Slope and aspect errors evaluation

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Introduction

Knowledge about vegetation cover distribution by different relief elements is very important to solve actual problems concerning forest territories. Slopes and aspect are easily computable from existent DEMs. But it is critical to know an accuracy of the estimations.

In this research equations to estimate errors of derived slopes and aspects from DEM were determined.

SRTM DEM with spatial resolution of 90 m was analyzed as example.

Analysis of larch stands distribution by relief elements was carried out for Tuva mountainous region.

Aspect error estimation

An aspect image is an image file that is gray scale coded according to the prevailing direction of the slope at each pixel. Aspect is expressed in degrees from north, clockwise, from 0 to 360. Due north is 0 degrees. A value of 90 degrees is due east, 180 degrees is due south, and 270 degrees is due west. Aspect uses a 3 × 3 window around each pixel to calculate the prevailing direction it faces. For pixel (x, y) with the following elevation values around it, the average changes in elevation in both x and y directions are calculated first. After that an aspect is calculated by the following equation (Erdas, 2006):

$$\theta = \frac{180}{\pi} arctg\left(\Delta x / \Delta y\right) \qquad (1)$$

Where θ – an aspect in degrees; Δx – the average changes by x direction; Δy – the average changes by y direction.

According to the error calculation theory (Taylor, 1982) and the equation (1) an error was determined as the following:

$$\delta(\theta) = \frac{180\delta H}{\pi}\sqrt{\frac{2}{3\left((\Delta x)^2 + (\Delta y)^2\right)}} \qquad (2)$$

Where $\delta(\theta)$ – an aspect root mean square error (RMSE); δH – the relative elevation error.

Rodriguez et al calculated the relative elevation error of SRTM 3 arc sec model for Eurasia, it is ~ 8.7 m. (Rodriguez, 2006)

To calculate errors the Erdas Spatial Modeler was used.

Calculation included three parts: 1) to calculate the average changes in elevation in both x and y directions; 2) to determine aspect and slope errors for the whole analyzed territory; 3) to estimate aspect and slope errors for forest area (fig. 1).

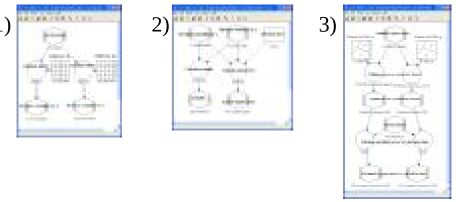


Figure 1. Aspect error estimation models created using of Erdas modeler.

Slope error estimation

Slope is expressed as the change in elevation over a certain distance. In this case, the certain distance is the size of the pixel. Slope is most often expressed as a percentage, but can also be calculated in degrees. A 3 × 3 pixel window is used to calculate the slope at each pixel. For a pixel at location x, y, the elevations around it are used to calculate the slope as shown in the equation (3).

$$\beta = \frac{180}{\pi} arctg\left(\frac{\sqrt{(\Delta x / X_s)^2 + (\Delta y / Y_s)^2}}{2}\right) \qquad (3)$$

Where β – a slope in degrees; X_s, Y_s – spatial resolutions by x and y directions accordingly, From the equation (3) an error was estimated as following

$$\delta(\beta) = \frac{587.88\delta H}{\pi L\left(4 + (\Delta x)^2 + (\Delta y)^2\right)} \qquad (4)$$

Where $\delta(\beta)$ – a slope RMSE.

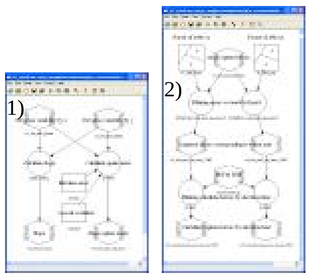
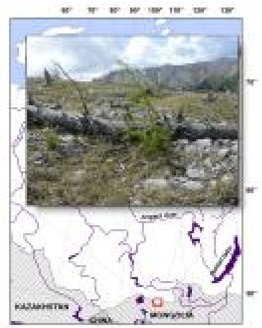


Figure 2. Slope error estimation models created using of Erdas modeler.

Experimental usage



Analysis of larch stands distribution by relief elements was carried out for Tuva mountainous region (Sengilen ridge, fig. 3).

Figure 3. Tuva region test site location (red square)

The forest distribution data was collected from topographic maps (1960, 1983) and the Landsat-based classification map (2002). Aspect and slope errors evaluation was carried (fig. 4, 5), and median-vector direction was calculated for different elevation slices (fig. 6).

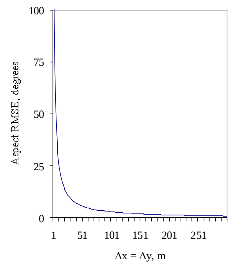


Figure 4. Aspect RMSE depending on average elevation difference (Δx, Δy) between neighboring pixels

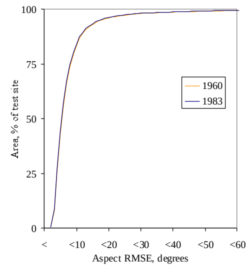


Figure 5. Aspect RMSE distribution relatively to test area.

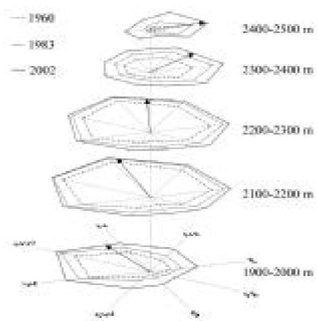


Figure 6. Distribution of forests with respect to azimuth. The radius-vector shows the dominant direction of forest distribution (for the year 2002). Areas of forest for a given year (1960, 1983, and 2002) are proportional to the areas within the boundaries.

With an elevation increase the forest distribution orientation changed clockwise (total shift was 120°±13°), and became east oriented at the highest elevation where trees were found (fig. 6). For the years 1960 and 1983 the radius-vector was shifted to 133°±15; p<0.05). The observed changes can be attributed to wind impacts, which increases as elevation increases.

The same calculation was done to determine slope RMSE (fig. 7, 8) and forest distribution by slopes (fig. 9, 10).

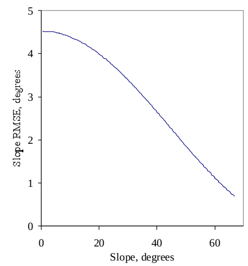


Figure 7. Slope RMSE depending on slope steepness.

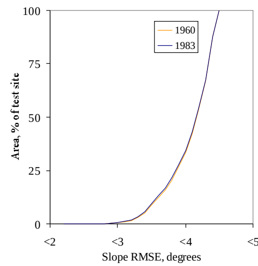


Figure 8. Slop RMSE distribution relatively to test area.

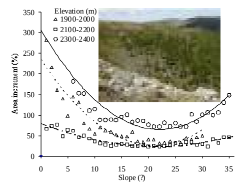


Figure 9. Forest area increment dependence on slope steepness (2002 vs. 1960 yrs.). Elevation belts: 1900 – 2000, 2100 – 2200, 2300 – 2400 m.

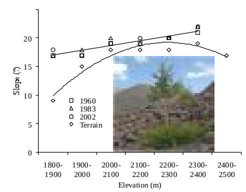


Figure 10. The dependence of "slope steepness medians" on elevation. Plotted values are median steepness values for forested slopes

Conclusions

Slope and aspect errors decrease with increment of elevation variation of neighboring pixels.

It was determined that the aspect RMSE is less than 13 degrees for 90% of the analyzed forest area, and the slope RMSE is not higher than 4.5 degrees (<3.5 degrees for slopes <30 degrees).

The results obtained showed that forest warming-induced response in Tuva region mountainous areas is dependent on relief features and this one significantly modified spatial patterns of high elevation forests during the last four decades.

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