LOCAL PARAMETER ESTIMATION OF TOPOGRAPHIC NORMALIZATION FOR FOREST TYPE CLASSIFICATION

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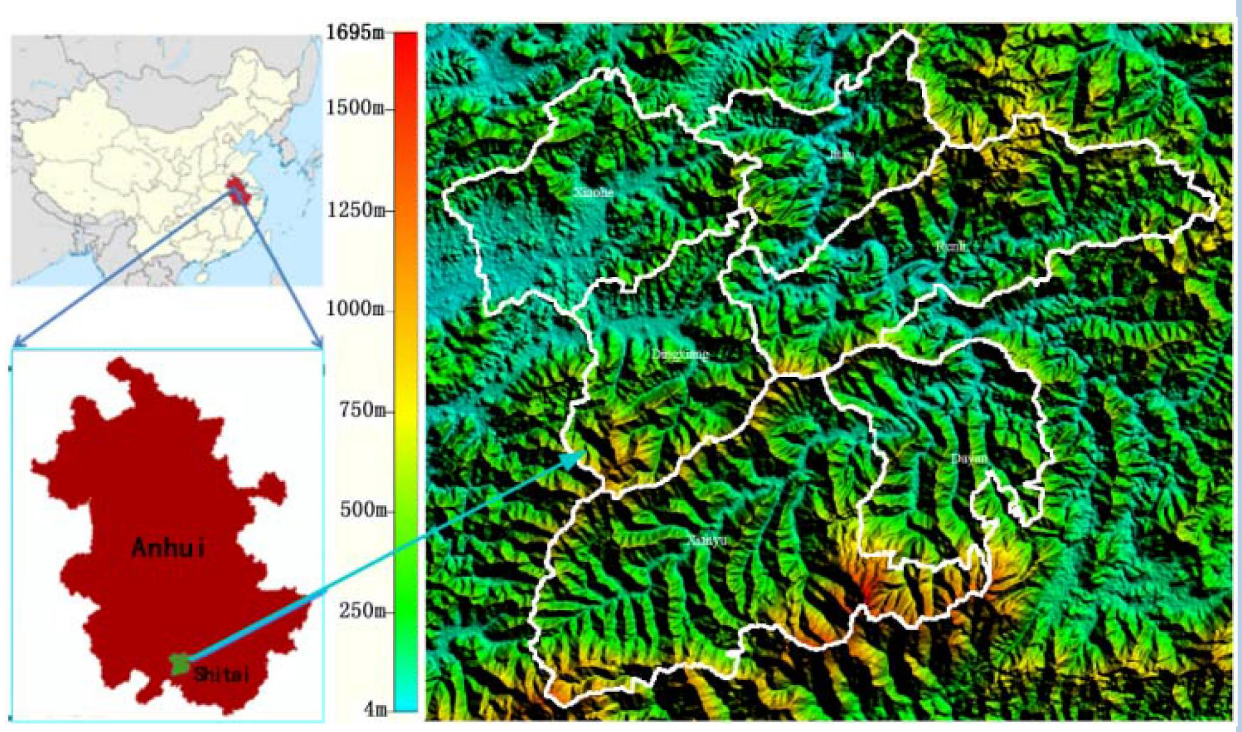
ABSTRACT

Radiometric distortions caused by mountainous terrain pose a challenge on the classification of forest types from satellite imagery a challenge. Various band-specific topographic normalization models are expected to eliminate or reduce these effects, and their quality depends on the approach to estimating empirical parameters. Generally, estimation of global parameters from a whole satellite image is simple, but it may tend to overcorrection, particularly for larger areas. A land-cover-specific method usually performs better, but it requires obtaining a priori land classification, which presents another challenge in many cases. Empirical parameters can be directly estimated from local pixels in a given window. In this study, we propose and evaluate a central-pixel-based parameter estimation method for topographic normalization using local window pixels. We tested the method with Landsat 8 imagery and the Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model (ASTER GDEM) in very rough terrain with diverse forest types. Visual comparison and statistical analyses showed that the proposed method performed better at a range of window sizes compared with an uncorrected image or with a global parameter estimation approach. The intraclass spectral variability of each forest type has been reduced significantly, and it can yield higher accuracy of forest type classification. The proposed method does not require the a priori knowledge of land covers. Its simplicity and robustness suggest that this method has the potential to be a standard preprocessing approach for optical satellite imagery, particularly for rough terrain.

INTRODUCTION

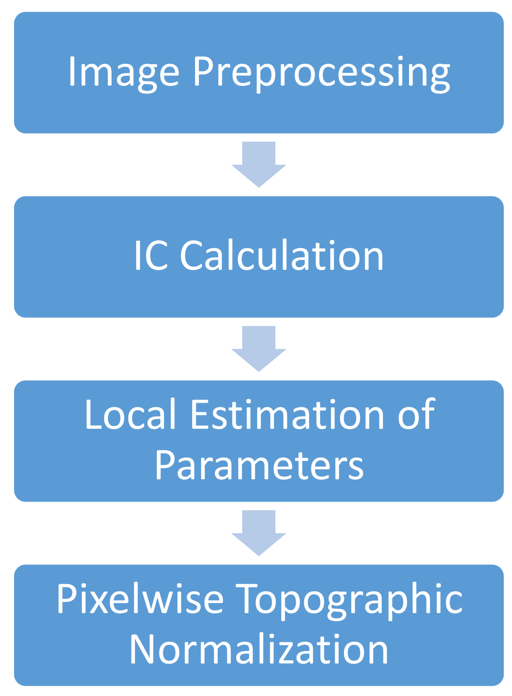
Optical satellite imagery provides large-area environmental monitoring data, but a spectral distortion caused by terrain models and solar illumination geometry requires correction. Topographic normalization models have been widely studied for optical satellite imagery to correct the differences in illumination conditions (ICs). These models aim to adjust the spectral reflectance values as a function of topographic and illumination characteristics so that image classification is facilitated and thus more accurate. Many topographic normalization models have been developed, and most wavelength-dependent models such as C-correction [1], Minnaert [2], and rotation correction models [3] outperform wavelength-independent models such as the cosine model [4]. Recently, some modified models such as modified C-correction [5] and modified Minnaert [6] models have been developed and tested. The performance of such models heavily depends on the quality of empirical parameter estimation (Minnaert constant k for Minnaert models, c factor for C-correction models, and b factor for rotation correction models). These empirical parameters are derived from the relationship between the spectral data and the topographic and illumination characteristics of the terrain.

Previous studies have compared these models under different conditions [1], [6], [7], but their performance is site dependent, and currently, no topographic normalization model is generally accepted. Good performance appears to only occur in relatively small study sites when using one global parameter for all pixels from one band image [1] or when complex prestratification approaches were used under conditions where the relationship between the spectral signature and an IC can be assumed topography specific or illumination specific [8], or land cover specific [9]. Sample selection is the key to an unbiased estimation of empirical model parameters. We found that global parameter estimation methods are prone to overcorrection, whereas landcover-specific methods are too complex to be directly applied in the topographic normalization of large-area optical satellite imagery.

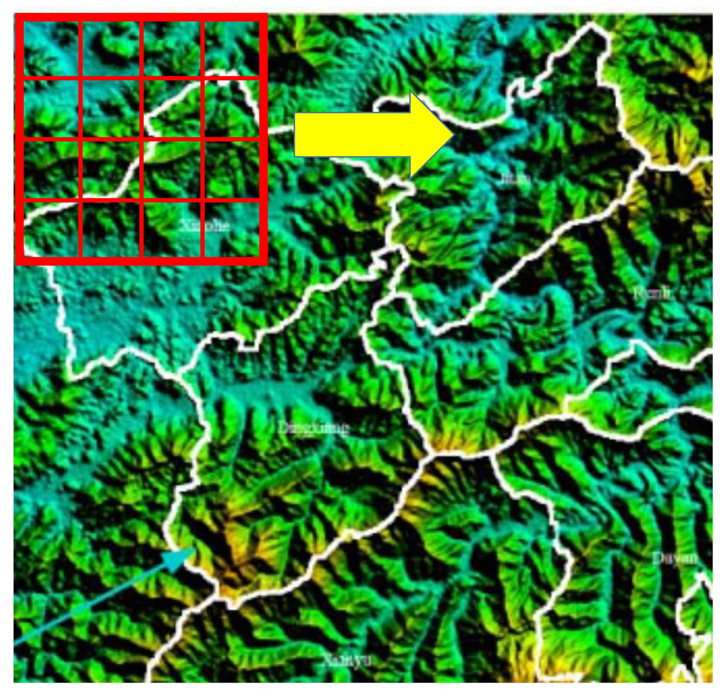


Location of the study area and ASTER GDEM

METHODS AND MATERIALS

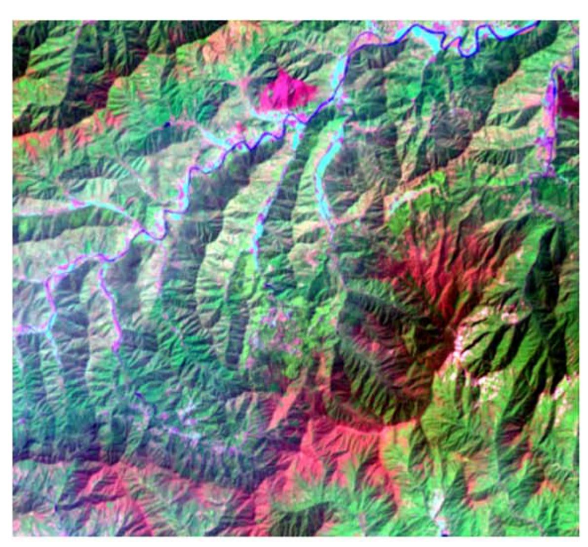


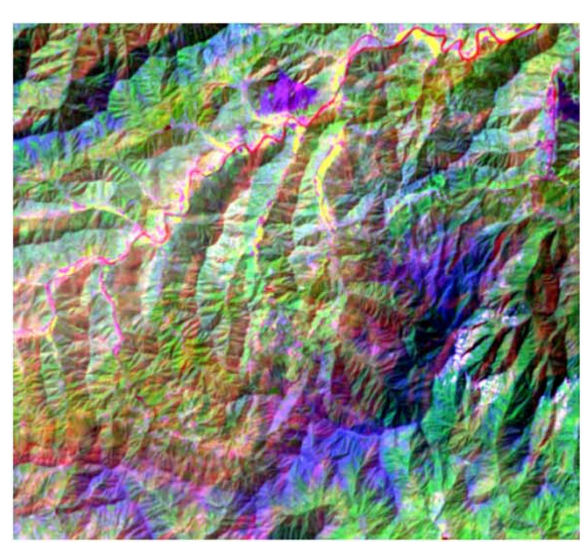
Empirical parameter estimation is the critical step in the rotation correction model. It was modified to a moving window-based method is pixel based and uses local window data sets.

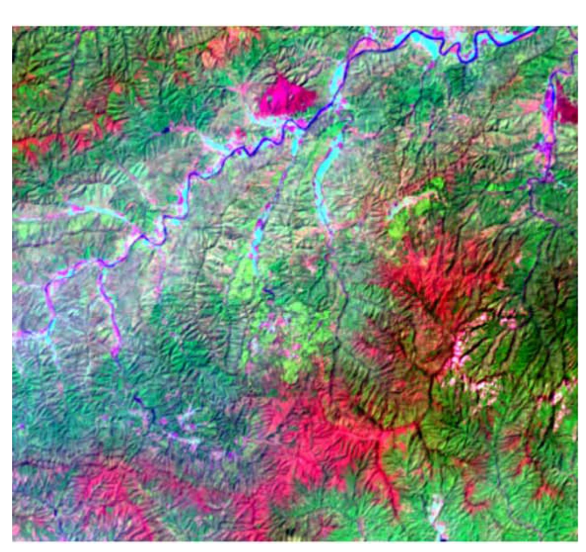

Moving Window based Estimation of Parameters

RESULTS

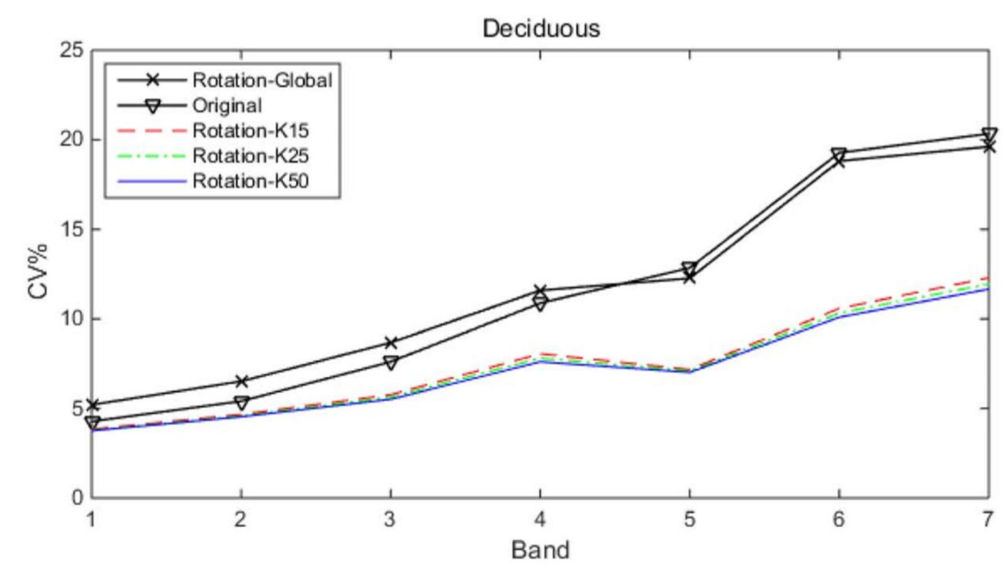
Visual comparison


Original Landsat 8

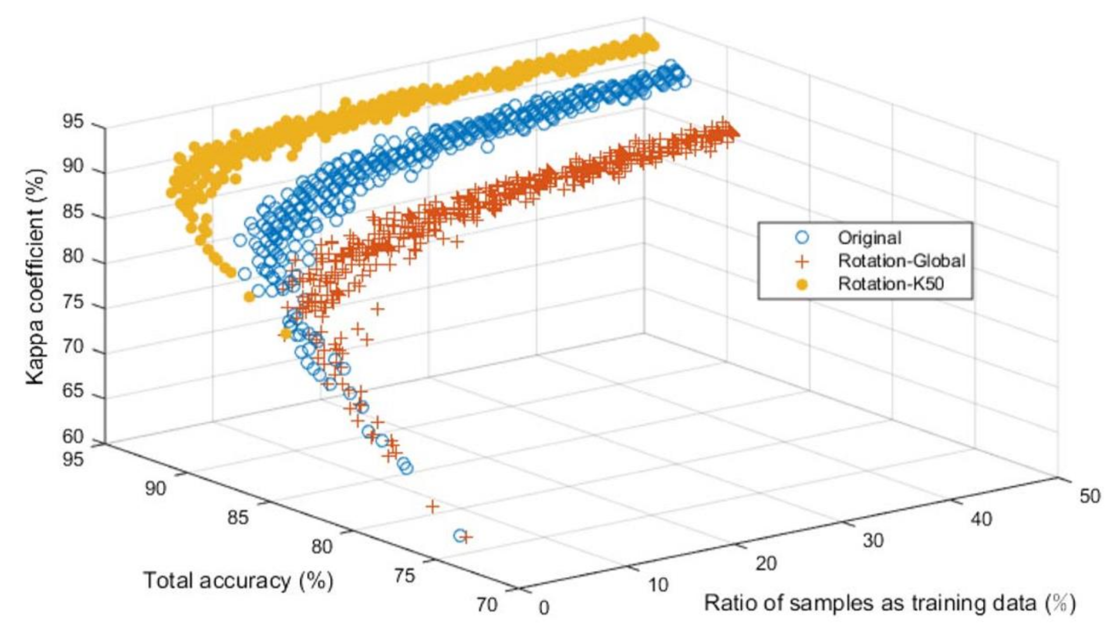

Rotation correction based on a global parameter


Moving window based method

Statistical analysis and classification simulation



CV% for the samples of the Deciduous class from images using different methods across Bands 1–7.



Performance comparison of the forest type classification simulation (band compositions 7, 5, 4, 3, and 2, and k =5with the *k*NN classifier).

DISCUSSION AND CONCLUSIONS

The results of this study has suggested that the proposed model is a simple, more robust, and effective topographic normalization model. It is a band-specific topographic normalization model, and it was based on the hypothesis that the relationship between spectral features and ICs is site specific. Our results support this hypothesis and indicate that this approach is more accurate than those using global parameter estimation methods. More importantly, the proposed method does not require a priori parameter information; this indicates the generalizability of the algorithm. Although the final forest type classification map has not been given in this letter, the classification simulation comparison has demonstrated the limit of the global parameter estimation method and the potential of the local parameter estimation method in forest type classification at least.

Some challenges remain unresolved. First, although the demonstrated robustness of the window size selection makes the image quality controllable, the optimization and evaluation of the window size selection are still needed. Second, the algorithm's computational demand is very high as the model executes all the steps of the global parameter estimation method pixel by pixel. Thus, the computing time linearly increases with the number of pixels in an image. Parallel computing design and further development could help solve this problem, or a more efficient and adaptive local parameter estimation method should be developed and evaluated for topographic normalization models. Third, to fully demonstrate generalizability, this site-specific approach needs further application to other models, such as the Minnaert or C-correction models, etc.

MAJOR REFERENCES

1. D. Riaño, E. Chuvieco, J. Salas, and I. Aguado, "Assessment of different topographic corrections in Landsat-TM data for mapping vegetation types (2003)," IEEE Trans. Geosci. Remote Sens., vol. 41, no. 5, pp. 1056–1061, May 2003.
2. H. Ge et al., "Pixel-based Minnaert correction method for reducing topographic effects on a Landsat 7 ETM+ image," Photogramm. Eng. Remote Sens., vol. 74, no. 11, pp. 1343–1350, Nov. 2008.
3. B. Tan et al., "Improved forest change detection with terrain illumination corrected Landsat images," Remote Sens. Environ., vol. 136, pp. 469–483, Sep. 2013.
4. D. L. Civco, "Topographic normalization of Landsat Thematic Mapper digital imagery," Photogramm. Eng. Remote Sens., vol. 55, no. 9, pp. 1303–1309, Sep. 1989.
5. S. Hantson and E. Chuvieco, "Evaluation of different topographic correction methods for Landsat imagery," Int. J. Appl. Earth Observ. Geoinf., vol. 13, no. 5, pp. 691–700, Oct. 2011.
6. R. Richter, T. Kellenberger, and H. Kaufmann, "Comparison of topographic correction methods," Remote Sens., vol. 1, no. 3, pp. 184–196, Jul. 2009.
7. M.-L. Gao et al., "Topographic correction of ZY-3 satellite images and its effects on estimation of shrub leaf biomass in mountainous areas," Remote Sens., vol. 6, no. 4, pp. 2745–2764, Mar. 2014.
8. H. Reese and H. Olsson, "C-correction of optical satellite data over alpine vegetation areas: A comparison of sampling strategies for determining the empirical c-parameter," Remote Sens. Environ., vol. 115, no. 6, pp. 1387–1400, Jun. 2011.
9. Z. Szantoi and D. Simonetti, "Fast and robust topographic correction method for medium resolution satellite imagery using a stratified approach," IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens., vol. 6, no. 4, pp. 1921–1933, Aug. 2013.

Note:

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