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

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Outline

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  - result of classification
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S. Lang

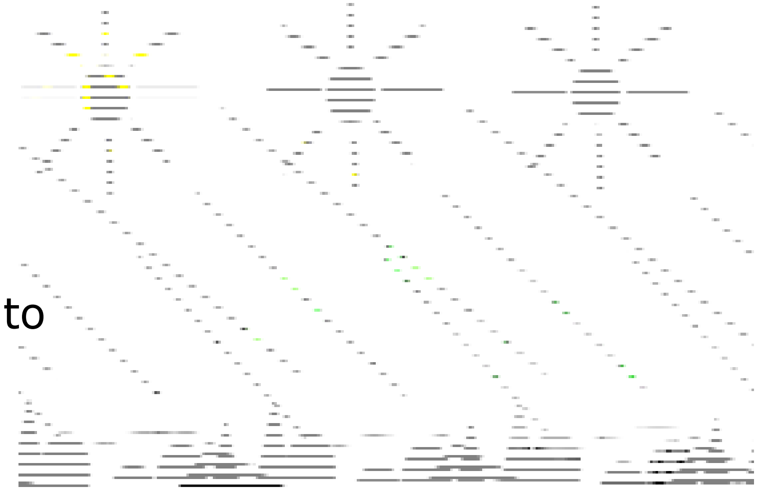
Introduction

- 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



effect of relief on illumination

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**

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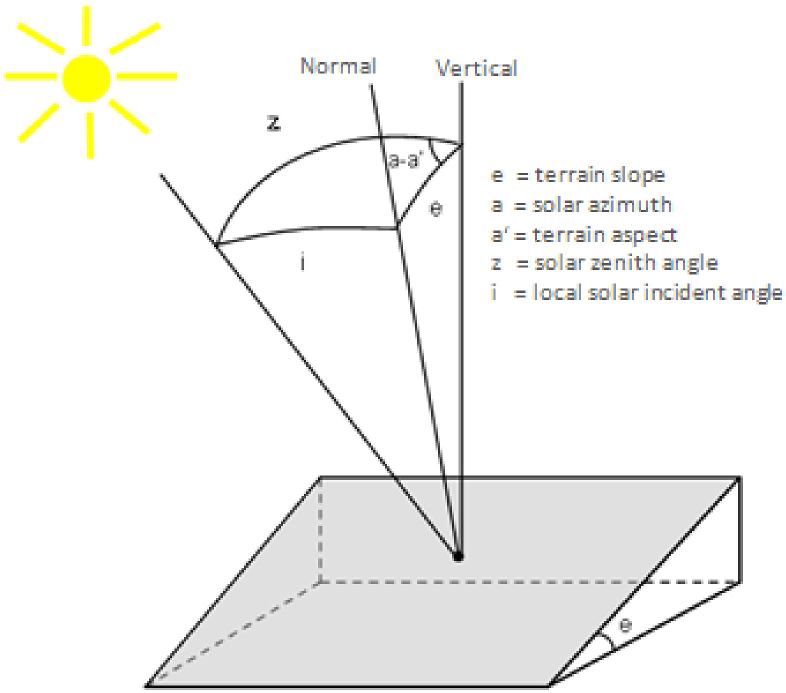
Topographic correction methods

- **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)

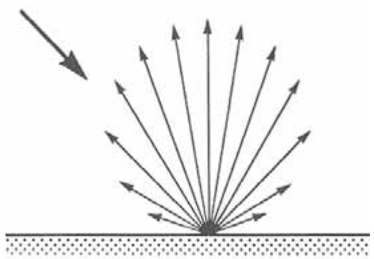
  $$\cos i = \cos e \; \cos z + \sin e \sin z \cos (a - a')$$

- $\cos i < 0$ → shadowed slopes



Topographic correction methods

Lambertian methods



Albertz, 2001

- 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

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 = reflectance of a horizontal surface

L_T = reflectance of an inclined surface

z = solar zenith angle

i = 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

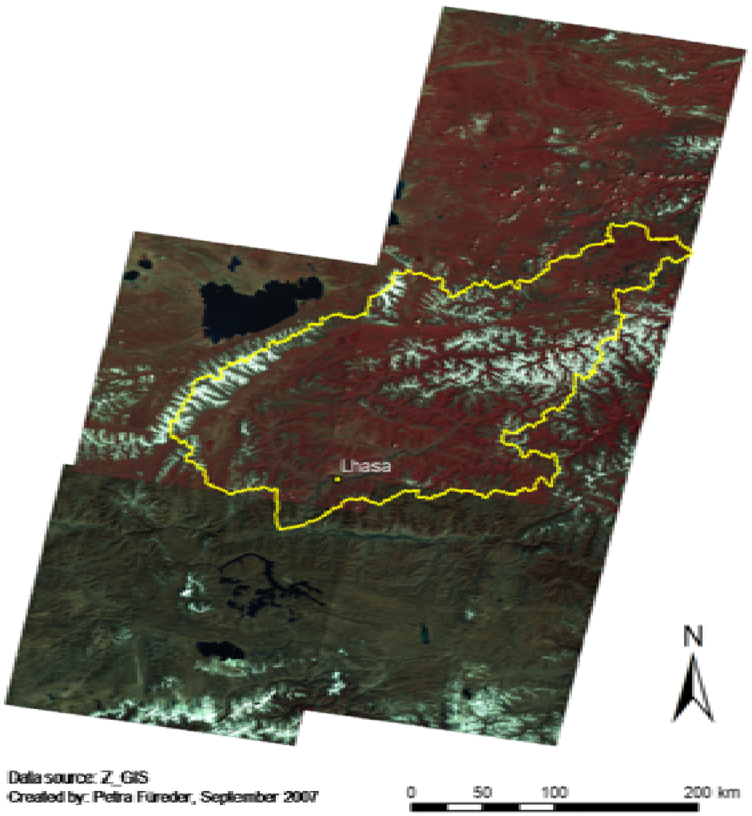
Data

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

path / row	acquisition date
137/038	14 September 1988
137/039	14 September 1988
137/040	01 November 1990
138/039	14 September 1991
138/040	14 November 1990

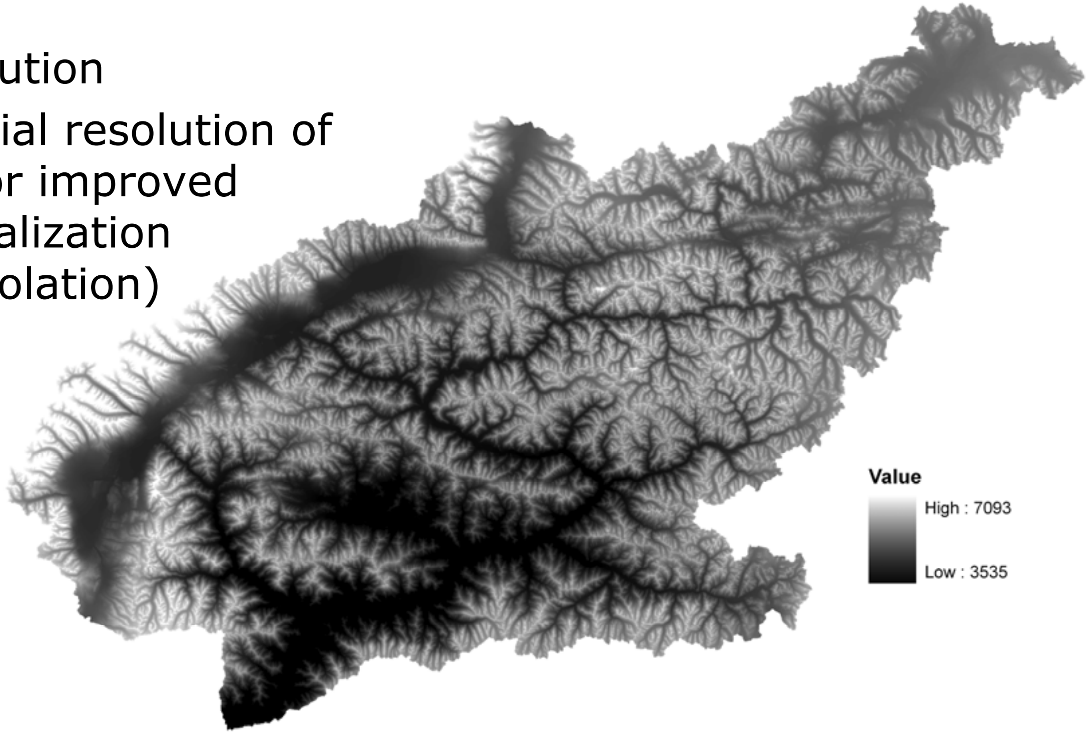
  - steep areas in winter images are fully shady due to low illumination angle



Data

Digital Elevation Model (DEM)

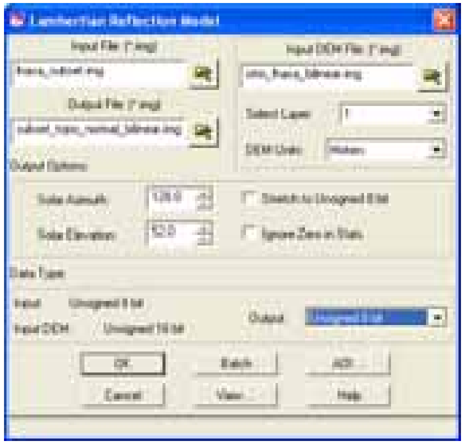
- **SRTM (Shuttle Radar Topography Mission)**
- 90 m spatial resolution
- resampled to spatial resolution of Landsat images for improved topographic normalization (by bilinear interpolation)



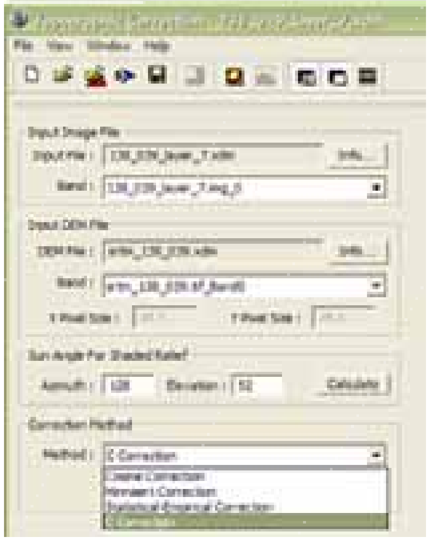
Implementation

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



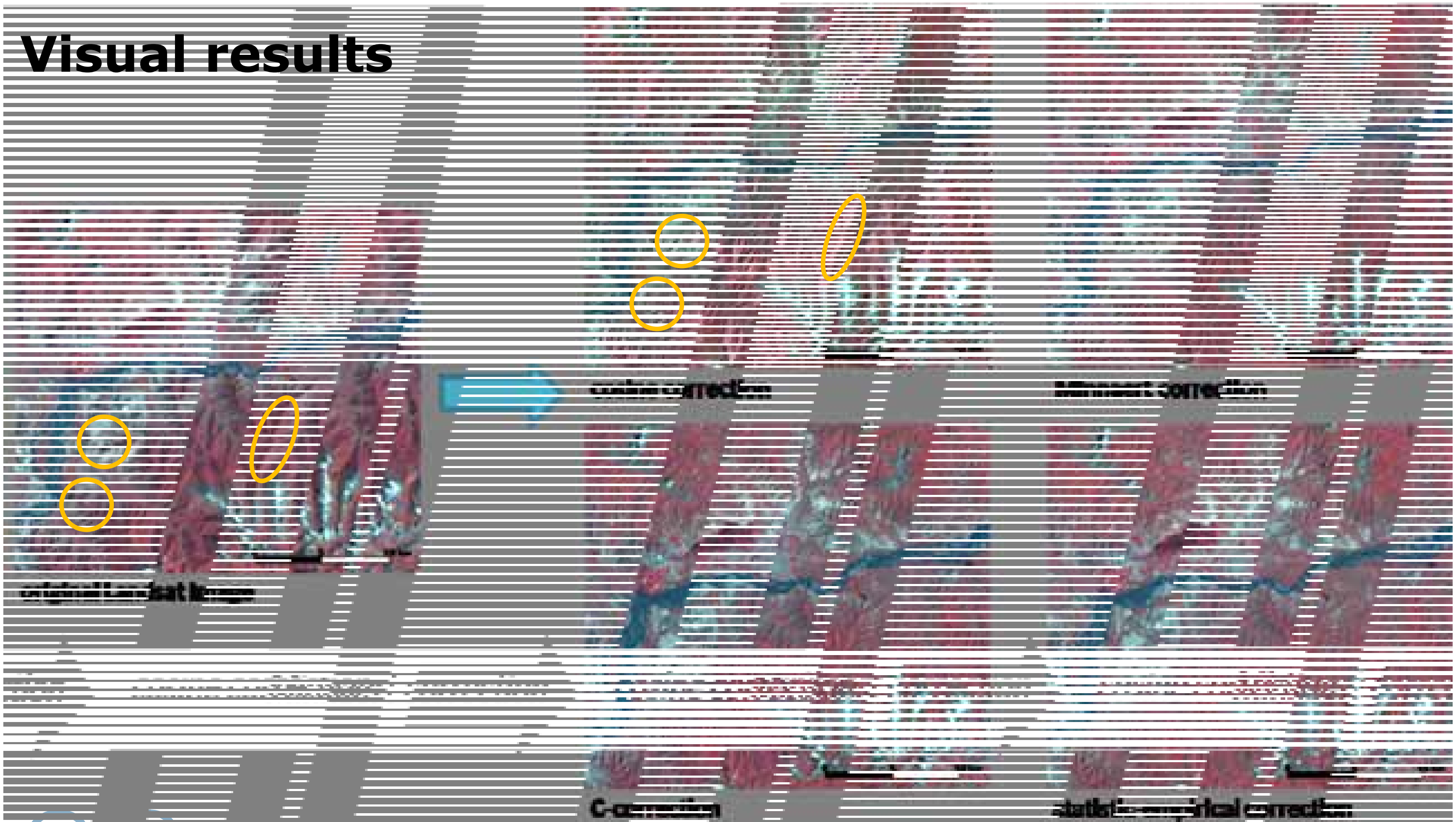
user interface of ERDAS Imagine



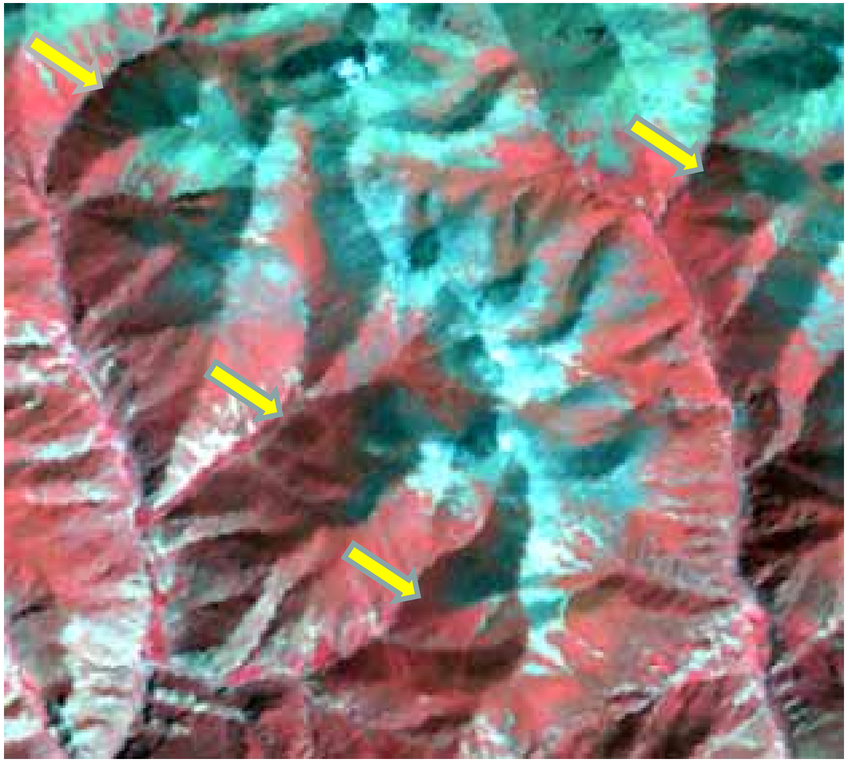
user interface of PG-Steamer

Results

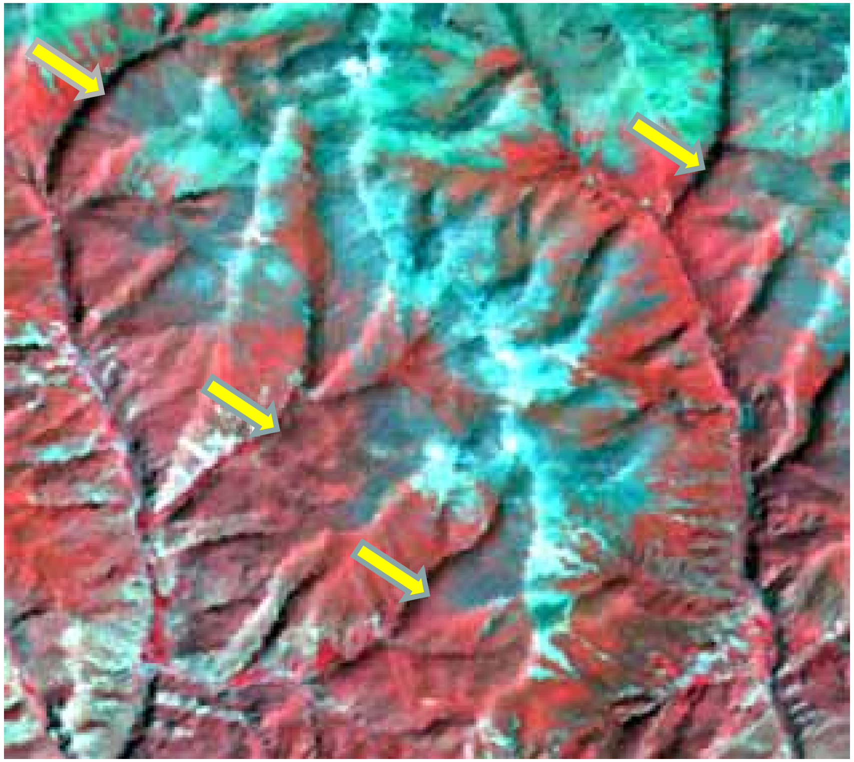
Visual results



Results



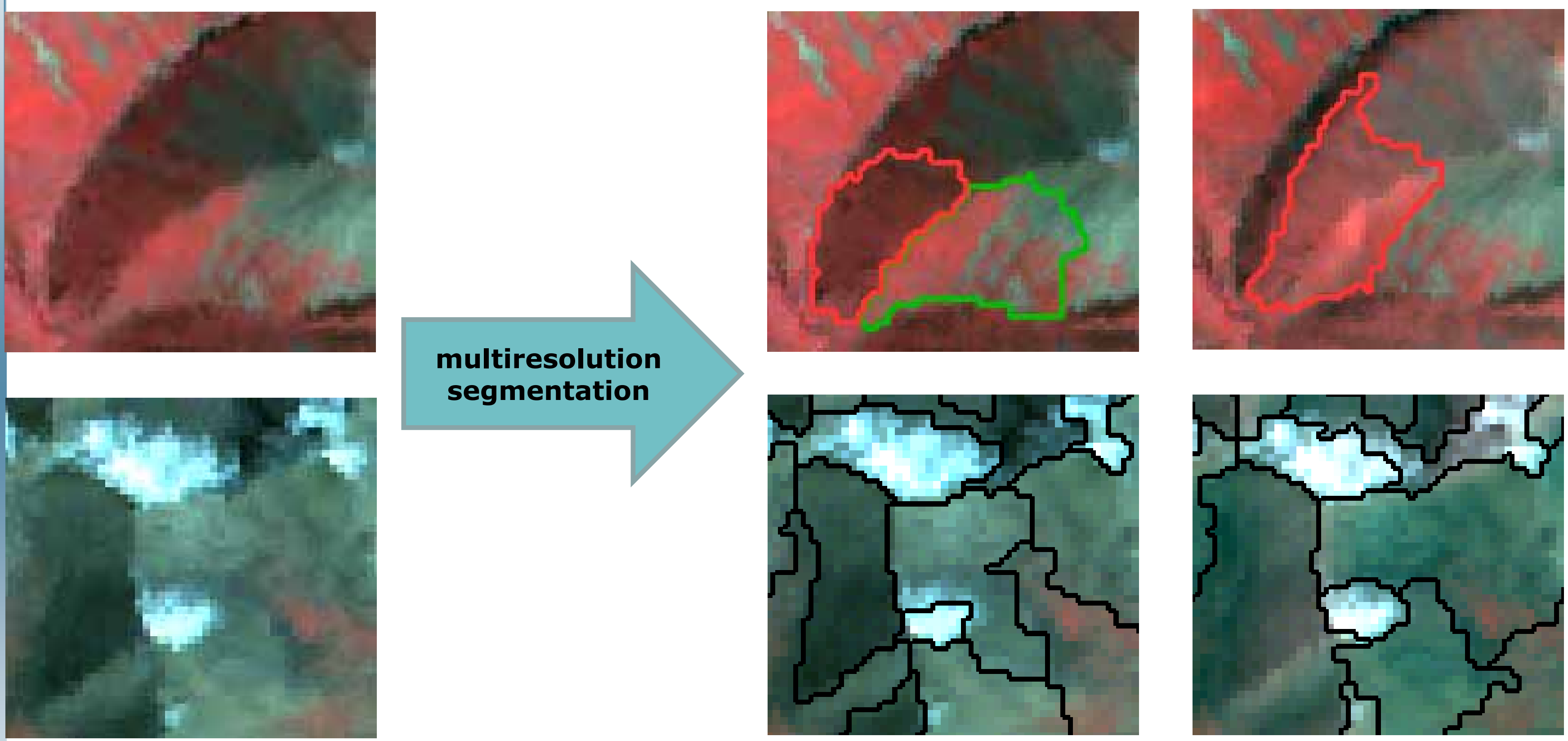
before topographic normalization



after topographic normalization
(statistic-empirical correction)

Results

Effect on image segmentation



original **topographic normalized**

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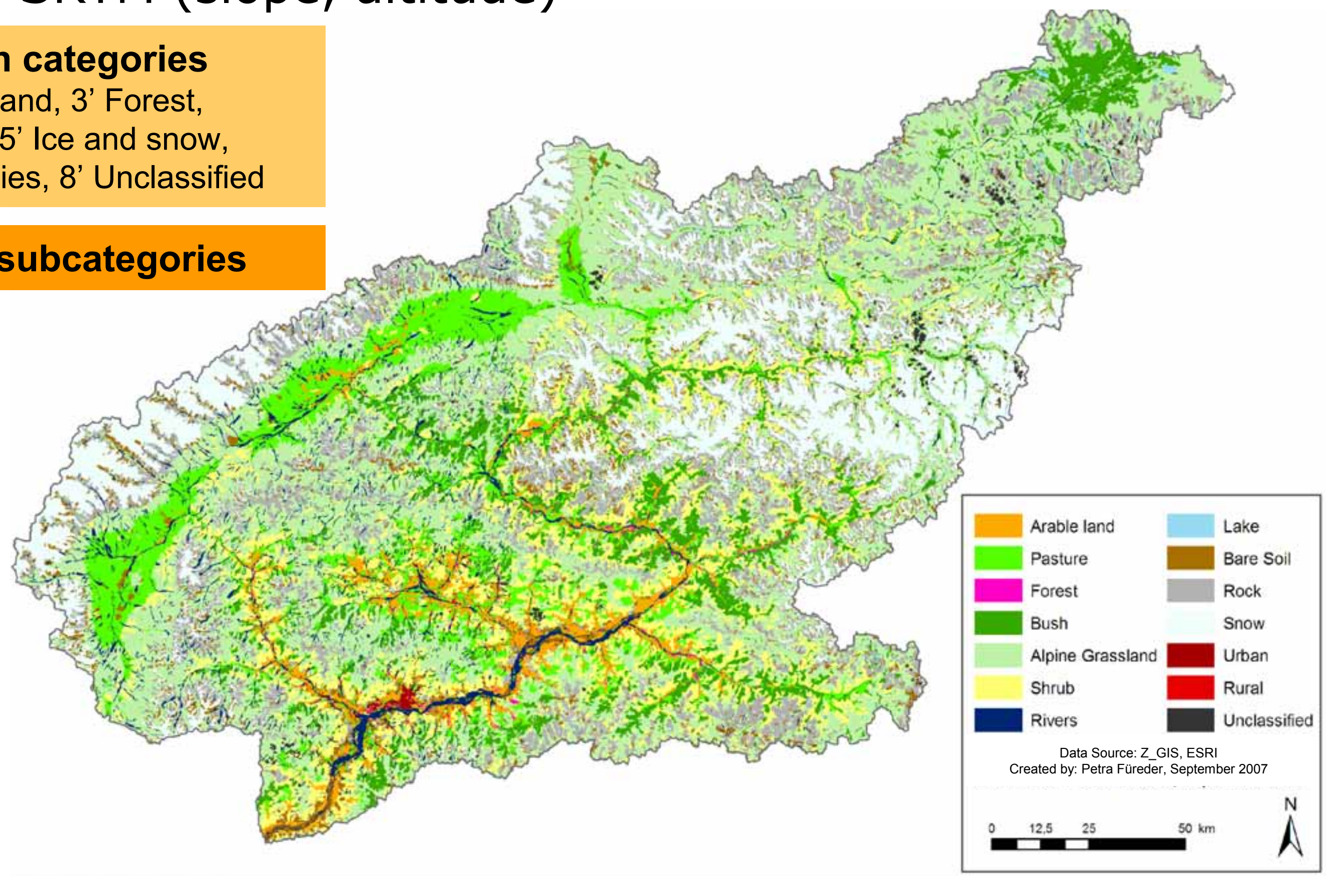
Results

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



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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

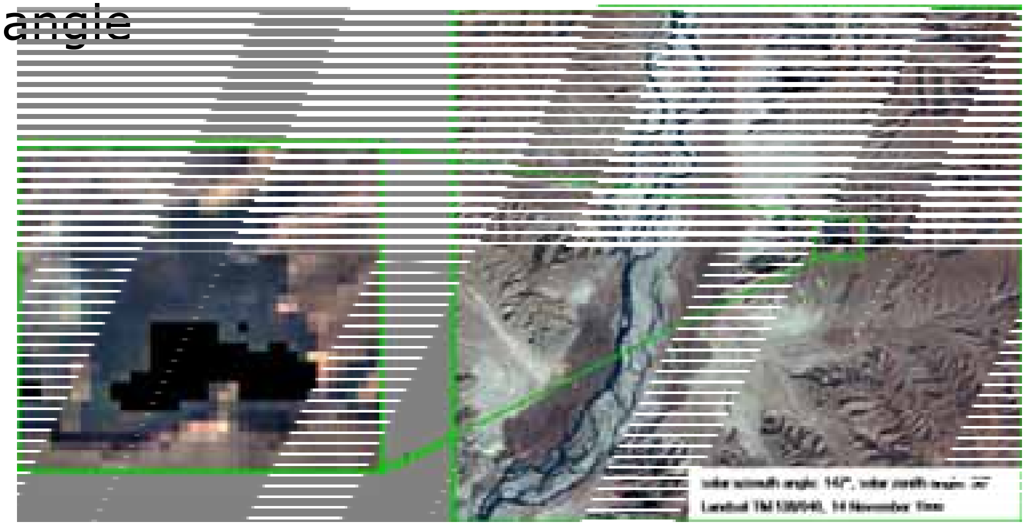
band	cosine correction		statististic-empirical correction		C-correction		Minnaert-correction	
	μ	σ	μ	σ	μ	σ	μ	σ
1	32.76	13.63	-0.59	-0.61	1.34	-0.03	0.36	0.87
2	16.39	7.79	-0.55	-0,6	0.96	0.2	0.56	0.65
3	19.4	7.53	-0.58	-1.07	1.75	0.11	1.5	0.58
4	28.09	11.02	-0.58	-1.54	2.2	-0.58	2.08	-0.14
5	37.22	9.74	-0.61	-3.48	4.72	-1.91	0.85	-1.12
7	17.8	5.32	-0.57	-1.85	2.49	-0.74	1.06	-0.15
total change	151.66	55.03	-3.48	-8.55	13.46	-2.95	6.41	0.69

Constraints

- if **cos *i* = 0** ⇨ 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

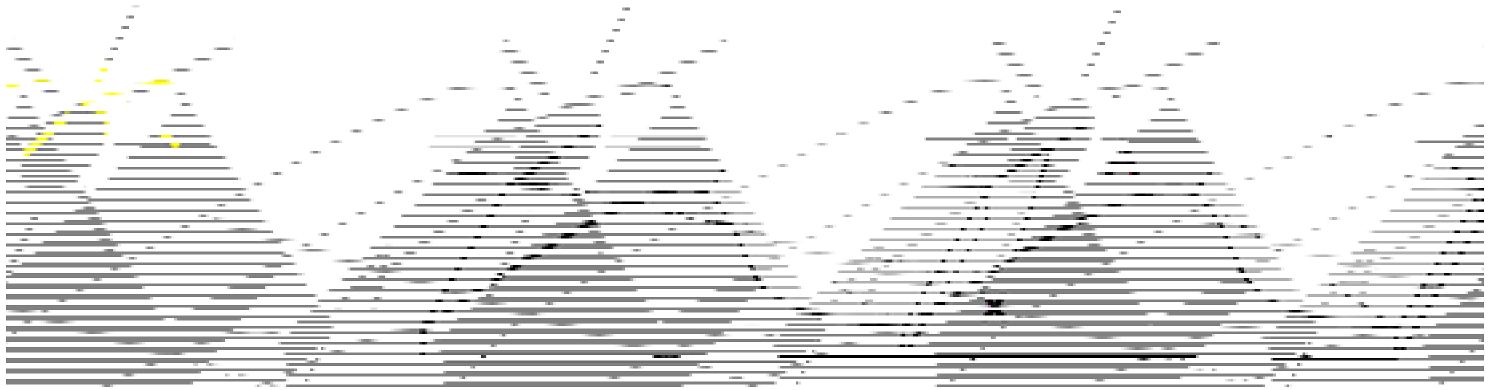


no-data values as cos i = 0

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

Outlook

- 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

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Thank you for your attention!

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