Topographic correction of satellite images for improved LULC classification in mountainous areas

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Outline

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Introduction

- irregular shape of terrain causes **variable illumination angles** and thus **diverse reflection values** within one land cover type
  - lower reflection values in shadow, higher values in sun
- reflection values of different land cover types in equal conditions of illumination can be more similar than within one land cover type in shadow and sun
- problems in image segmentation and possible misclassifications
- topographic normalization methods try to compensate topographically induced illumination variations

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Study area

- defined within the project BrahmaTWinn (http://www.brahmatwinn.uni-jena.de)
- located as part of the Brahmaputra catchment in Tibet - represents the **catchment of the Lhasa River**
- a major part of the area is situated in the prefecture-level city Lhasa, a minor part in the prefecture Naqu
- total area: about **33,000 km²**

- mountainous area with steep slopes and rugged terrain and elevations from 3,500 to more than 7,000 meters

⇒ significant **shadowing effects**
Topographic correction methods

- **Band ratio**: simplest method
  - relative topographic effect is similar in all bands
  - diffuse irradiance neglected, loss of spectral resolution

- Real topographic correction methods try to model illumination characteristics of a horizontal surface by means of a **DEM**

- Calculation of the **local solar incident angle** $i = \angle$ between the current position of the sun (depending on solar zenith angle and solar azimuth) and the local surface (terrain slope and aspect)

\[
\cos i = \cos e \cos z + \sin e \sin z \cos (a-a')
\]

- $\cos i < 0 \rightarrow$ shadowed slopes
Topographic correction methods

**Lambertian methods**

- surface reflects irradiation in all directions equally
- only direct irradiance considered

**Non-Lambertian methods**

- diffuse irradiance is modeled by means of constants
- wavelength dependent ⇒ assessment of the constants for each band separately
- reflection characteristics depending on land cover ⇒ individual constants for each land cover

Albertz, 2001
Topographic correction methods

- **cosine correction**
  - Lambertian assumption
  - diffuse irradiance is neglected
  - strong overcorrections for steep and sun-averted slopes
  - frequently used

\[
L_H = L_T \times \frac{\cos z}{\cos i}
\]

where
\[
L_H = \text{reflectance of a horizontal surface} \\
L_T = \text{reflectance of an inclined surface} \\
z = \text{solar zenith angle} \\
i = \text{local solar incident angle}
\]

- **Minnaert correction, C-correction**
  - non-Lambertian assumption
  - extend formula of cosine correction by constants

- **Statistic-empirical correction**
  - regression-based approach
  - contains average reflectance of land cover type under investigation
Satellite data

- **5 Landsat TM scenes**
  - 30 m spatial resolution
  - UTM WGS 84, Zone 46 North
  - cloud cover: 0 %
  - acquisition date differ according to year and season

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- steep areas in winter images are fully shady due to low illumination angle
Digital Elevation Model (DEM)

- SRTM (Shuttle Radar Topography Mission)
- 90 m spatial resolution
- resampled to spatial resolution of Landsat images for improved topographic normalization (by bilinear interpolation)
Software Programs

- ERDAS Imagine
  - cosine correction
  - Minnaert correction
    ⇒ no automated calculation of constant $k$

- PG-Steamer
  - cosine correction
  - Minnaert correction
    ⇒ no automated calculation of constant $k$
  - C-correction
    ⇒ automated calculation of constant $c$
  - statistic-empirical correction
    ⇒ input of average reflectance from each land cover type required
Results

Visual results
Results

before topographic normalization

after topographic normalization (statistic-empirical correction)
Results

Effect on image segmentation

multiresolution segmentation

original

topographic normalized
Results

Object based image classification

- spectral values, standard deviation, shape, neighborhood
- additional data: SRTM (slope, altitude)

Level 1 - Eight main categories
1' Agriculture, 2' Bare Land, 3' Forest,
4' Non-forest vegetation, 5' Ice and snow,
6' Settlement, 7' Water bodies, 8' Unclassified

Level 2 – twenty-two subcategories
Results

Statistical Analysis

- requirements
  - low spectral differences
  - shady slopes should get higher values, sunny slopes lower values
  - decrease of spectral variances and standard deviation
  - retention of mean
- worst result: cosine correction
- best result: statistic-empirical correction

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<th>statistic-empirical correction</th>
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<td>total change</td>
<td>151.66</td>
<td>55.03</td>
<td>-3.48</td>
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Constraints

- if $\cos i = 0 \Rightarrow$ no data values
  - as division by zero is impossible
    ($L_h = L_T \times \cos z / \cos i$)

possible solutions:
- changing sun zenith angle
- smoothing of slope
- replacing with original values

no-data values as $\cos i = 0$
Constraints

*cast shadow*

- cast shadow of surrounding topographic features is **not** considered within topographic normalization
- reflection values of sun-facing slopes lying in cast shadow are corrected **downwards**
- line-of-sight algorithm can detect areas of cast shadow
Conclusion

- cosine correction could not reduce topographic effect in the study area successfully

- satisfying results of C-correction, Minnaert correction and statistic-empirical correction
  - only minor visual differences

- overcorrection in areas of low illumination due to
  - inadequate estimation of the diffuse irradiance
  - inaccurate geometric correction
  - insufficient spatial resolution of the DEM
  - availability of high resolution DEMs is limited
- Topographic normalization should be applied to each land cover type separately
  - Requires knowledge of land cover in advance
  - Time consuming
  - Easier: divide image according to NDVI (e.g. vegetated / non-vegetated)

- Topographic normalized satellite images can obtain better classification results

- Topographic normalization is still rarely used due to lack of standardized methods
Thank you for your attention!

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