Object-based Vegetation Type Mapping from an Orthorectified Multispectral IKONOS Image using Ancillary Information

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ABSTRACT:

Traditional pixel-based image classification approaches have some limitations with the use of very high spatial resolution imagery. In recent years, object-based image analysis (OBIA) approaches has emerged with an attempt to overcome those limitations inherited to the conventional pixel-based approaches. When using OBIA approach, it is known that the quality of segmentation directly affect classification results. In this study, object-based vegetation type classifications for a steep mountain area were conducted from a multispectral IKONOS image by using spectral as well as topographic information such as elevation, aspect, and slope. In addition, another ancillary information, i.e., stream GIS data, was incorporated into image segmentation procedure. This study demonstrated that OBIA with topographic variables produced higher classification results than OBIA with only spectral information by 4.2 % and 0.04 for overall accuracy and Kappa coefficient, respectively. However, the most improved classification accuracies were acquired by using Euclidean distance as well as spectral and topographic information. In this approach, the highest classification accuracies were obtained at a scale of 48 with an overall accuracy of 76.6 % and a Kappa of 0.57. In addition, a final classification result from the scale was the most agreeable to manual interpretation. In future study, we plan to conduct a study associated with topographic correction on the multispectral IKONOS image by using a lidar-derived digital elevation model to remove spectral variation caused by terrain in the mountainous area.

1. INTRODUCTION

Object-based image analysis (OBIA) approach has been widely utilized for remote sensing studies as an alternative methodology to conventional pixel-based image classification approaches in recent years. When performing thematic image classifications from very high spatial resolution (VHR) imagery, the traditional pixel-based approaches have some limitations. VHR imagery is characterized by high variation of spectral reflectance values for the same landscape feature. The high spectral variation causes the decrease of conventional pixel-based classification accuracies (Woodcock and Strahler, 1987; Marceau *et al.*, 1990; Shiewe *et al*., 2001; Yu *et al*., 2006; Lu and Weng, 2007). In addition, the pixel-based approaches ignore the spectral reflectance coming from neighboring pixels (Fisher, 1997; Townshend *et al*., 2000; Brandtberg and Warner, 2006). The OBIA approach is considered as a methodology to overcome these limitations of pixel-based image classification approach.

The OBIA approach is divided into two major steps: image segmentation and image classification. The image segmentation is a procedure to partition an entire image area into image objects (or segments) that are groups of pixels with homogeneous spectral values. After segmentation, supervised or knowledge-based image classifications are conducted based on image segments. The quality of segmentation is known to directly influence object-based classification results (Blaschke, 2003; Dorren *et al.*, 2003; Meinel and Neubert, 2004; Addink *et al*., 2007). When conducting object-based vegetation/forest types mapping, Dorren *et al.* (2003) and Ryherd and Woodcock (1996) demonstrated the critical effect of the size of image segments on classification results. Kim *et al*. (submitted) conducted a study associated with object-based forest type classification in a U.S. National Park unit from a multispectral IKONOS image. The forest types included deciduous, evergreen, and mixed classes. According to their study, segmentation scales associated with the size of image objects were very closely related to forest type classification results. They also found that optimal segmentation scales were similar to the size of minimum mapping unit, i.e., 0.5 ha, required for vegetation/forest classification of U.S. National Park. In addition, Kim *et al.* (2008) found that optimal segmentation scales produced image segmentation results most similar to a manually-interpreted forest stands at the optimal segmentation scales in terms of average size and number

Keeping the critical impact of segmentation quality on object-based classification results in mind, we performed an object-based vegetation type mapping from an orthorectified multispectral IKONOS image covering a portion of Great Smoky Mountains (GRSM) National Park, U.S. Madden (2004) performed overlay analysis of vegetation polygons representing individual community-level forests with several topographic variables, such as elevation, slope, and aspect in the Thunderhead Mountain, a portion of the GRSM. According to the study, it was found that the spatial coincidence of vegetation and topographic variables agreed with field observations, *e.g.*, 65 % of cove hardwoods were located on moist environment north, northwest, and northeast aspects. This study conducted object-based vegetation type classification based on spectral information as well as ancillary information from topographic variables such as elevation, slope, and aspect in order to investigate the effect of topographic variables on image segmentations for mountainous areas. In addition, we

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utilized a GIS data set describing the location of streams in the study area to incorporate the association relationship between stream and vegetation communities.

2. STUDY AREA AND DATA

The study area is a portion of U.S. Geological Survey (USGS) 1:24,000-scale Smokemont quadrangle that is a part of GRSM National Park (Figure 1). The total area of the study is around 40 km^2. Great Smoky Mountains National Park, established in 1934, is located along the North Carolina-Tennessee border in southeastern United States and encompasses over approximately 2,070 km^2 of continuous forest cover including over 100 different species of trees and containing one of the most extensive virgin hardwood forest areas remaining in the eastern U.S. (Welch *et al.*, 2002; Madden *et al.*, 2004). Community-level vegetation types of GRSM National Park were manually interpreted and a geodatabase of the vegetation types were created by Center for Remote Sensing and Mapping Science (CRMS), Department of Geography, the University of Georgia. The community-level vegetation types of Smokemont quadrangle were collapsed to 5 general types according to terrestrial ecological communities based on Community Element Global (CEGL) codes of GRSM All Taxa Biodiversity Inventory (http://www.dlia.org/atbi/grsmnp_habitats/index.shtml). The vegetation types included deciduous forest, evergreen forest, mixed forest, shrub, and grass.

A multispectral IKONOS image, acquired in October 30, 2003, was utilized for object-based vegetation types mapping. It was orthorectified with ±6 m root mean square errors by using OrthoEngine of PCI Geomatica (Version 9.1). Ground control points (GCPs) of 24 were selected with a reference to 1:12000-scale color infrared (CIR) air photos, acquired in 1997 by U.S. Forest Service (Welch *et al.*, 2002), and entered into an orthorectification procedure of satellite orbital math model. A 10-m National Elevation Dataset (NED) from USGS was employed to determine elevation of each GCP and derive topographic variables such as slope and aspect. All other landscape units than vegetation were masked out from an orthorectified multispectral IKONOS image. Sample points for accuracy assessment were derived from a manually-interpreted geodatabase with stratified random sampling method.

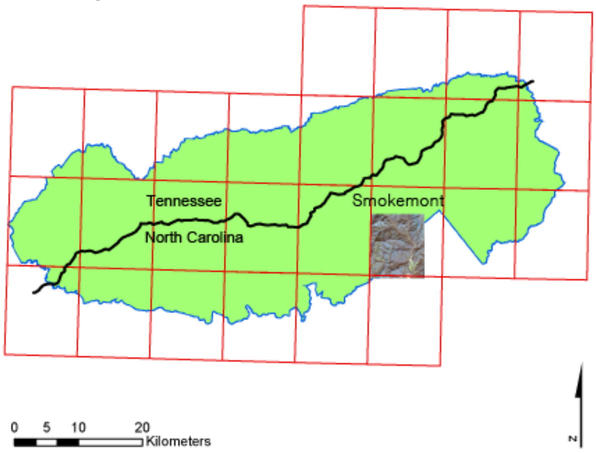

Figure 1. Locator map of study area in USGS Smokemont quadrangle.

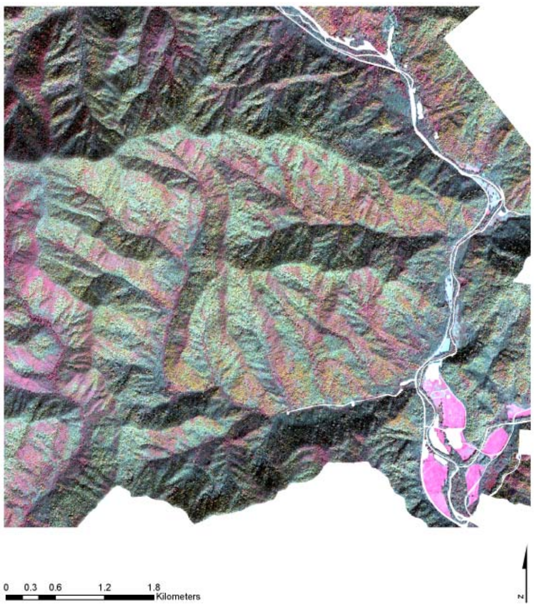

Figure 2. Orthorectified multispectral IKONOS image of study site.

3. RESULTS

This study adopted two different scenarios for object-based vegetation type mapping from the VHR satellite imagery: 1) OBIA only based on spectral information (spectral OBIA approach), 2) OBIA based both spectral information and topographic information (topographic OBIA approach), and 3) OBIA based on stream information as well as spectral and topographic information. All the procedures of the study were performed by using Definiens Developer (Version 7.0). Multiresolution segmentation algorithm and standard nearest neighbour classifier were used for image segmentations and classifications, respectively. We employed arbitrarily-determined segmentation scales, i.e., scale parameters, from 10 to 80 in steps of 5.

Object-based vegetation type classifications produced overall classification accuracies for the two scenarios across all segmentation scales as shown in Figure 3. At small segmentation scales, e.g., scale of 10, OBIA vegetation type mapping produced salt-and-pepper appearance due to the small size of individual image objects when compared with the manual interpretation. Figure 4a illustrates a five-class vegetation type from the manual interpretation and Figure 4b represents an OBIA classification result from scale of 10 with spectral alone. In Figure 4a, individual objects' boundaries are described in black solid line. The highest overall classification results were acquired at a scale of 65 with 67.1 % of overall accuracy and 0.44 of Kappa coefficient from spectral OBIA approach. Considering individual classification accuracies, 'Grass' class was most accurately classified with 89.3 % and 93.8 % of producer's and user's accuracies, respectively. However, as shown in Figure 5a, the shapes and locations of vegetation types from spectral OBIA approach were very different from those of the manual interpretation. This difference between the manual interpretation and spectral-only OBIA approach was attributed to the quality of segmentation as shown in Figure 5a. The boundaries of individual image objects were delineated in black-solid line in the figure. Spectral OBIA approach produced a segmentation result of vegetation stands that were very different from those of the manual interpretation (see Figures 4a and 5a).

In the second scenario, topographic variables of elevation, slope, and aspect were entered into segmentation procedures with scales of 10 to 80 in steps of 5. Only mean spectral values of individual image objects were utilized in a series of object-based vegetation type classifications.

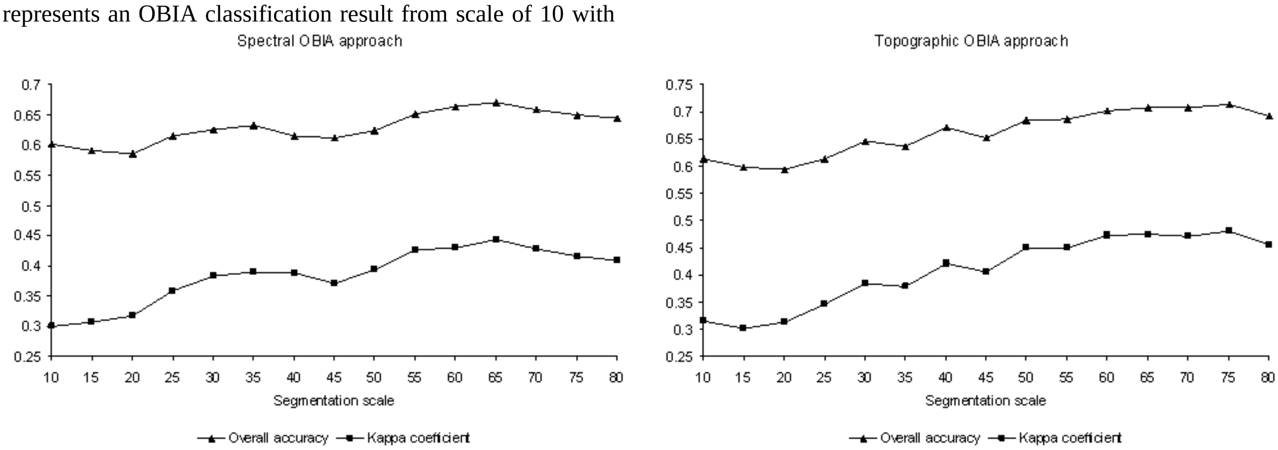

Figure 3. Overall classification accuracies as a function of segmentation scales.

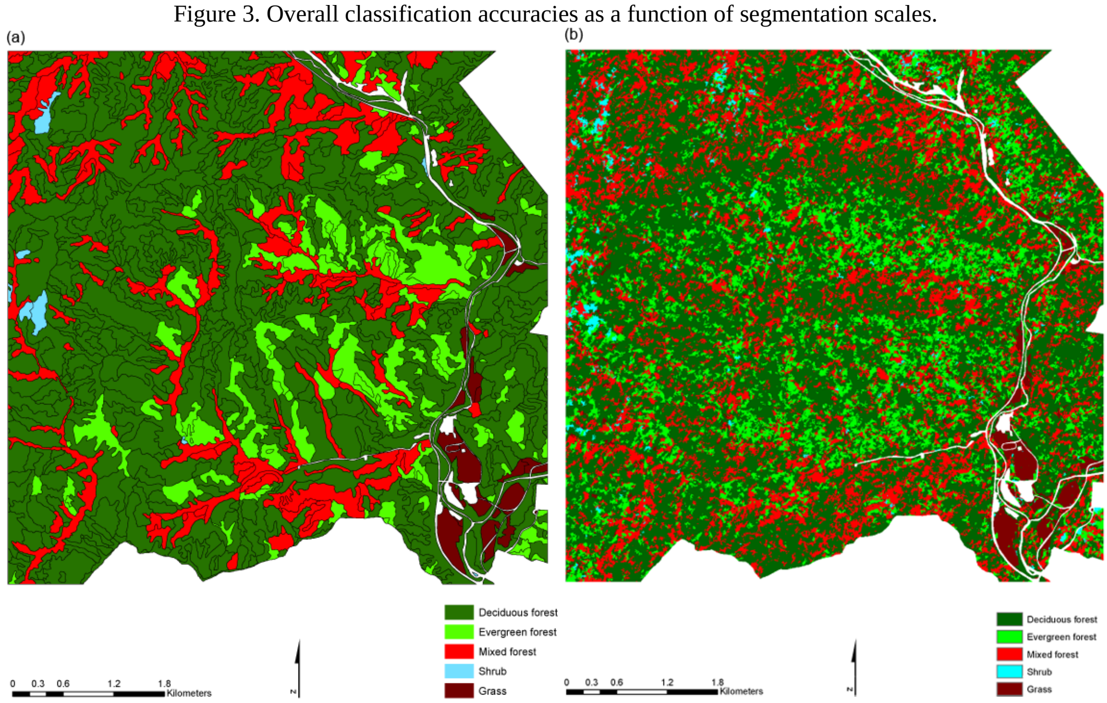

Figure 4. Manual interpretation (a) and spectral OBIA result from a scale of 10.

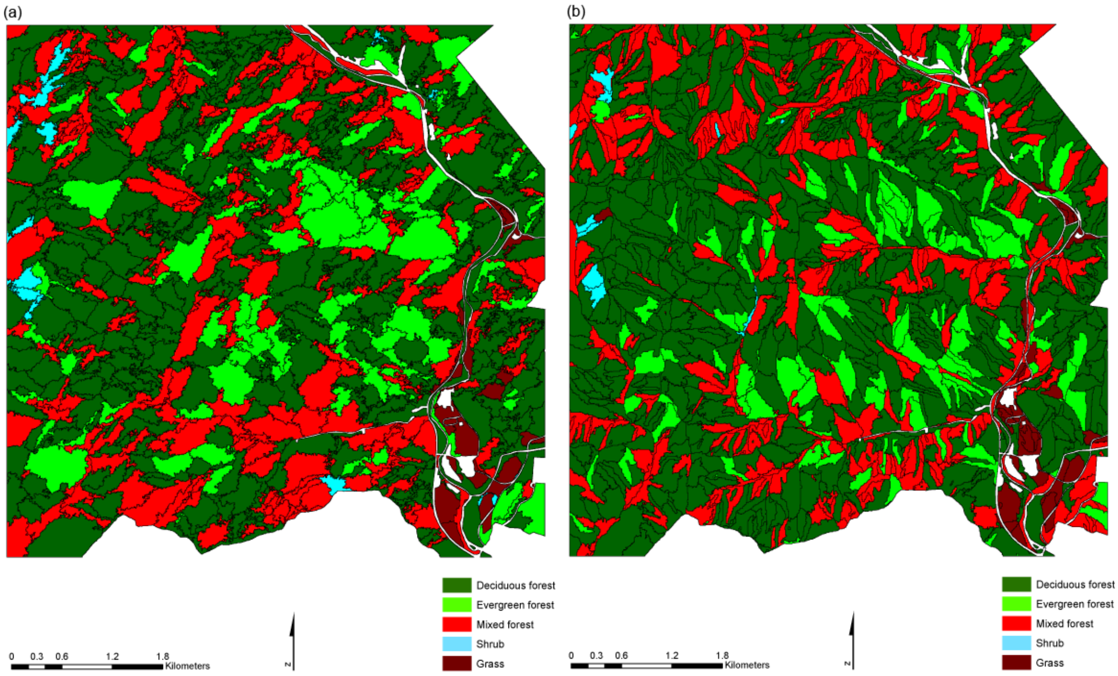

Figure 5. Spectral OBIA result (a) and topographic OBIA result (b) both from a scale of 55.
The spectral OBIA produced an overall accuracy of 65.2 % and the topographic OBIA resulted in an overall accuracy of 68.7 %.

As shown in Figure 3, the pattern of topographic OBIA results across all segmentation scales was similar to that of spectral OBIA results. However, the highest accuracies of topographic OBIA approach were 71.3 % of overall accuracies and 0.48 of Kappa coefficient at a scale of 75. The inclusion of topographic variables in OBIA approach could improve classification accuracies of five vegetation types. In addition, the quality of segmentation was enhanced by incorporating topographic information such as elevation, slope, and aspect. As shown in Figure 5b, the topographic OBIA approach resulted in a more agreeable vegetation type map to the manual interpretation than the spectral OBIA approach.

As for the last scenario, we derived an image describing Euclidean distance from stream channels that are distributed in the study area. The distance image was entered into image segmentation procedures with spectral bands and topographic variables (i.e., elevation, aspect, and slope). The same range of segmentation scales was employed in this OBIA scenario, and only mean values of individual image objects were utilized in vegetation type classification procedures. Then, we subdivided segmentation scale in step of 1 around a 5-step scale that produced the highest accuracies. Figure 6 describes overall classification accuracies. In 5-step scale classification, the scale of 50 resulted in the highest overall accuracy of 75 %. When subdividing scales around 55, we obtained more improved classification results with an overall accuracy of 76.6 % and 0.57 at a scale of 48. Figure 7a illustrates a vegetation type classification from the scale of 48. When compared with spectral and topographic OBIA, stream channel information yielded the most agreeable vegetation type map among three scenarios to the manually-interpreted vegetation geodatabase.

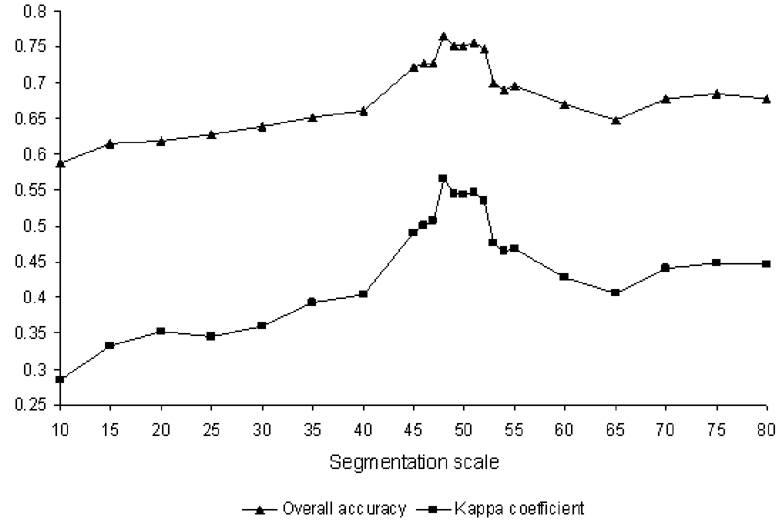

Figure 6. Overall classification accuracies from segmentations by using spectral, topographic, and stream information.

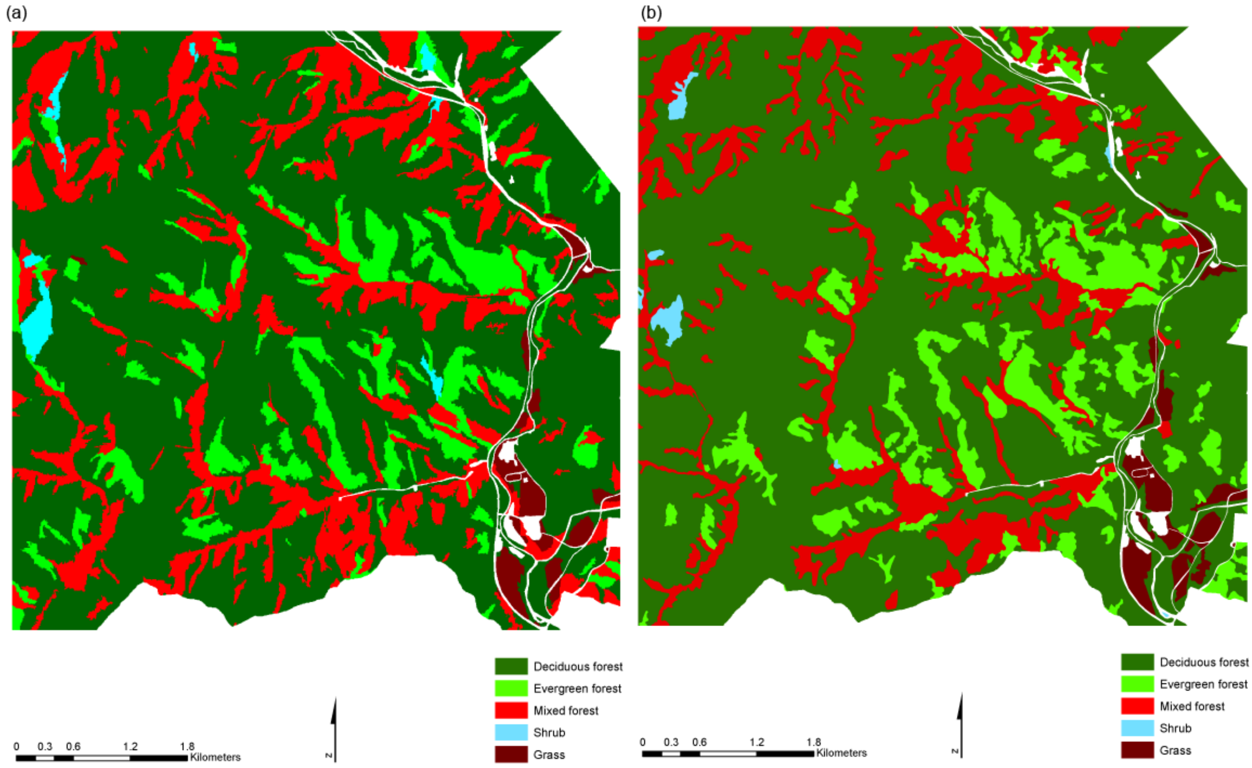

Figure 7. A vegetation type classification from a scale of 48 by adding Euclidean distance of stream (a) and a vegetation type map collapsed from the CRMS manual interpretation (b).

4. CONCLUSIONS

Object-based vegetation type classifications were performed by using spectral and topographic information. In this study, various scales were utilized for image segmentations. Object-based classification results were visually compared with a manually-interpreted vegetation type geodatabase and their accuracies were evaluated by using sample points derived from the manual interpretation.

This study demonstrated that object-based vegetation type classification in a mountain area was directly affected by segmentation quality. Spectral OBIA approach produced the highest classification accuracies of 67.1 % and 0.44 for overall accuracy and Kappa coefficient, respectively. When topographic variables were added into image segmentation procedures, classification accuracies could be improved up to 71.3 % of overall accuracy and 0.48 of Kappa coefficient. When adding a Euclidean distance image derived from stream GIS data into image segmentation procedures, overall classification accuracies were enhanced up to 76.6 % and 0.57 for overall accuracy and Kappa coefficient, respectively. Considering visual comparisons of the three different OBIA approaches with the manual interpretation, image segmentations assisted by spectral bands, topographic variables, and stream GIS data could yield an object-based vegetation map that most closely resembled manual interpretation.

In near future, we plan to utilize lidar-derived high resolution digital elevation model in an orthorectification procedure, topographic correction to remove spectral variation effected by topography in mountainous areas, and image segmentation steps.

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