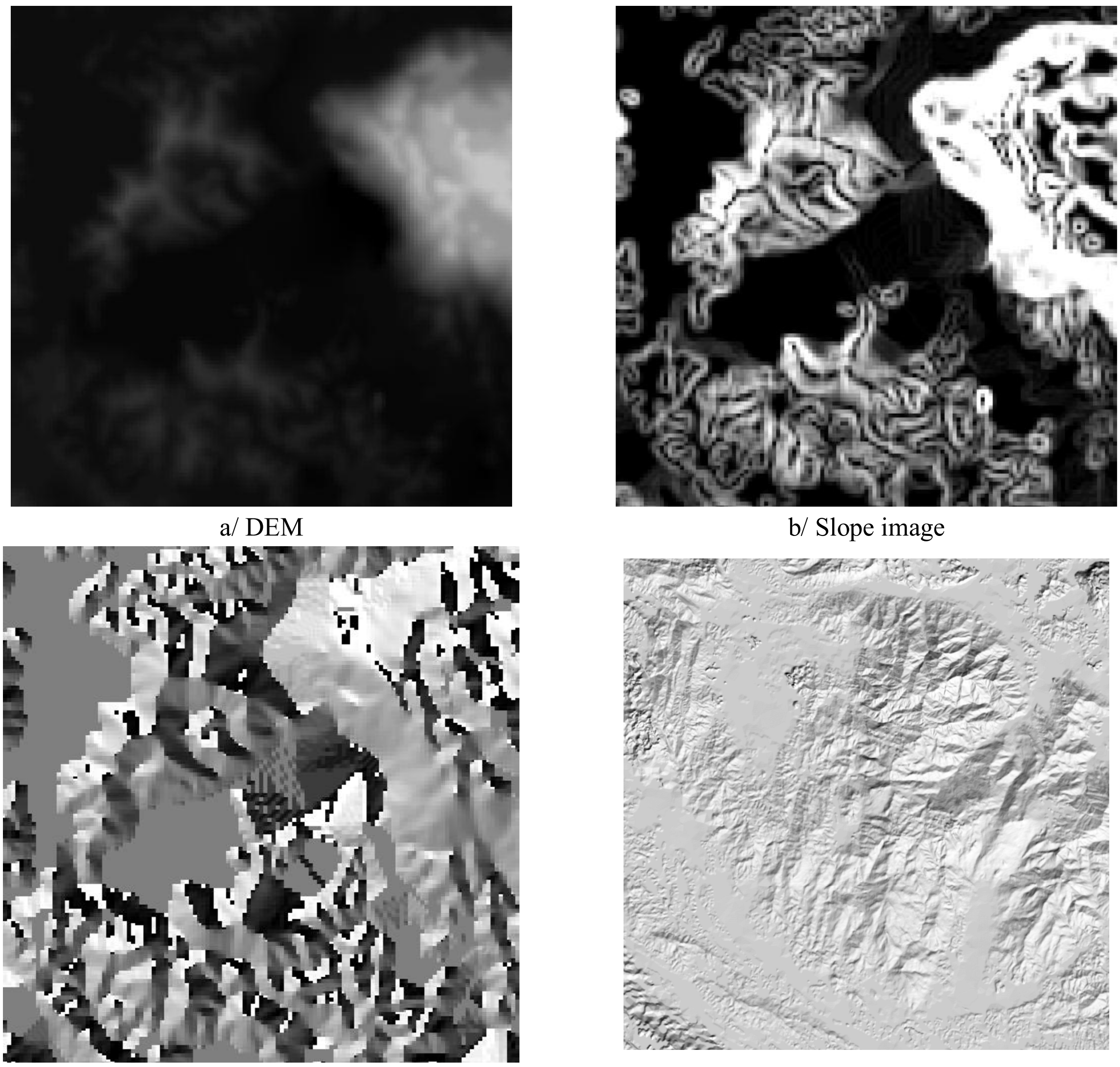
Satellite image data.

Satellite image is used the SPOT 5 of Hoa Binh province. SPOT 5 parameters are represented in table 1 as below:

Table 1: SPOT 5 parameters

No	Attributes	Parameters
1	Image ID	269-309
2	Time of taking image	2010-11-02 03:30:44.1
3	Equipment	HRG 2
4	Level	1A
5	Channel number	4
6	Angle orientation	12.307103^0
7	Angle of incidence	$R17.930865^0$
8	Solar elevation angle	50.776214^0
9	Solar azimuth angle	151.966534^0
10	Spatial resolution of three multispectral image channels	10 m

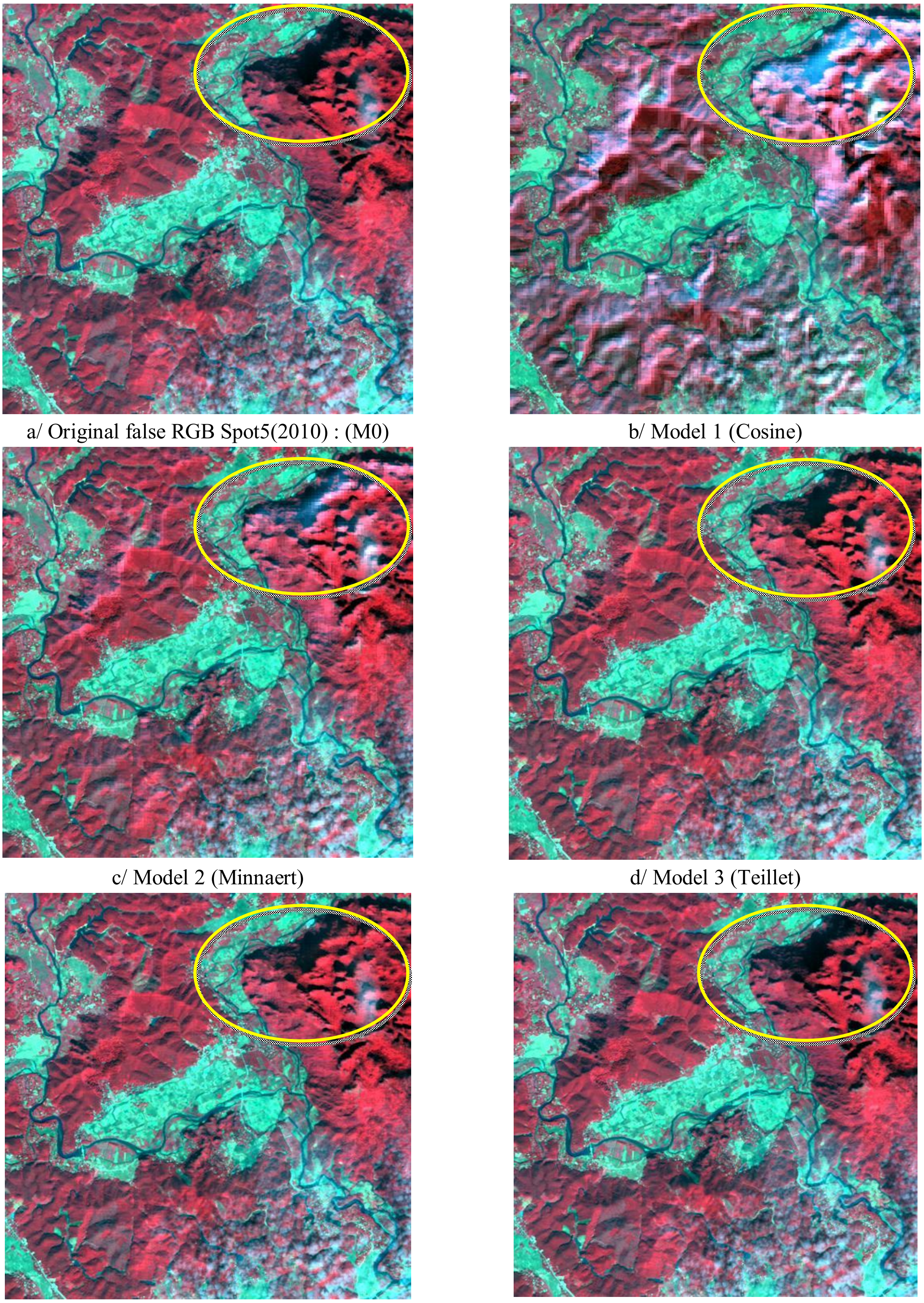
False colour image combination (M0) of three original image channels XS1, XS2 XS3 at level 1A with digital number DN is showing in figure 2a. Image processing softwares for correcting the terrain caused by high terrain elevation are used ENVI and ArcGIS.



a/ DEM b/ Slope image

c/ Slope aspect (azimuth) image d/ Topographic illumination image IL from the Sun

Figure 2. DEM and its enhance products



a/ Original false RGB Spot5(2010) : (M0)

b/ Model 1 (Cosine)

c/ Model 2 (Minnaert)

d/ Model 3 (Teillet)

e/ Model 4 (Meyer)

a/ Original false RGB Spot5 (2010) : (M0)

Figure 2: Comparison between corrected images (M1-M4) and the original image (M0) – (False colour image combination, 2010)

Implementation

DEM and satellite images are put on the same coordinate system VN 2000 and are cut according to the experimental area. DEM is used for calculating slope index and slope aspect (slope azimuth) images (figure 1b, and figure 1c), which are done in ArcGIS.
According to the slope index and slope azimuth image combined with satellite images' parameters, we calculate topographic image illumination from the Sun IL firstly. Among models (M1 – M4) of correcting terrain effect caused by high terrain elevation, the IL image is an important role of image transformations. Results of the image calculation are representing in the figure 1d.
Parameters, constants of correction models as showing in the second section are determined and correction models of high terrain elevation effect to spectral radiance of each image channel being also determined; after that doing false colour image combination. Results are presenting in figures 2b-2e.
The second model (the Minnaert model) needs to determine a constant *k* of the terrain of the experimental area. After using suitable image transformations, we have received the k for each corresponding image channel. Determined results are showing in the table 2.

Table 2: The constant k of the Minnaert model for three multispectral channels SPOT 5.

Image channel	XS1	XS2	XS3
Minnaert constant *k*	0,342	0,243	0,206

Results assessment

Results assessment of correcting terrain effects can be carried out by two ways:
- By intuitiveness
- By statistical parameters

In order to assess the result of correction models because of high terrain elevation objectively, we use the CV coefficients calculated by the formula:

$$CV = \frac{\sigma}{\mu} \qquad \textbf{(Equation 5)}$$

Where: σ - standard deviation and μ - mean of the image
The results of calculated indices CV of the original (M0) and 4 corrected images (M1-M4) according to 4 correction models presented in the second sections are in the table 3.

Table 3: The coefficient of variation, CV (%) of the original and the corrected images by four models for 2010.

Image channel	Original image (%)	Model 1 (%)	Model 2 (%)	Model 3 (%)	Model 4 (%)
	M0	M1	M2	M3	M4
XS1	17.39	18.94	17.28	16.60	16.78
XS2	22.48	23.39	21.83	22.19	18.06
XS3	13.15	16.73	12.88	12.95	11.04
Average	**17.67**	**19.68**	**17.33**	**17.25**	**15.29**

CV graphs of three original image channels XS1; XS2; XS3 and four corrected images according to four correction models of reflection spectrum caused by high terrain elevation for experimental area are shown in the table 3.
Summary of the assessment as below:
1/ Intuitively, we realize the image before correcting high terrain elevation effect to spectral radiance of land surface cover (example, in the area with a sign of the yellow colour is shadow of the terrain), which belongs to invisible shadow areas. After correcting images because of high terrain elevation effects to spectral radiance, we can see objects sharply, the model 3 and 4, especially. The area that was flashed images had balancing light levels, which increased significantly.

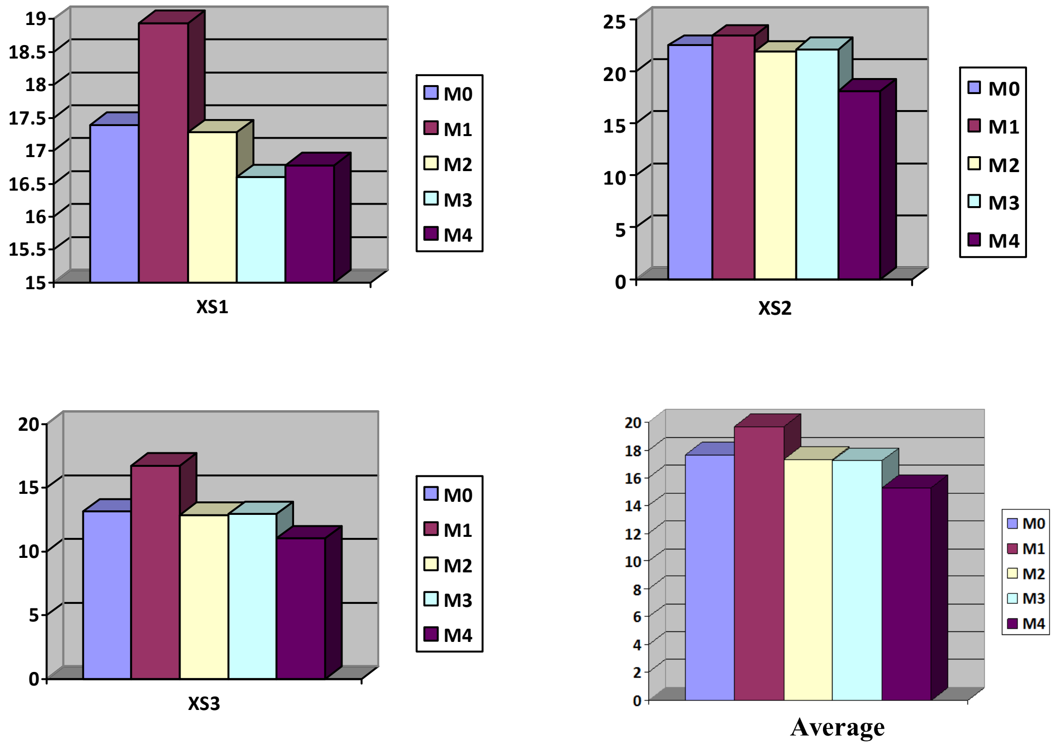


Figure 3. The charts of the CV indices (from table 3) of three XS channels after correcting through four models (M1-M4) compared to the original image (M0).

2/ Looking into CV coefficient table (table 3) and the charts in the figure 3 we considered the CV indices of the model 3 and 4 are smaller than the other correction models for each multi-spectral images, synonymically with information quality on these images of two correction models M3 and M4 are better than the original image.
Among 4 models participated in the studying show the fourth correction model has gave the best image quality after correcting terrain effect.

CONCLUSION

Correcting illumination effect of the terrain to radiant image due to high terrain elevation is necessary. Corrected images can be in different qualities this belongs to choosing correction model. In order to carry out it, need to select suitable correction model corresponding terrain characteristics of interested area. The image corrected by selected model will give better image quality compared to original one; this is synonymic to capacity of improving accuracy of image classification as well as in studying land surface cover changes. Intuitively, we can identify it; however, in order to ensure objectivity, the CV coefficient is considered as an index for assessment images quality before and after correcting.
For the mountainous terrain of Hoa Binh province, the statistical-experimental model (M4) to correct SPOT5 radiant image caused by high terrain elevation is the appropriate model to improve image quality compared to the original image of 13,5%. If we continuously correct radiant image due to radiation sensor calibration and atmosphere effects, the image quality will be further improved.

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