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## Urban objects classification by spectral library: feasibility and applications

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## Abstract

Objects recognition in urban environment using multiband imagery, is a difficult process, implying the use of elaborated and complex image processing methods, which are used to enhance the detection efficiency. The urban mosaics are characterized by multiple materials (e.g. manmade, urban vegetation, bare soil, transport infrastructure, etc.), which are combined together to form a complex patchwork. This study aim to take advantage of the multiband imagery, to assess the feasibility degree of the urban objects detection, and to explore some of the applications related to the multiband hyperspectral imagery classification.

## 1. Hyperspectral data and spectral library acquisition

### 1.1. Hyperspectral image and study zone

The airborne hyperspectral image was captured in Kaunas city center (Lithuania), in July 2015, using the Finnish hyperspectral imager RIKOLA LTD (Vis-NIR), embedded in a single-seat aircraft. The airborne imager was configured to produce 16 bands, with a spectral range of 400-1000nm and a spatial resolution of 0.7 meter, the mean aircraft altitude was equal to 1000 meter during the flight mission. The image was converted in reflectance using a MODTRAN radiative transfer model. Three different test zone corresponding to industrial, mixed (i.e. public/private buildings, houses), and residential zones, of respectively 0.58 km<sup>2</sup>, 0.6 km<sup>2</sup> and 0.4 km<sup>2</sup>, were extracted from the original image to experiment the morpho-spectral classification method.

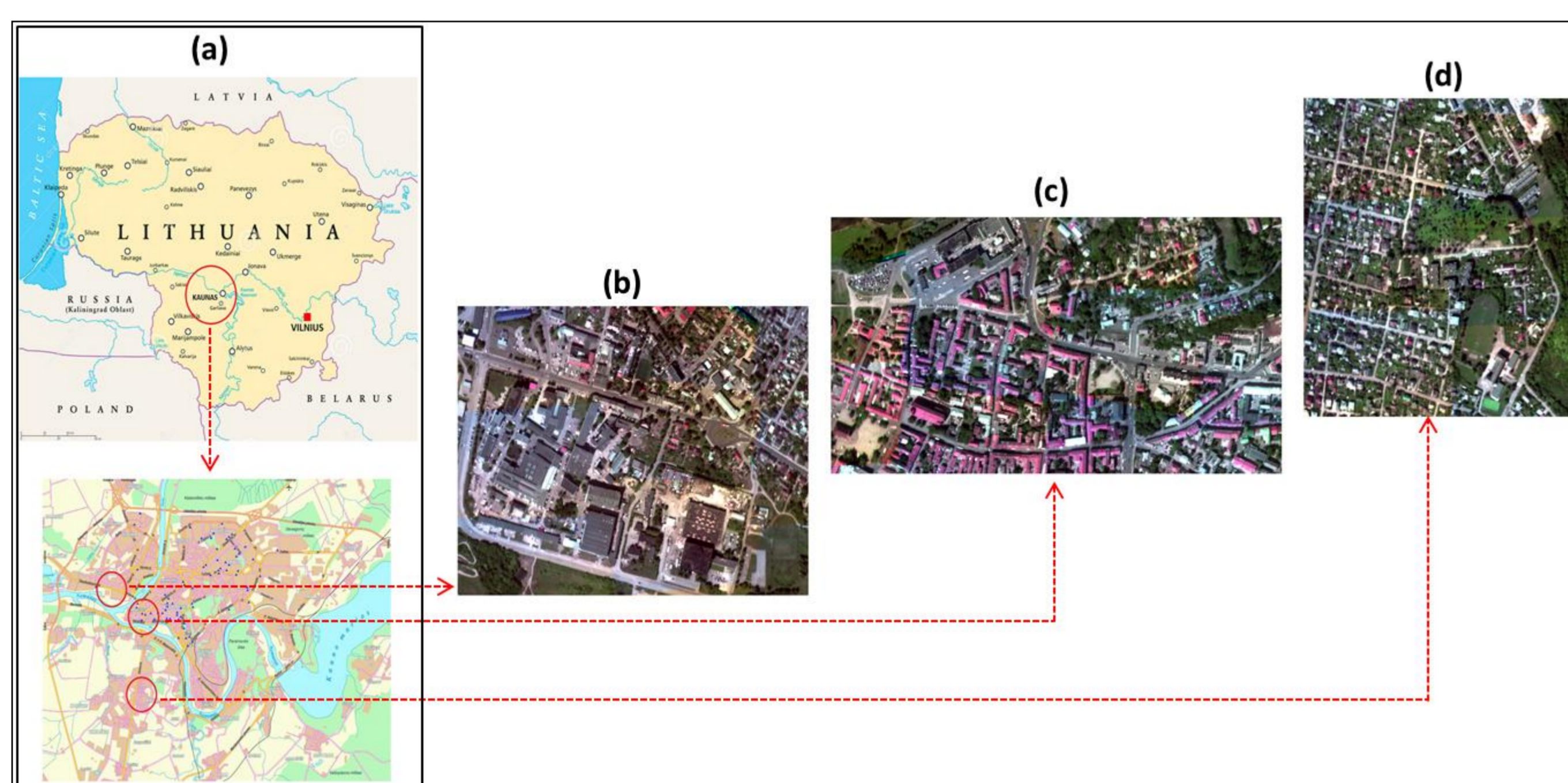


Figure 1. (a) Kaunas and study zones location, (b) Industrial, (c) Mixed, and (d) Residential zones.

### 1.2. Spectral library

Kaunas is the second largest city of Lithuania, and it is characterized by a large heterogeneity in terms of urban materials. For a better characterization of the urban mosaic composing Kaunas, a spectral library of the common materials of the city was created in July 2015, and updated in April 2016 with at the moment 50 materials collected, essentially of roofing's, roads, different vegetation species and bare soils. The measurements were made in laboratory conditions, in a black room, under artificial light.

The spectral library was generated using the hyperspectral laboratory camera Themis-Vision VNIR400H. The sensor was developed by the US Company Themis Vision Systems LLC 2011, and is able to measure the electromagnetic radiation from 400 nm to 1000 nm using 1024 narrow bands; the spectral resolution is equal to 0.6 nm.

## 3. Spectral variability

### 3.1. External library use

A variability study was carried to extract 1) the degree of resemblance between the urban common materials (i.e. interclass correlation) and 2) the degree of resemblance between samples of the same materials (i.e. intraclass correlation). The goal is to highlight the existing correlations or not between the materials, and also the existing correlation between the  $n$  samples of each material. For this study, 9 common urban materials were used, which are; tile, bitumen, asbestos, dark painted metal, clear painted metal, red painted metal, clear painted fiber cement, asphalt, and pavements.

### 3.2. interclass and intraclass correlations

Concerning the interclass correlation (Tab.I), the presence of high interclass correlations could affect the spectral classification efficiency, and produce misclassifications between the classes. Nevertheless, the global interclass correlation variability still acceptable (i.e. Max = 97%, Min = 40% and SD = 0.15), and enforces the hypothesis of a reasonable heterogeneity between the materials.

Concerning the intraclass correlation (Tab.II), the correlation values are extracted in TABLE II, with Maximum correlation, minimum correlation, and standard deviation, for each material. The tile, fiber cement, red painted metal and pavements, present the lower standard deviation which mean that the intraclass correlation for these materials is low, thus, their spectral variability is low, and they present a low risk to be misclassified. The remaining materials have a higher standard deviation and present a high risk to be misclassified.

		Interclass correlation table per material								
		Tile	Bitumen	Asbestos	Dark painted metal	Clear painted metal	Fiber cement	Asphalt	Red painted metal	Pavements
Tile		100%	94%	89%	82%	74%	87%	72%	93%	96%
Asbestos		89%	81%	100%	77%	40%	72%	43%	88%	97%

TABLE I. Interclass correlation table of urban materials

		Intraclass correlation per group of materials								
Measured specs		Tile	Bitumen	Asbestos	Dark painted metal	Clear painted metal	Fiber cement	Asphalt	Red painted metal	Pavements
Max correlation		99%	98%	99%	92%	98%	98%	96%	99%	98%
Min correlation		98%	67%	78%	61%	63%	95%	80%	99%	96%
Standard Deviation		4.10 <sup>-4</sup>	9.8.10 <sup>-3</sup>	4.7.10 <sup>-3</sup>	8.7.10 <sup>-3</sup>	7.9.10 <sup>-3</sup>	8.7.10 <sup>-4</sup>	6.6.10 <sup>-3</sup>	7.8.10 <sup>-5</sup>	8.1.10 <sup>-4</sup>

TABLE II. Intraclass correlation table of urban materials

## 5. Conclusion

An original technique based on the urban objects identification by spectral library, using airborne hyperspectral imagery, is presented in this study. The potential to distinguish some of the common roofing's materials in the city of Kaunas was demonstrated. Nevertheless, some issues need to be addressed in the future, as the high interclass and intraclass correlations regarding some urban materials, leading to misclassifications. Asbestos type roofing's and bitumen roofing's were difficult to identify and presents high correlation with the other materials like asphalt roads and pavements. To improve the spectral classification results, we proposed a morphological rectification based on attributes filtering, and rules construction, the rectification seemed suitable, and permits to eliminate the misclassified pixels (i.e. artefacts, roads, shadows, etc.). For the future, we are planning to 1) enrich the spectral library with more materials, 2) test other datasets including more bands, and 3) use other classifiers (e.g. SVM, neural networks).

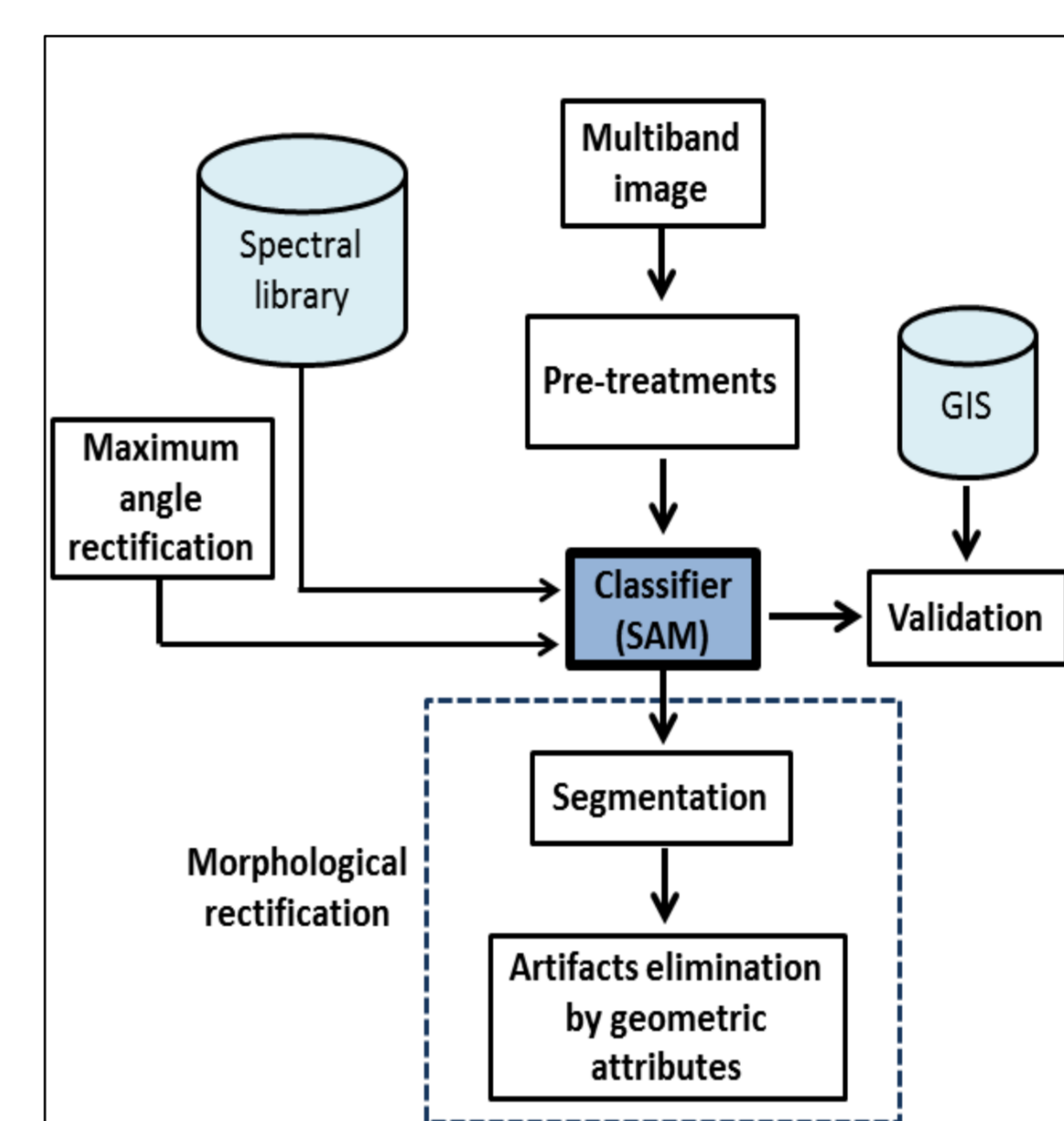
## 2. Method

**Pretreatments:** the reflectance is estimated by a simplified MODTRAN radiative transfer model, a contrast enhancement filter is then applied to the image.

**Urban objects classification:** the classification is carried using the Spectral Angle Mapper, the training samples were extracted from our spectral library; each sample is an average spectrum of multiple spectra of the same material (i.e. the average is calculated over 10 or 5 spectra depending on the available data). The maximum angle affected to each material (i.e. SAM measure) is rectified to match the spectral characteristics of the 16 bands hyperspectral image. In addition to these data, we have used a Geographic Information system to validate the classification results.

**Image segmentation and objects extraction:** the segmentation is applied on each class vector, and the different objects are extracted and their geometric attributes measured (i.e. area, elongation, convexity, circularity, etc.).

**Artefacts elimination:** this step permits to filtering the misclassified pixels, by geometric attributes, and/or by group of attributes. The objects detection was carried by a thresholding segmentation algorithm.



\***Spectral library:** an external urban spectral library in the Visible range (i.e. 400nm-1000nm), acquired of the city of Kaunas (Lithuania).

\***GIS:** Ground truth data including pictures, expert knowledge, Metadata about the samples of interest.

Figure 2. Urban objects classification by spectral library and morphological rectification of multiband image.

## 4. Urban objects recognition

### 4.1. Classification

Concerning the residential zone (i.e. Fig.3.a), the clear painted metal, and red painted metal roofing's, were well distinguished, the asbestos roofing's were partially identified, and are correlated with roads and some bitumen roofing's, the overall accuracy and Kappa coefficient are respectively of 33% and 0.22.

Concerning the industrial zone (i.e. Fig.3.b), the bitumen roofing's which compose most of the scene were well distinguished, however, a correlation with the asphalt roads is noticed, clear painted metal, red painted metal, and tile roofing's were also well identified, asbestos roofing's were partially identified and were correlated with pavements, the overall accuracy and Kappa coefficient are respectively of 67% and 0.44.

Concerning the historical center of Kaunas city (i.e. mixed test zone), we have almost a good identification of all the materials, with a correlation of the bitumen and asbestos with roads, the overall accuracy and Kappa coefficient are respectively of 73% and 0.56.

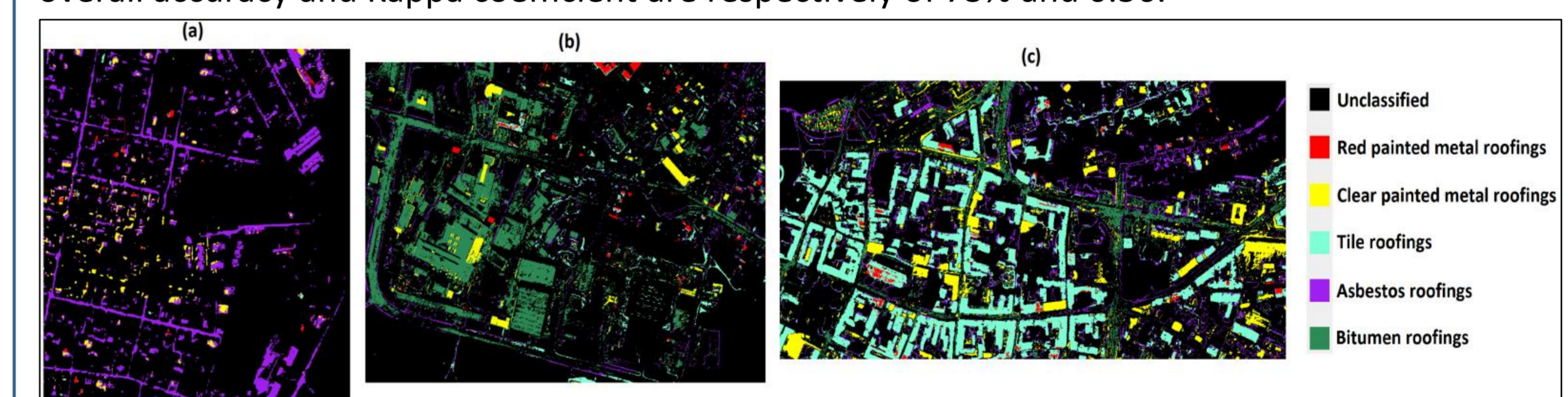


Figure3. Spectral classification by spectral library of (a) residential zone, (b) industrial zone, and (c) Historical center of Kaunas city.

### 4.2. Morphological rectification

A morphological rectification was carried over the classified image to enhance the objects detection, and to minimize the misclassifications. an important misclassification of the asbestos and bitumen type roofing with asphalt roads and pavements is noticed, in addition to the presence of artefacts. Fig 4.b shows the classification enhancements after morphological rectification; the roads and artefacts were eliminated, using simple and combined rules.

Concerning the roads detection; elongation and [circularity + elongation] attributes performed well; the elongation was used for roads segments detection, the circularity was added to detect circular roads portions. Concerning the artefacts detection, area and [convexity + area] attributes performed well; the area was used for lines type artefacts detection (i.e. few pixels), the convexity was added for complex type artefacts detection, other rules could be used to eliminate further objects (e.g. irregular roads, perpendicular roofs, trees).

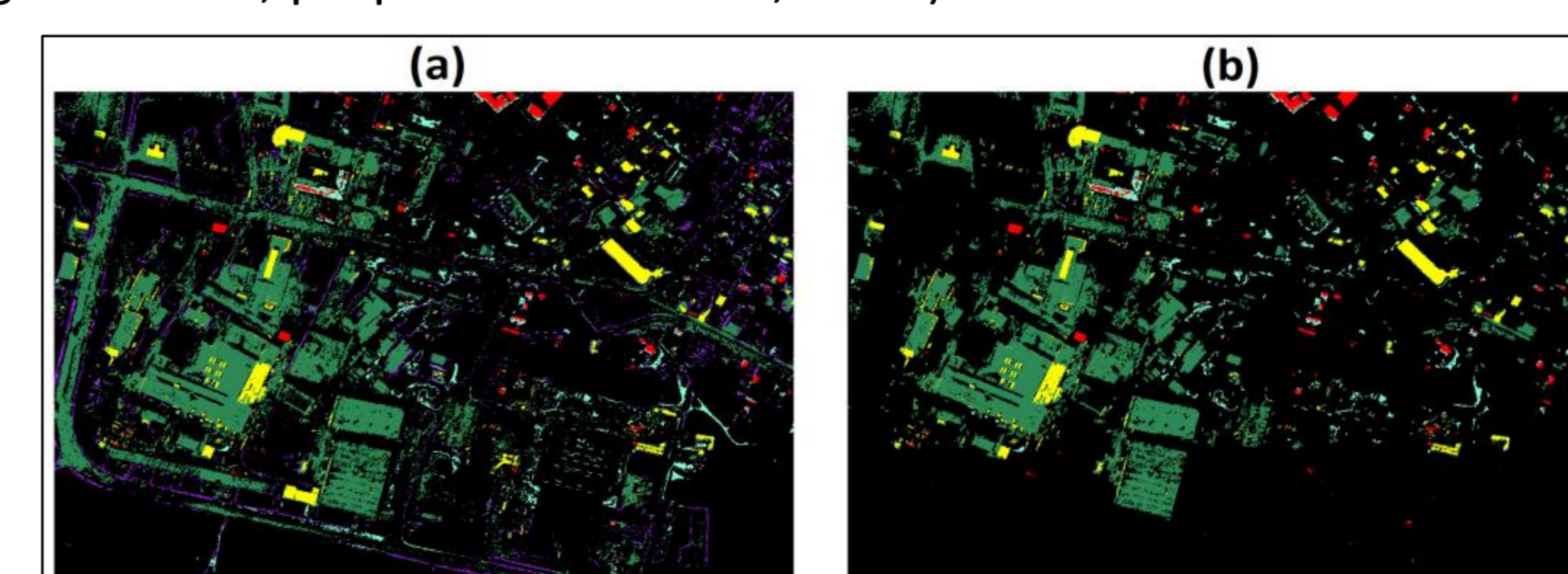


Figure 4. Morphological classification of class "Tile".