Q1. Acquire, provide, and present necessary information about Hyperspectral Images (HSI) and their properties. This task is essential for performing further steps. Perform the following tasks for both datasets mentioned above using MATLAB.

Hyperspectral imaging collects and analyzes information from the entire electromagnetic spectrum. The goal of hyperspectral imaging is to acquire the spectrum for each pixel in images so that structures, materials, and processes may be explored. The human eye only detects color in three bands of visible light, but spectral imaging splits the spectrum into many more bands and waves. In contrast to multi - band scanning, which measures dispersed spectral bands, hyperspectral imaging captures continuous spectral bands.

Q2. Normalize all spectral signals.

In the MATLAB code the normalizing between 0 and 1 as following:

```
data = rescale(hcube.DataCube);
ncube = assignData(hcube,':',':',':',data);
```

data would be normalized with rescale command and then to have data in the hypercube matlab structure assignData is used.

Q3. Select 3 suitable bands at different wavelengths from the dataset, create an appropriate false-color image and show it.

In order to show a hyperspectral image, we need to consider 3 waves and look at it as a RGB image. To need the requirements the following code is written:

```
rgbImg = colorize(ncube,[36 10 29]);
figure; imshow(rgbImg); title('indian pines');
```

first command colorized returns a false-color image using the specified spectral bands band.
For the Indian_pines data the output image is shown in Fig. 1, and for the pavia data the output is demonstrated in Fig. 2.

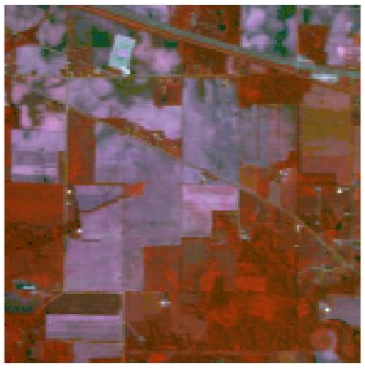
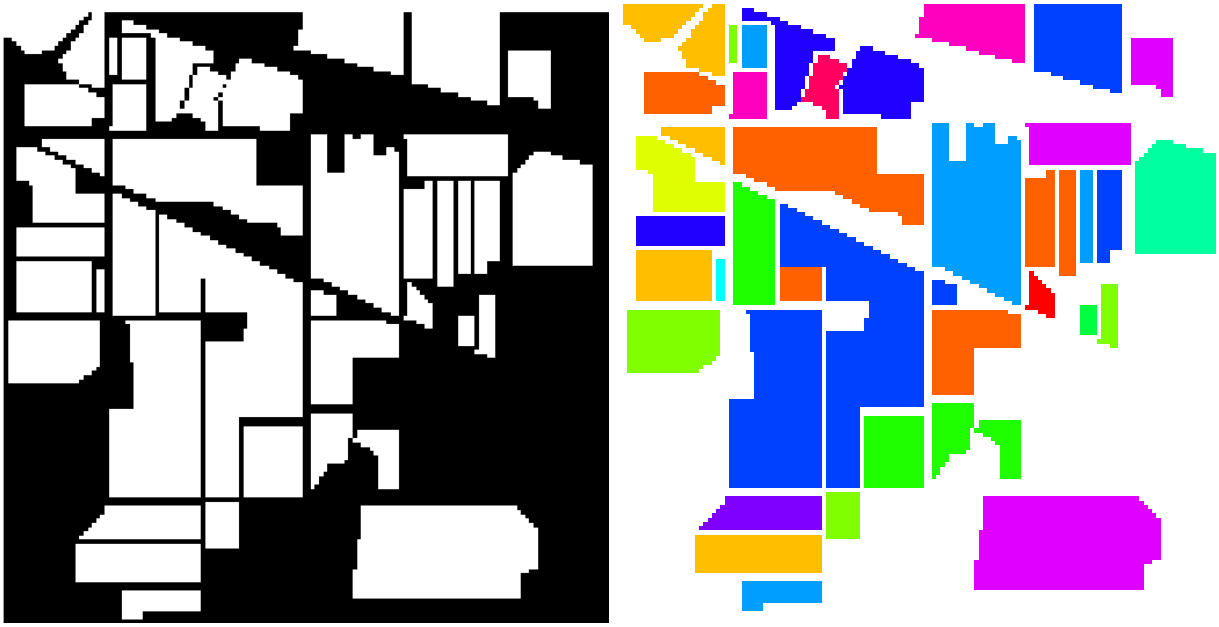


Fig. 1: False-color image of Indian_pines

Fig. 2: False-color image of pavia dataset

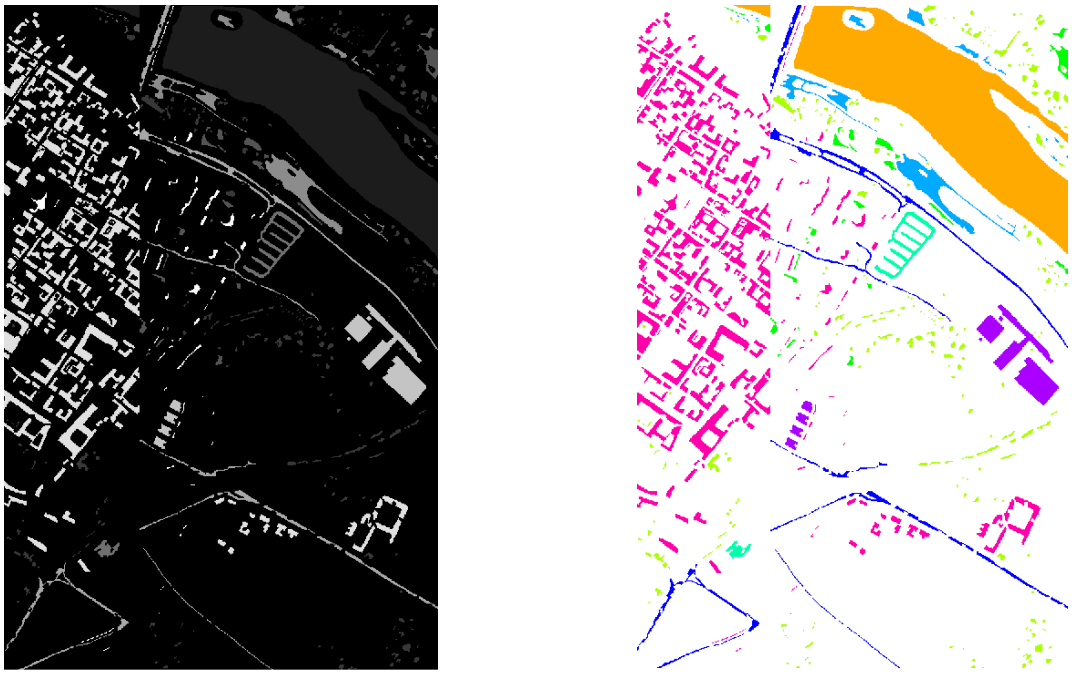
Q4. Visualize the ground truth data. Assign a different color to each label to distinguish the classes properly in the image.

The ground truth of Indian_pines and pavia dataset are illustrated in Fig. 3 and Fig. 4 respectively.



(a) (b)

Fig. 3: (a): shows the ground truth of Indian_pines with raw pixels
(b) shows the ground truth of Indian_pines with assigning color for each of the classes



(a) (b)

Fig. 4: (a): shows the ground truth of pavia with raw pixels
(b) shows the ground truth of pavia with assigning color for each of the classes

Q5. Present the number of elements belonging to each class using histogram plot. Exclude the 0 valued entities since they indicate background pixels.

For the Indian_pines data the classes are 16 classes as shown in Table I.

Table I: The ground truth classes for the Indian_Pines image and samples number

#	Class	Samples
1	Alfalfa	46
2	Corn-notill	1428
3	Corn-mintill	830
4	Corn	237
5	Grass-pasture	483
6	Grass-trees	730
7	Grass-pasture-mowed	28
8	Hay-windrowed	478
9	Oats	20
10	Soybean-notill	972
11	Soybean-mintill	2455
12	Soybean-clean	593
13	Wheat	205
14	Woods	1265
15	Buildings-Grass-Trees-Drives	386
16	Stone-Steel-Towers	93

The histogram diagram for showing the number of each class of Indian_pines is as Fig. 5.

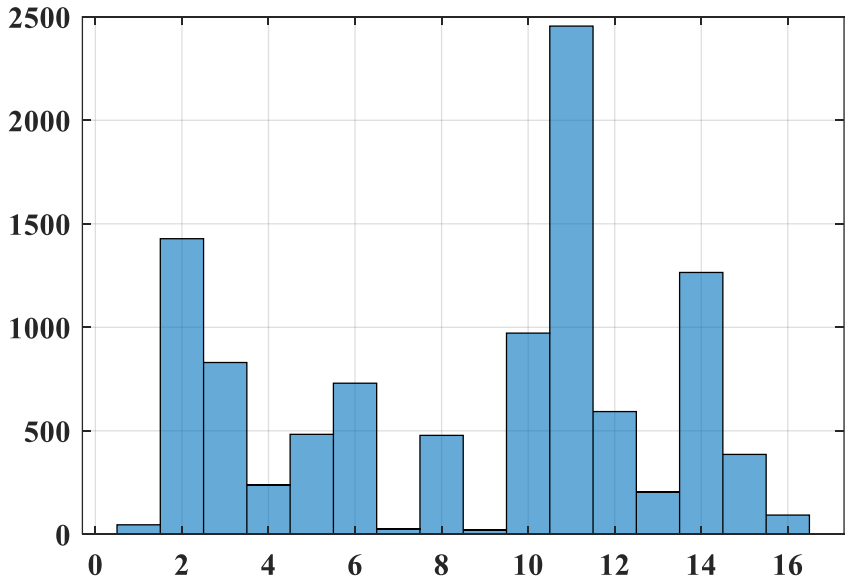


Fig. 5: histogram diagram of each class for Indian_pines dataset showing the number of each class

For the pavia data the classes are 9 classes as shown in Table II.

Table II: The ground truth classes for the pavia image and samples number

#	Class	Samples
1	Water	824
2	Trees	820
3	Asphalt	816
4	Self-Blocking Bricks	808
5	Bitumen	808
6	Tiles	1260
7	Shadows	476
8	Meadows	824
9	Bare Soil	820

The histogram diagram for showing the number of each class for pavia is as Fig. 6.

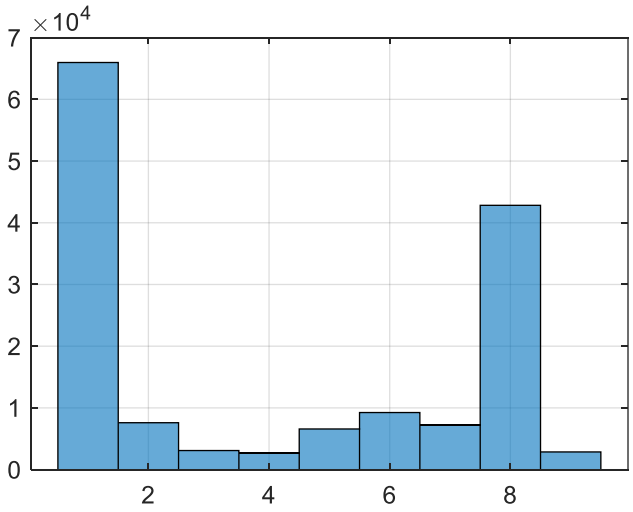
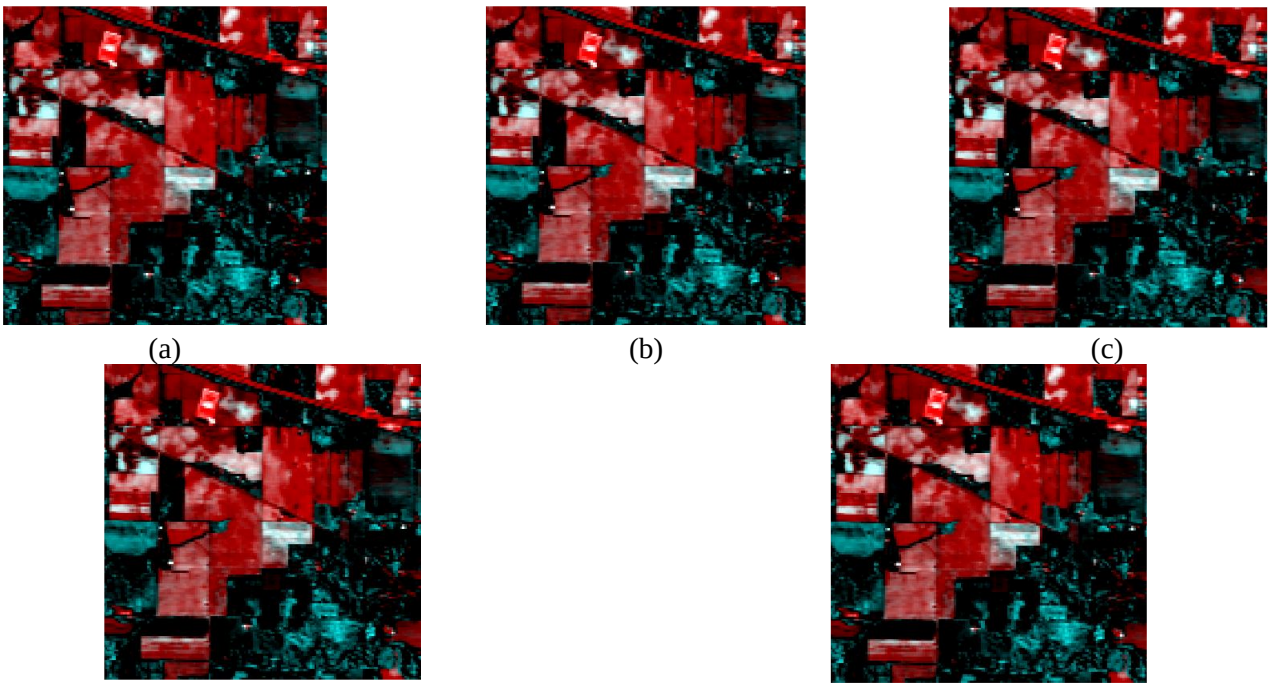


Fig. 6: histogram diagram of each class for pavia dataset showing the number of each class

Q6. Apply PCA to the HSI dataset and reduce the band number to 3, 5, 10, 20 and 25, respectively.

Hyperpca command in MATLAB specifies the principal component analysis (PCA) method. Usingn this command can add PCA to dataset with separating the number of bands that we want to have from that dataset.

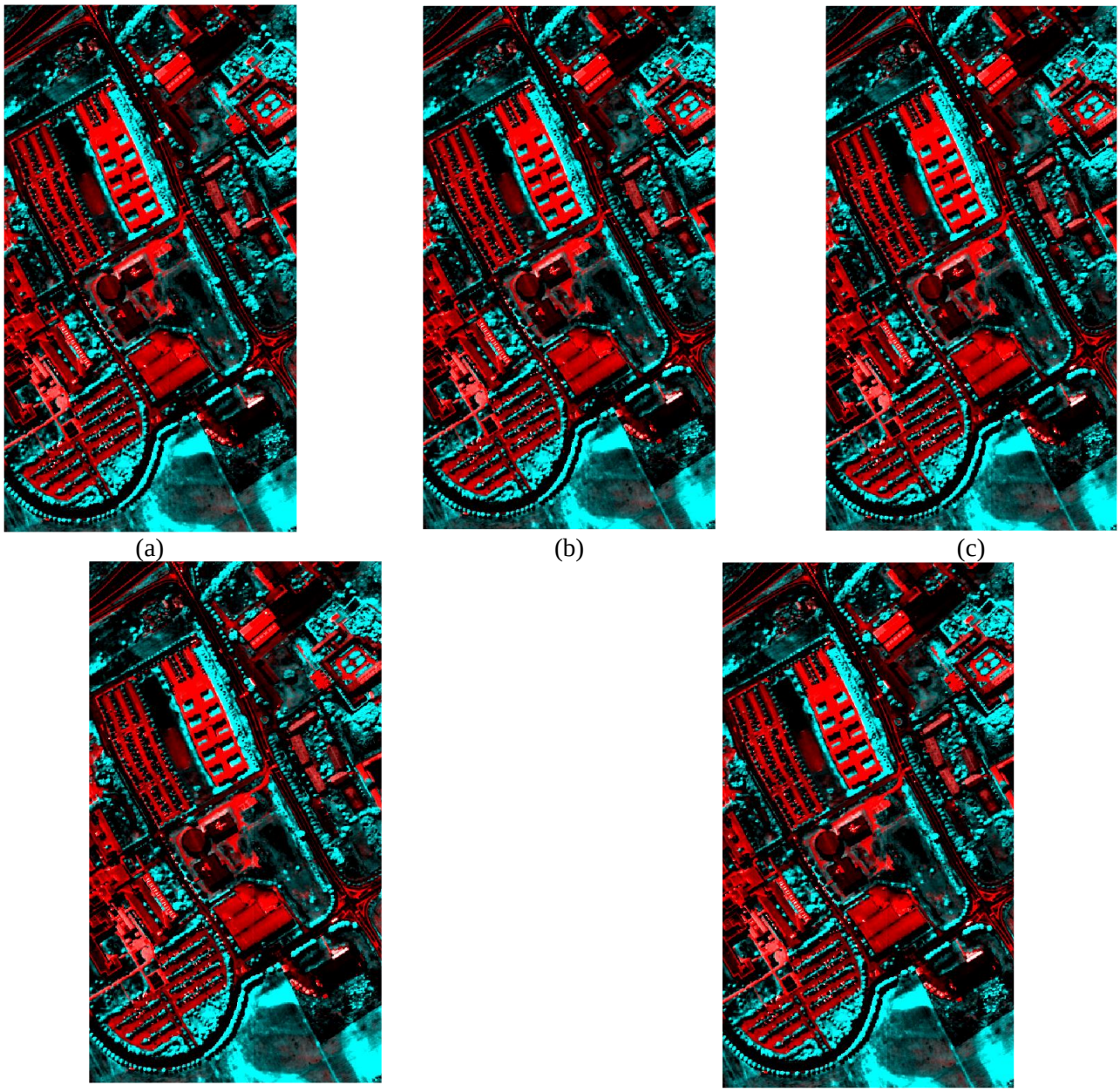
Q7. Generate another false color image for the dataset by using the 3-band version obtained using PCA.



(a) (b) (c)

(d) (e)

Fig. 7: false color image for the Indian_pines dataset by using the 3-band version obtained using PCA. (a) 3, (b) 5, (c) 10, (d) 20, and (e) 25 reduced band number with band limit of [1 1 2]



(a) (b) (c)

(d) (e)

Fig. 8: false color image for the pavia dataset by using the 3-band version obtained using PCA. (a) 3, (b) 5, (c) 10, (d) 20, and (e) 25 reduced band number with band limit of [1 1 2]

Q8. Create similarity matrices and heat maps for each reduced data obtained in step 6 and determine which class is closer to which class.

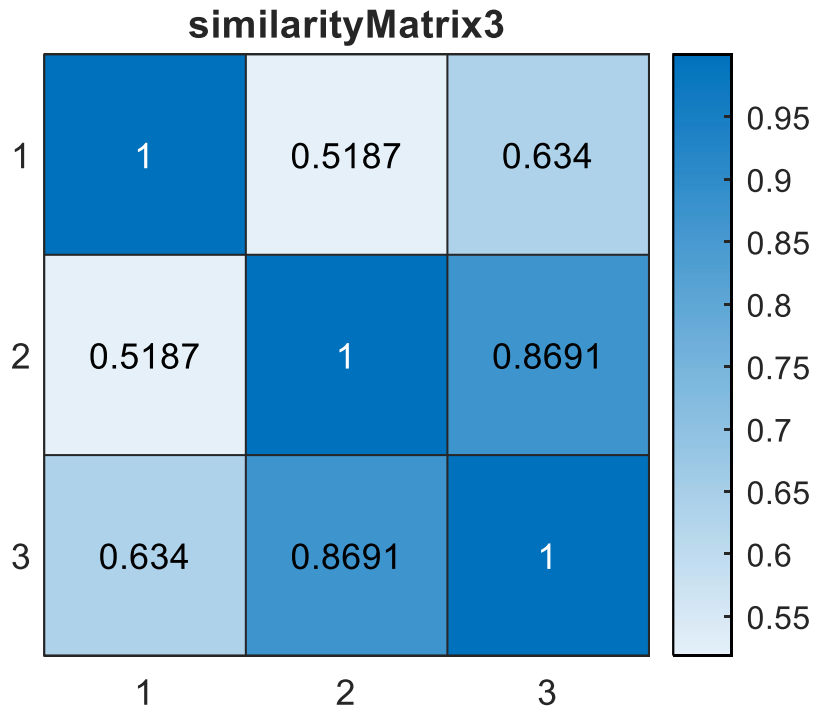


Fig. 9: similarity matrix for Indian_pines with reduced 3 bands

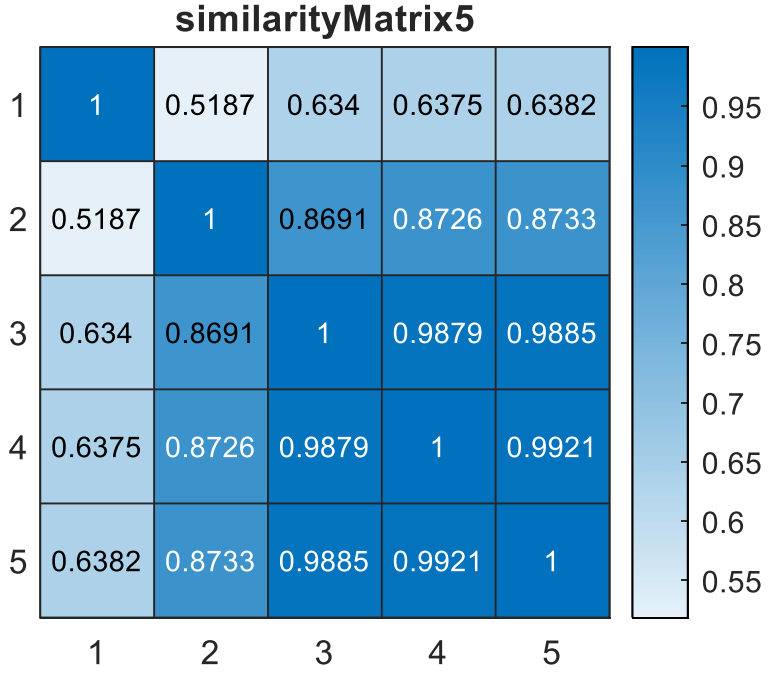


Fig. 10: similarity matrix for Indian_pines with reduced 5 bands

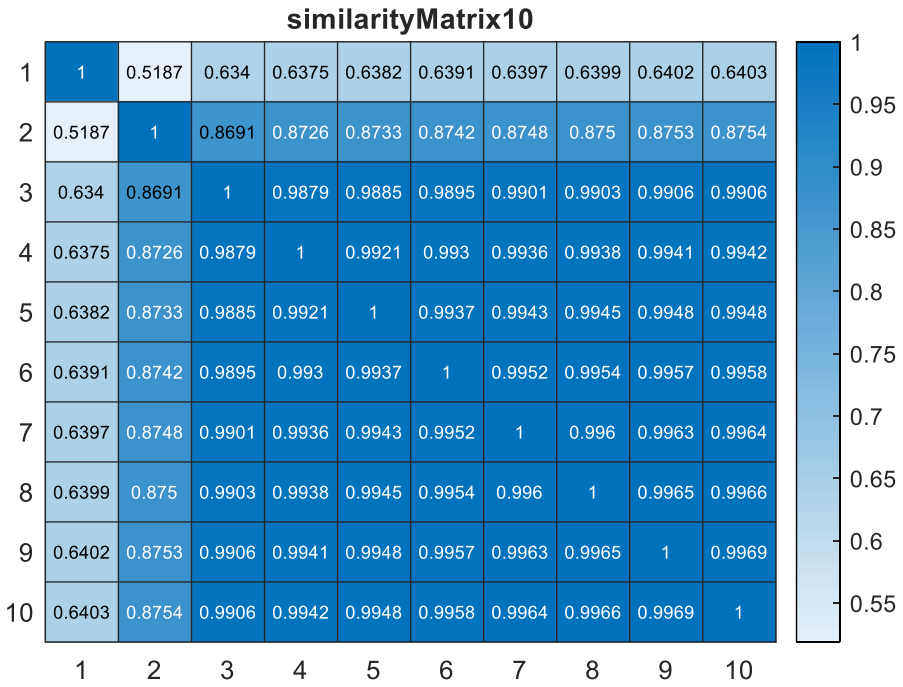


Fig. 11: similarity matrix for Indian_pines with reduced 10 bands

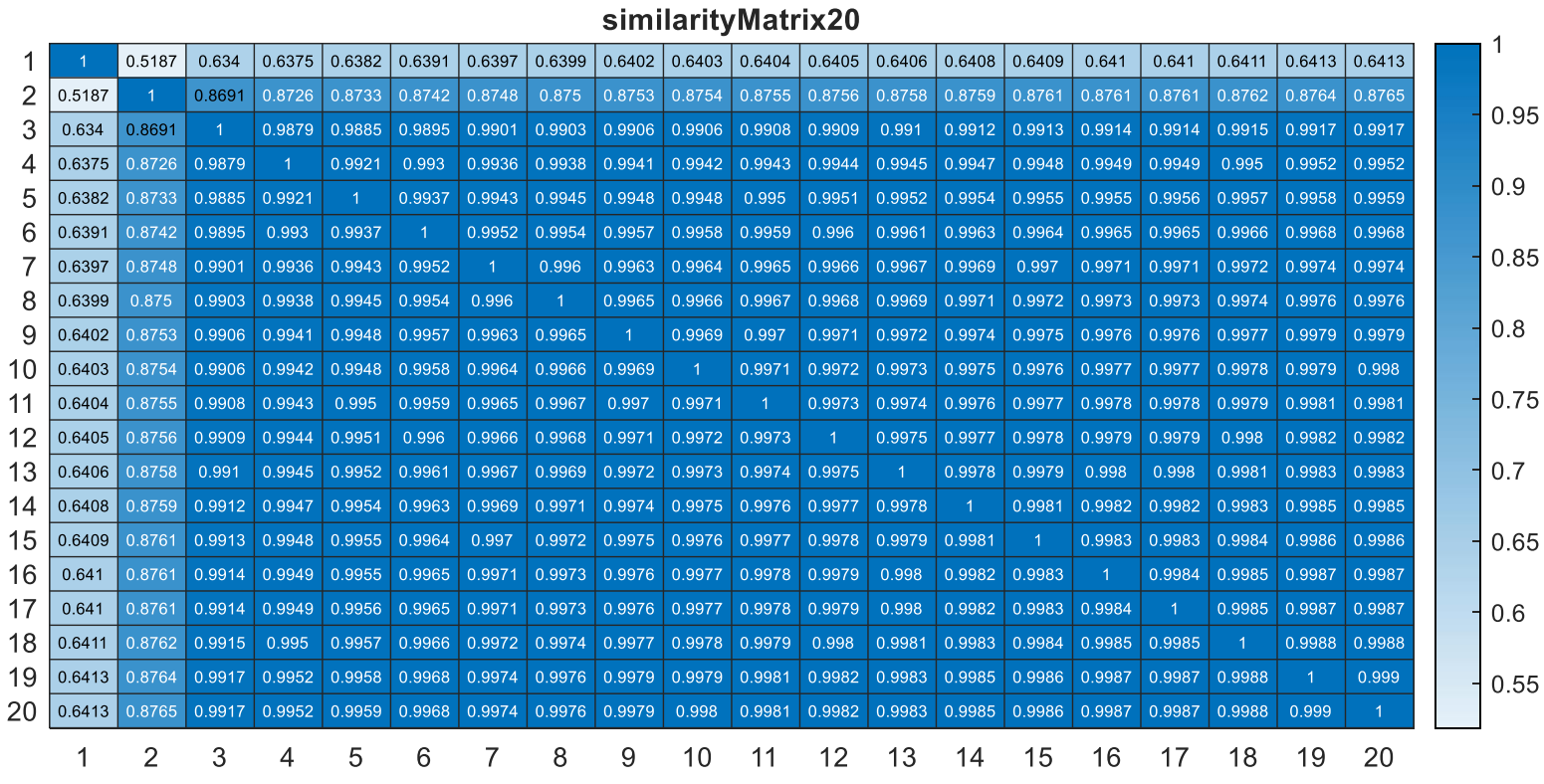


Fig. 12: similarity matrix for Indian_pines with reduced 20 bands

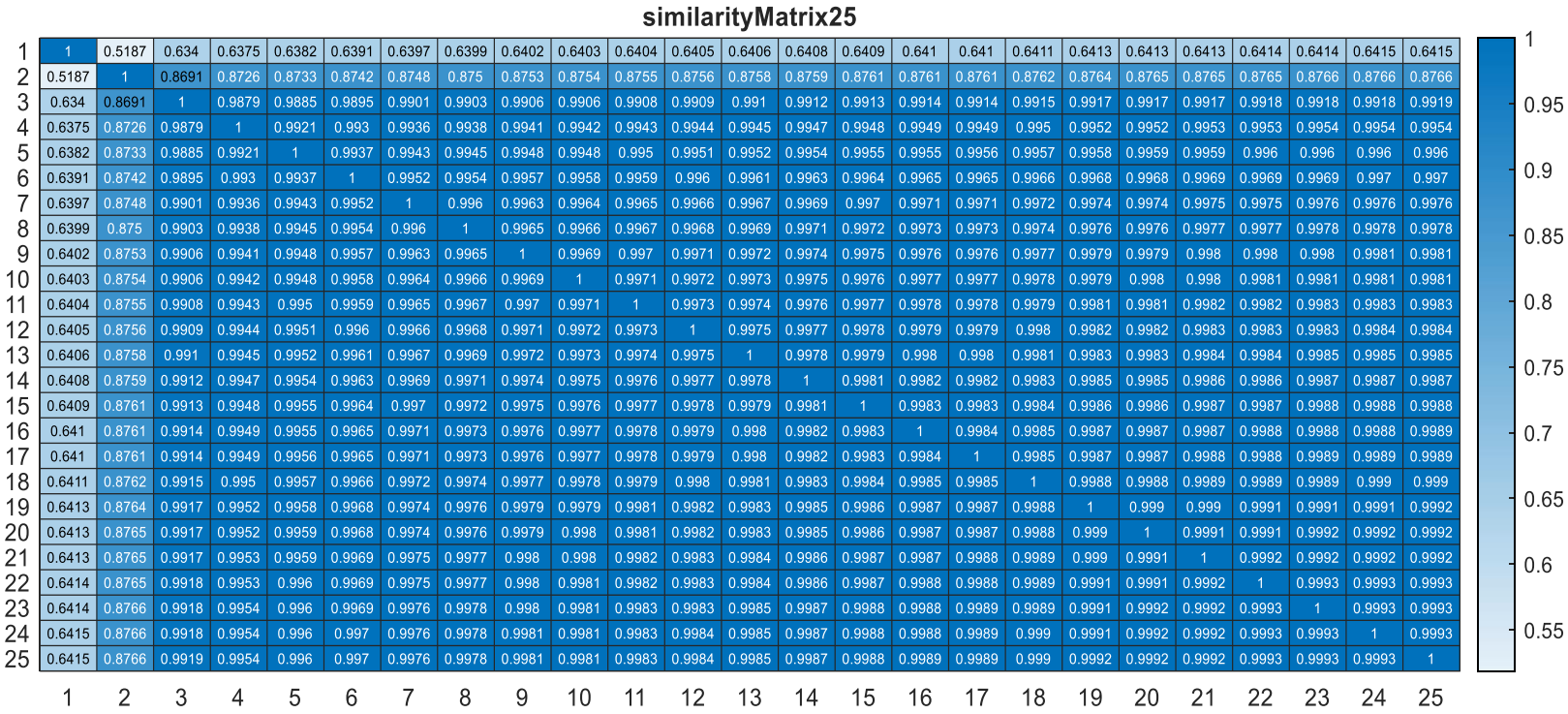


Fig. 12: similarity matrix for Indian_pines with reduced 25 bands

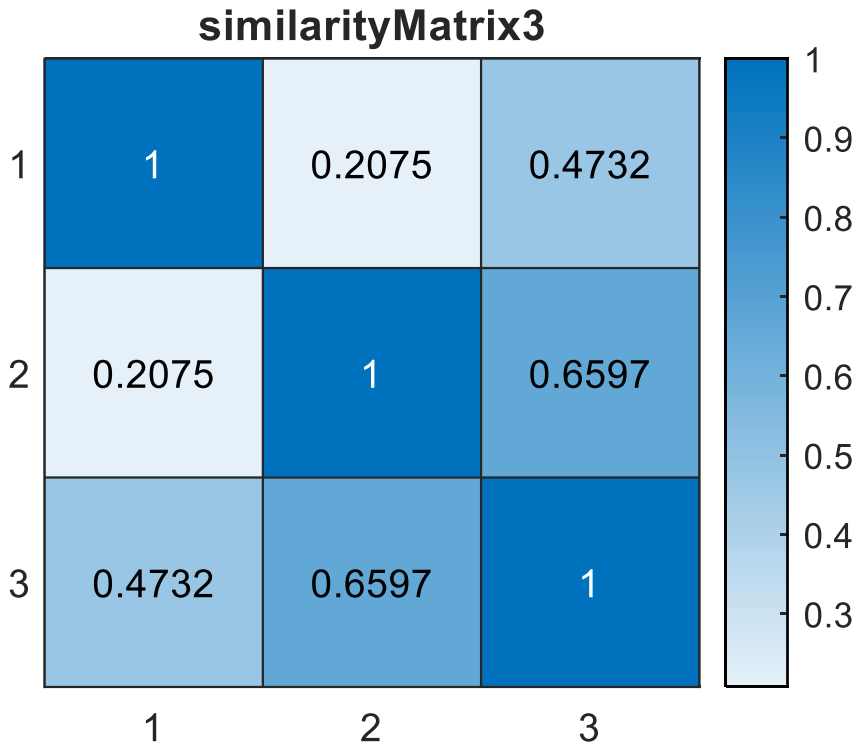


Fig. 13: similarity matrix for pavia with reduced 3 bands

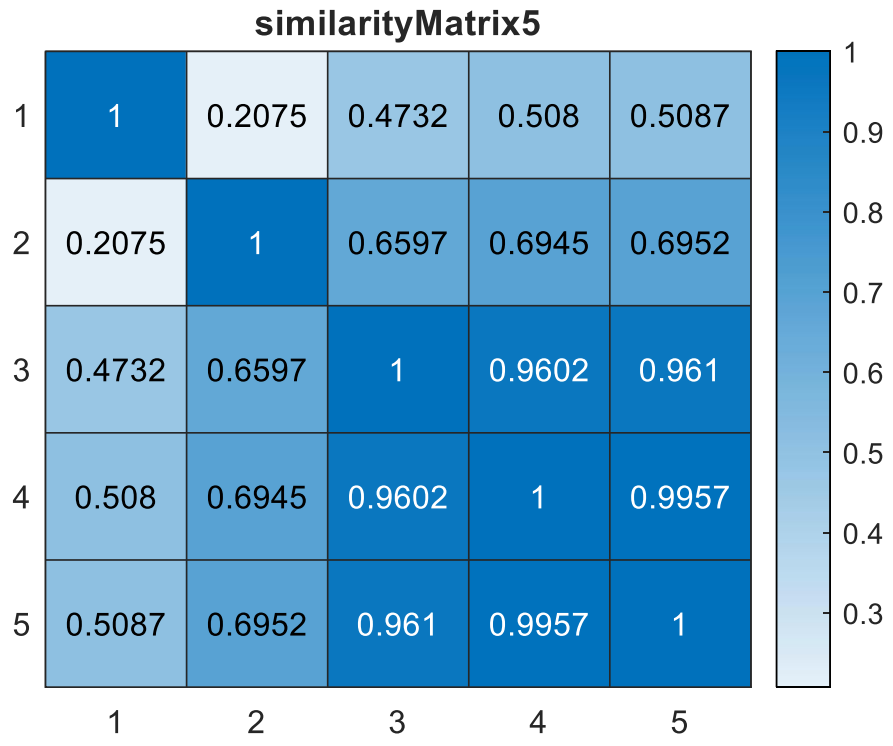


Fig. 14: similarity matrix for pavia with reduced 5 bands

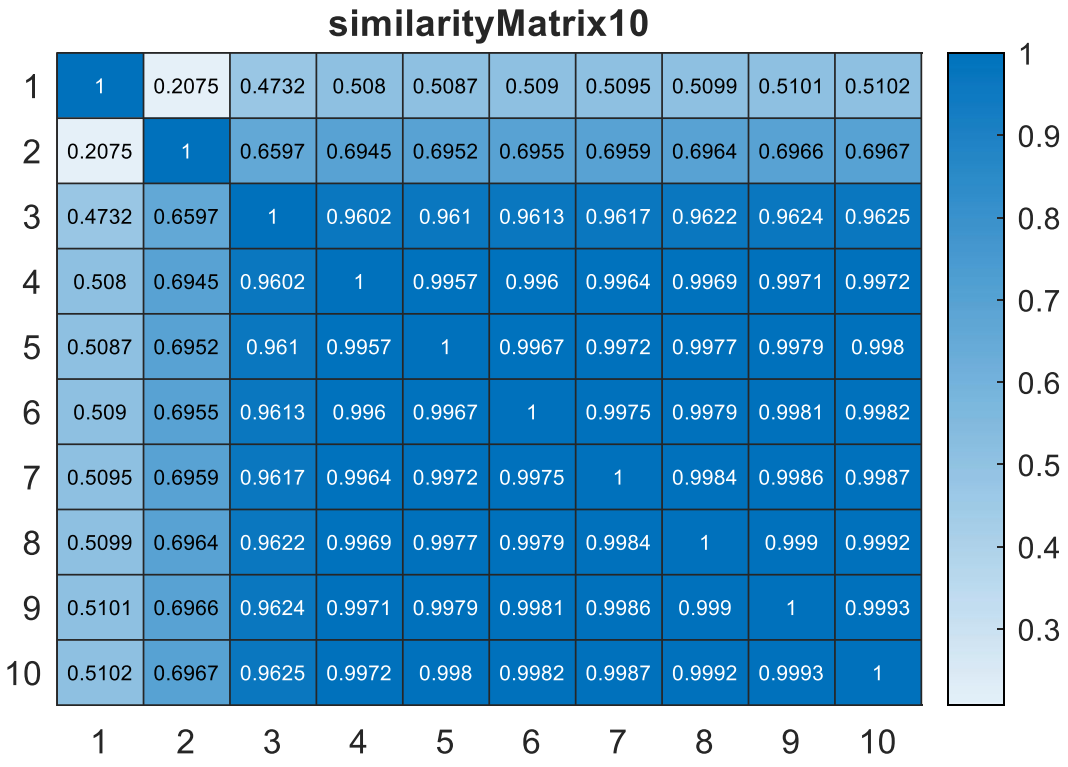


Fig. 15: similarity matrix for pavia with reduced 10 bands

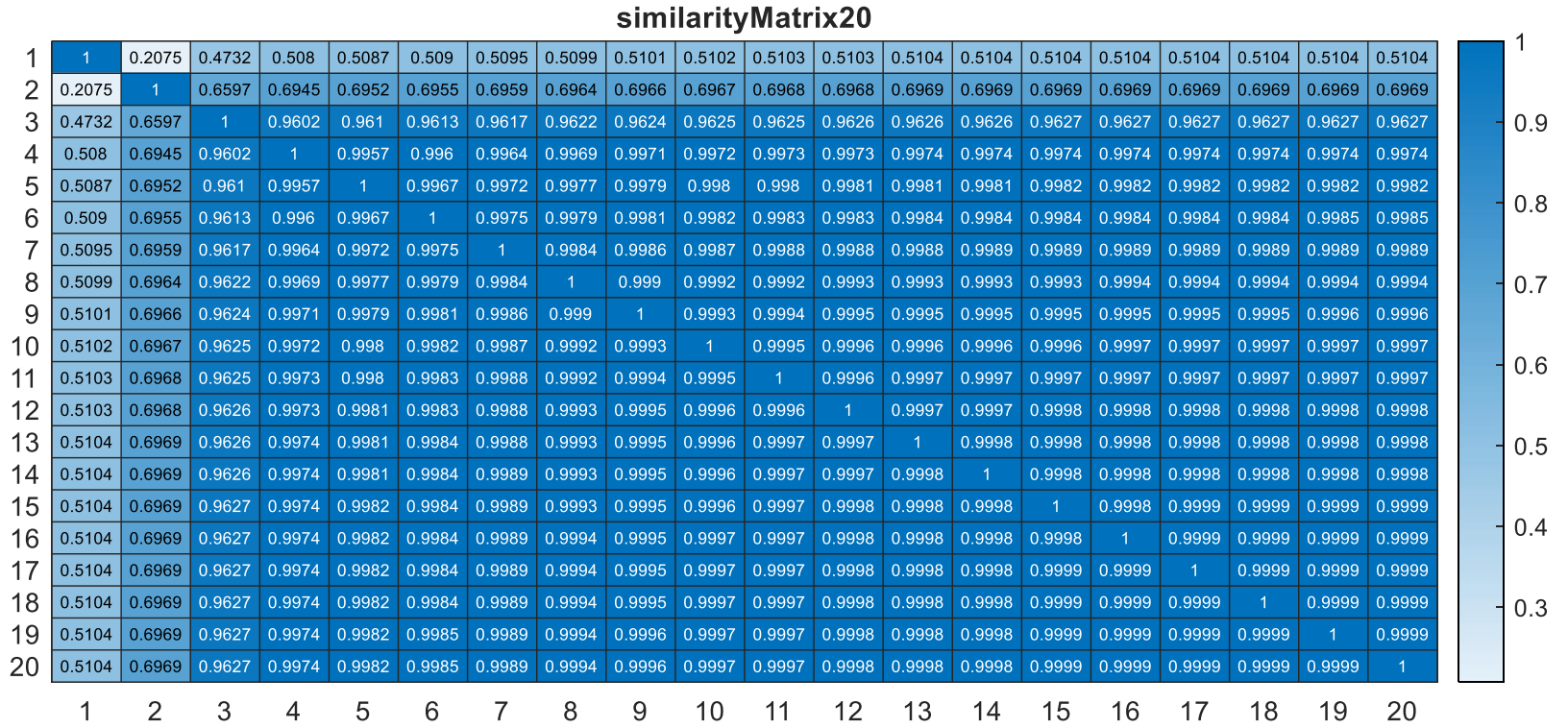


Fig. 16: similarity matrix for pavia with reduced 20 bands

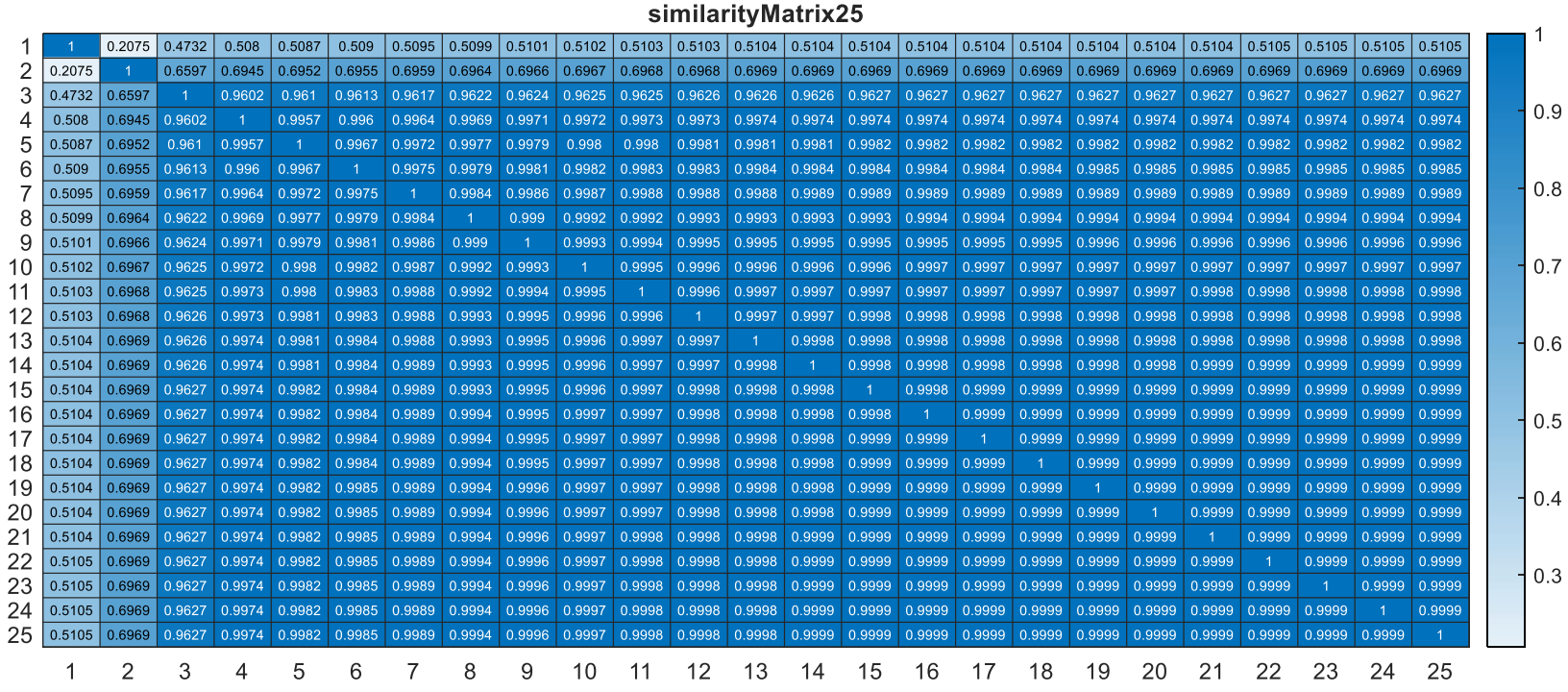


Fig. 16: similarity matrix for pavia with reduced 25 bands

Q9. Classification phase (Support Vector Machines). Use LIBSVM package to implement the following tasks: a. Classify the dataset and calculate the overall accuracy (OA) and the average accuracy (AA).
b. Use radial basis function as SVM kernel.
c. Perform classification for training ratios 5%, 10% and 20%.
d. Sketch a graph to present the OA and AA values vs training ratio.
e. Find OA and AA values by classifying the reduced data in the 6th step at 10% training ratio. Sketch the corresponding accuracy values vs band number on a single graph.

Overall and average accuracy of trained Indain_pines and pavia is shown in Table III.

Table III: OV and AA of datasets

	Indian_pines	*Pavia*
Overall Accuracy	0.6105	0.8224
Average Accuracy	0.4822	0.6689

LIBSVM is downloaded to be used in the code. The default kernel is set on radial basis. Fig. 17 and Fig. 18 shows the classification for training ratio of 5%, 10%, and 20%.

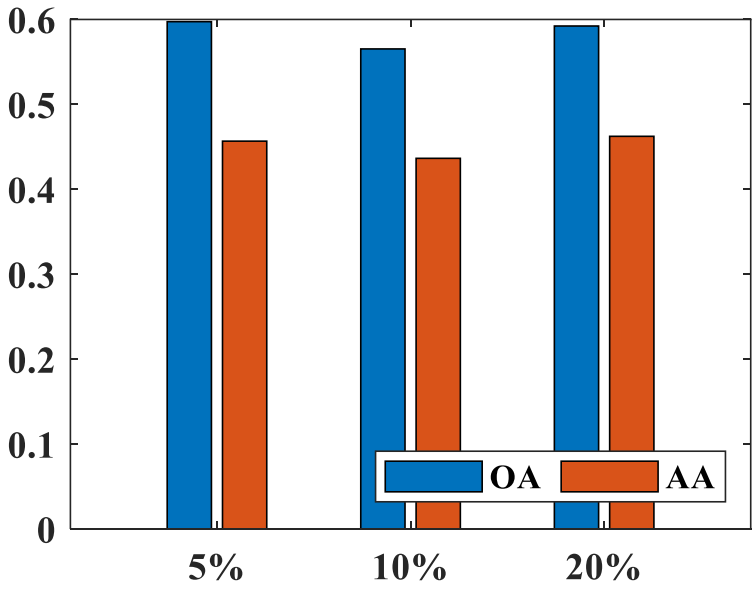


Fig. 17: classification for training ratios 5%, 10% and 20% of Indian pine

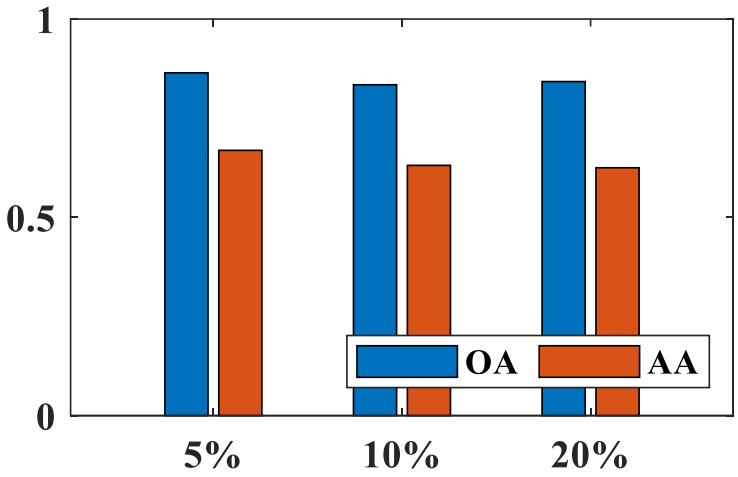


Fig. 18: classification for training ratios 5%, 10% and 20% of pavia

Fig. 19 and Fig. 20 shows the OA and AA values by classifying the reduced data in the 6th step at 10% training ratio.

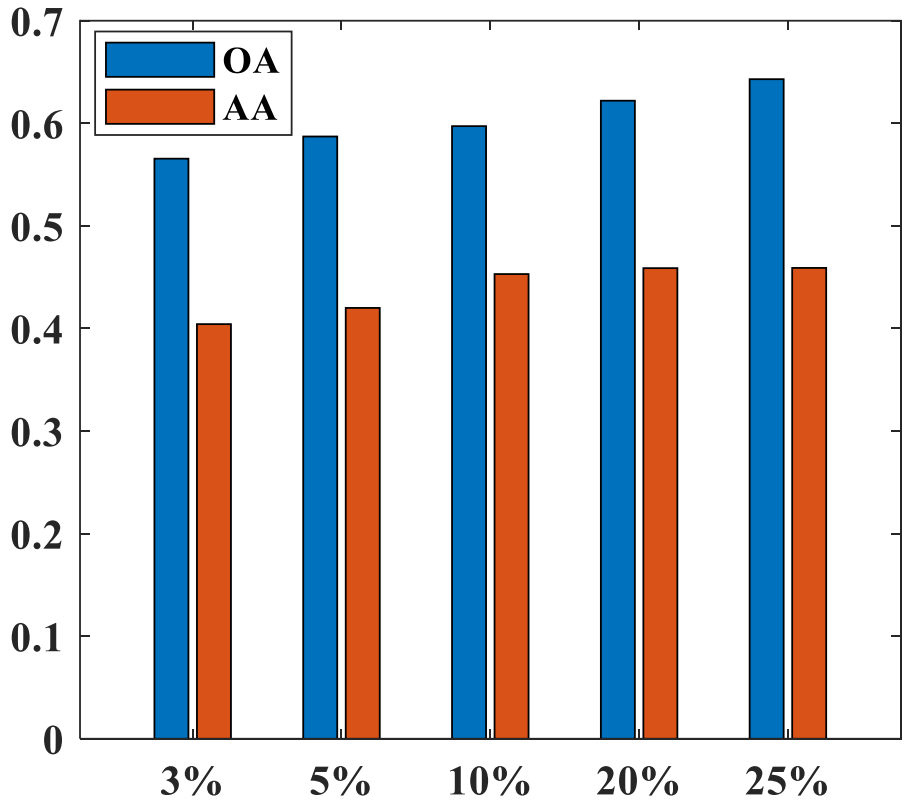


Fig. 19: OA and AA values of Indian pine by classifying the reduced data

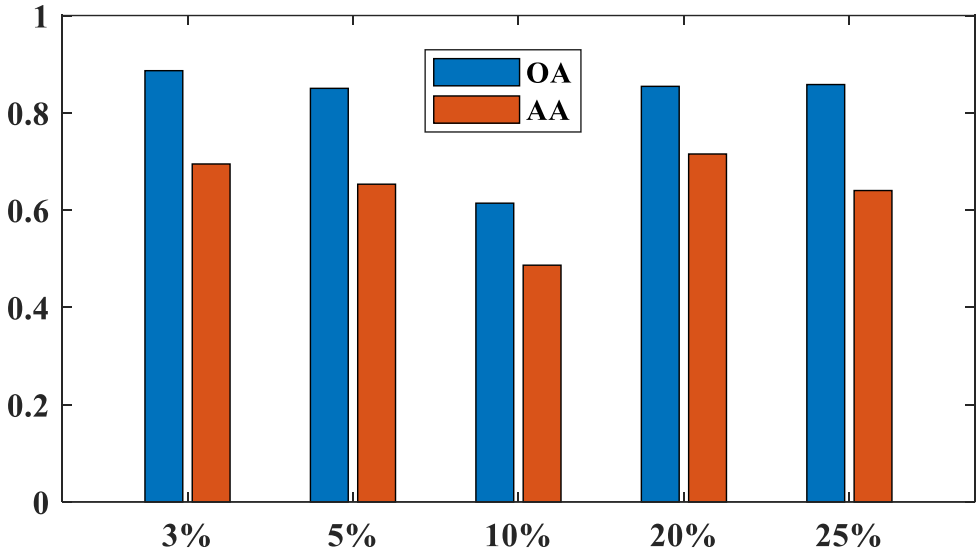


Fig. 20: OA and AA values of pavia by classifying the reduced data