A Parcel-Based Local Climate Zone Classification Method

Using CNN Model

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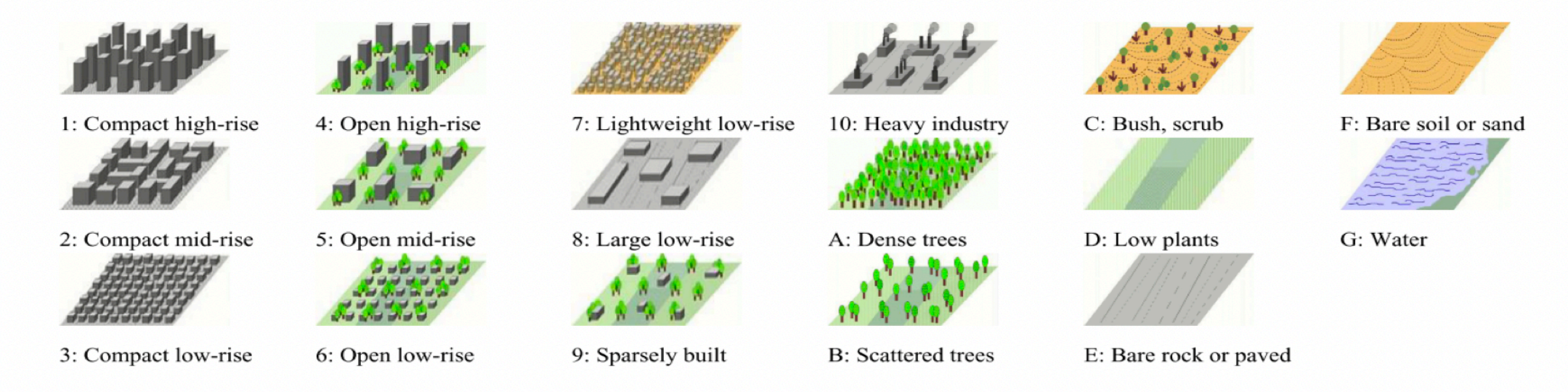
Contents

Background

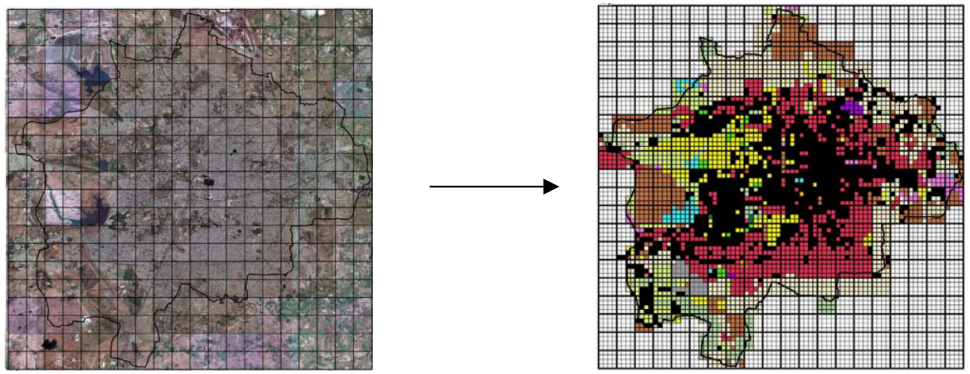
In order to study the urban climate in a more standardized way, some studies have divided the climate types of cities into 17 categories according to complete surface climatic characteristics in a certain area. In this way, the classification according to the local climate type is defined as local climate zones (LCZ).



Background

Previous classification methods mostly used standard grids as the smallest classification unit. The study area is divided by grid, and then classified by grid.

Many mixed units will be produced by this segmentation. Mixed units will affect the classification results.

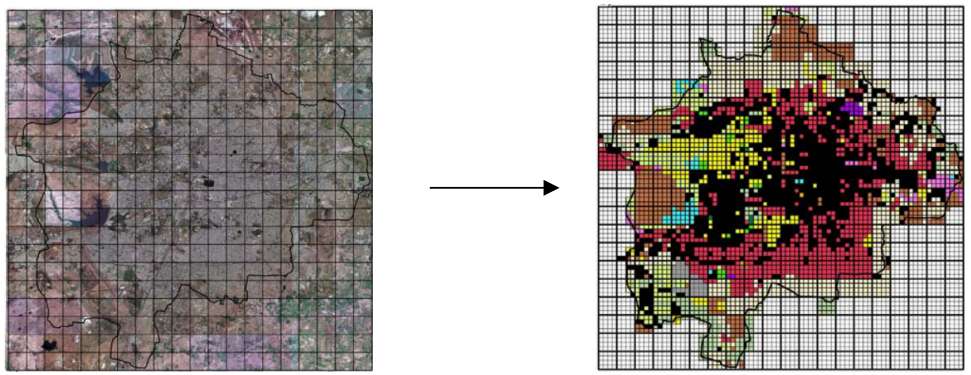


Grids as unit

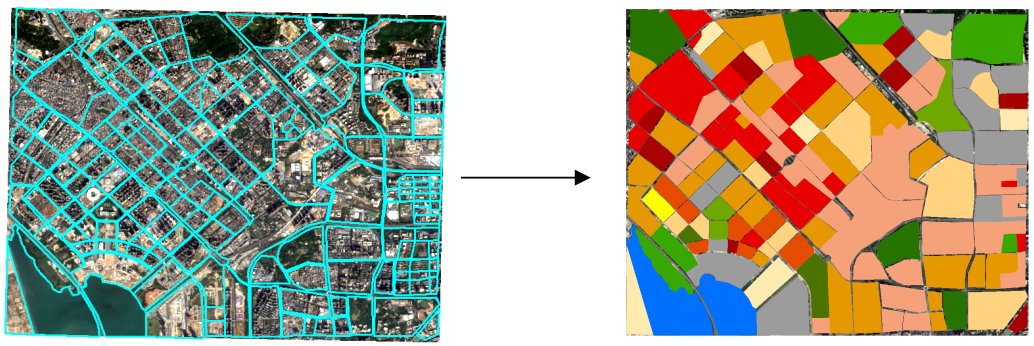
Objectives

In order to reduce the influence of mixed units, this work proposes a classification method that uses parcel as the smallest classification unit.

Parcel is defined as an adjacent area with similar surface coverings and similar functions.



a. Grids as unit

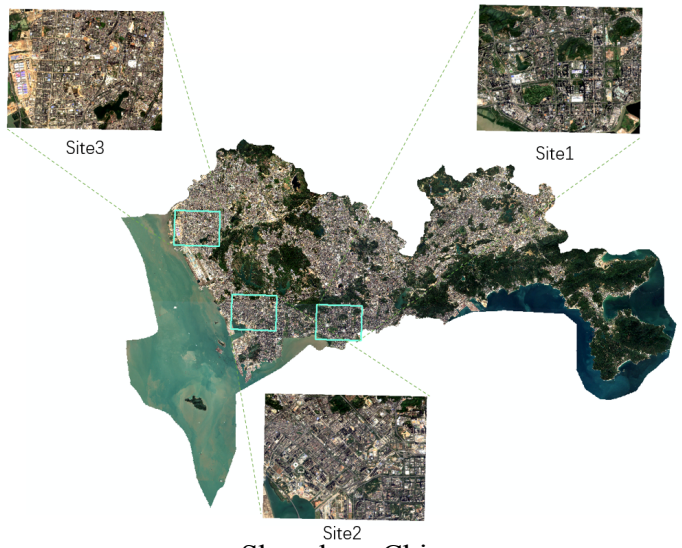


b. Parcels as unit

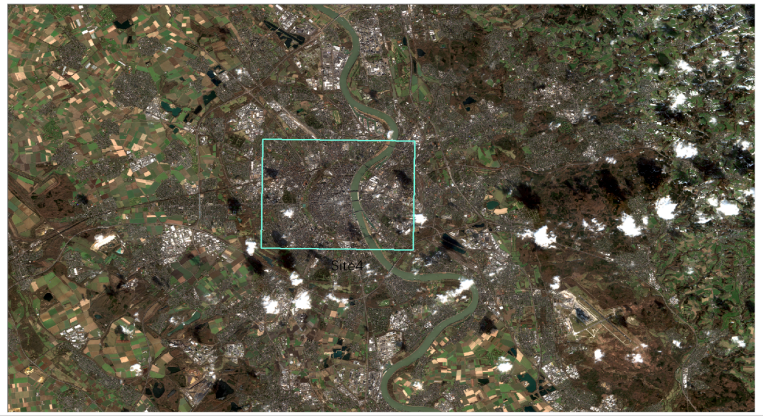
Contents

Data & Sites

- ***So2Sat LCZ42***
  - 42 urban agglomerations across the globe
  - Half a million labeled Sentinel-2 image patches
- ***OSM Road Network***
- ***ALOS DSM and DEM Dataset***
  - Spatial resolution is 30m
- ***Sentinel-2 Image***
- ***4 Sites***
  - 3 Sites in Shenzhen and 1 Site in Cologne



Shenzhen, China


Cologne ,Germany

Distribution of the 4 Sites

Contents

Methodology

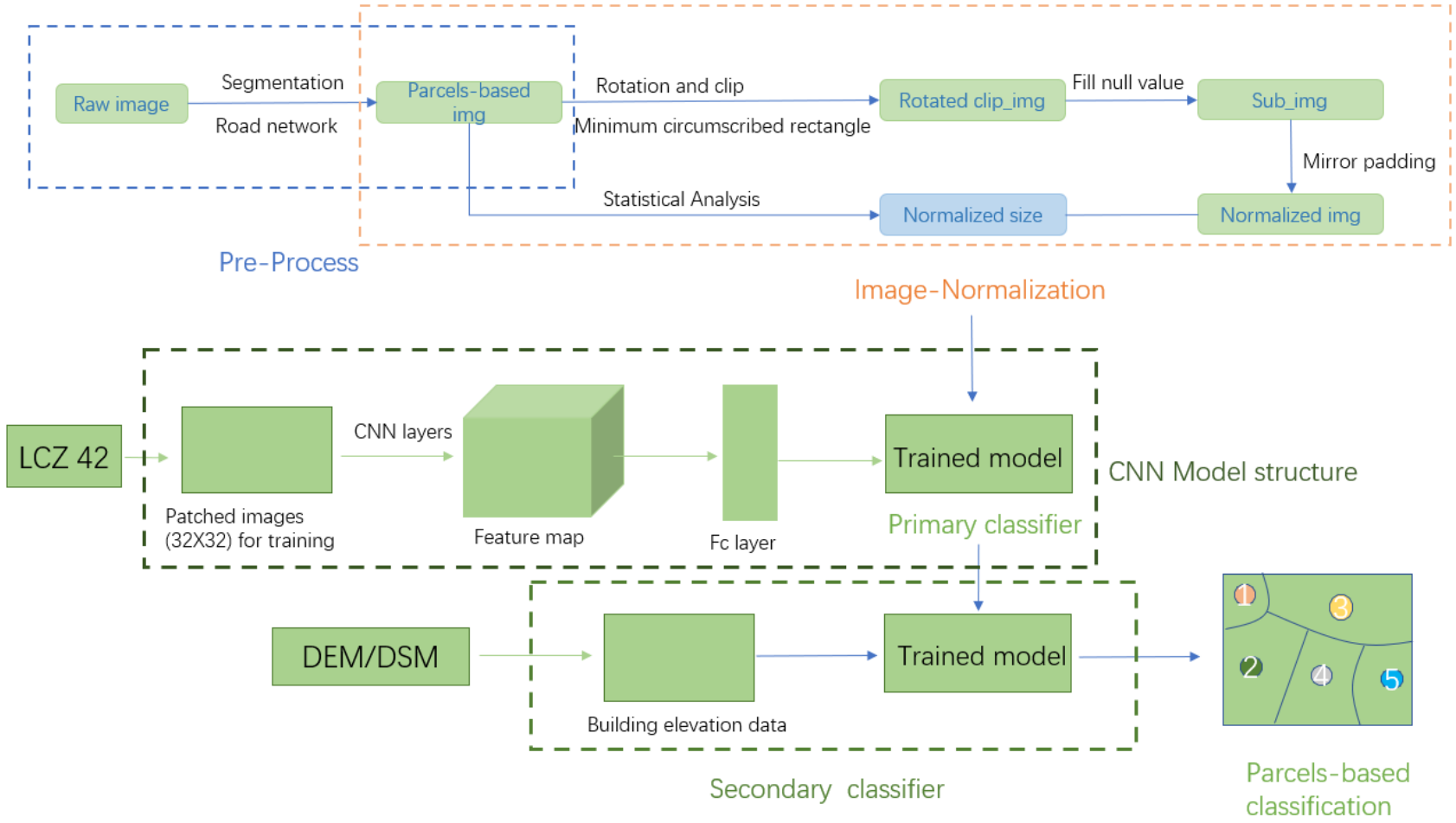
- **To segment remote sensing images.**
  - LCZ should have a diameter of 400–1,000 m.
  - Avoid mixed units

- **To use CNN to classify the segmented images.**
  - The segmented remote sensing images are irregular patches. But CNN model requires regular input data.

- **To build a suitable CNN model for LCZ classification task.**
  - The size of the patches from the training dataset is 32*32. Relatively small size data requires the CNN model do not loss features during the training. A suitable structure of the CNN model is necessary.

Methodology

- **Workflow**
  - Pre-Process module Image-Normalization module Primary classifier Secondary classifier

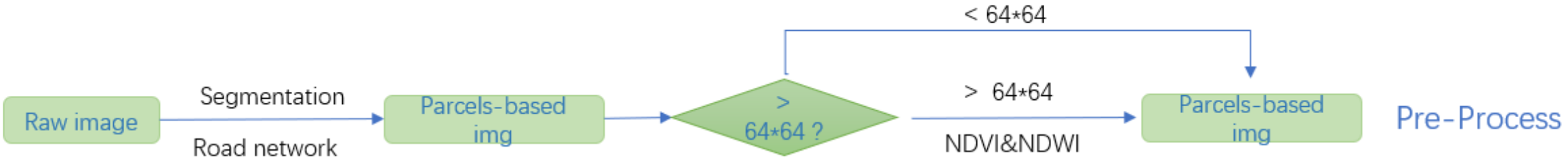


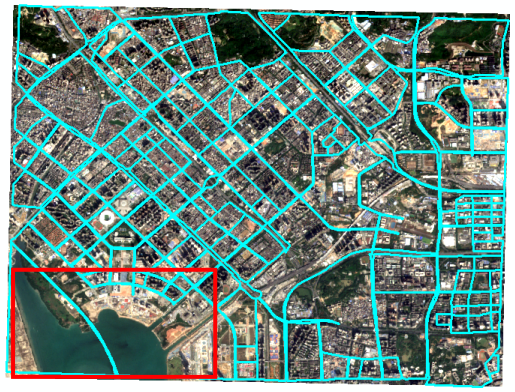
Workflow of parcels-based method

Methodology

- Pre-Process module

1. Use the road network data to segment the remote sensing image
2. Perform a second segmentation for the large segmentation unit according to NDVI and NDWI

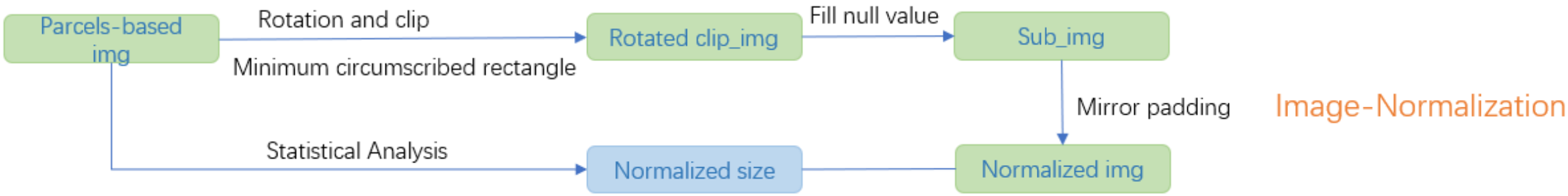




Methodology

- Image-Normalization module

1. Find the smallest circumscribed rectangle of each segmented image then rotate and crop it
2. Count the size of all segmented images in the study area to determine the standard size
3. Fill in null values in segmented images based on nearby pixel values
4. Use mirror padding to convert the segmented image to the standard size



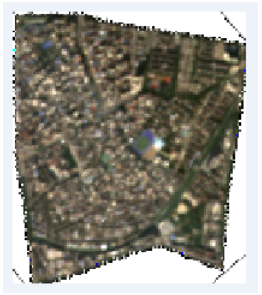
Methodology

- Image-Normalization module

161 X 157

Rotation and clip

Minimum circumscribed rectangle



112 X 131

Fill null value

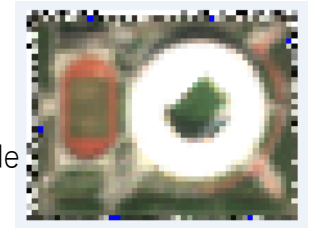
Mirror padding

64 X 64

60 X 61

Rotation and clip

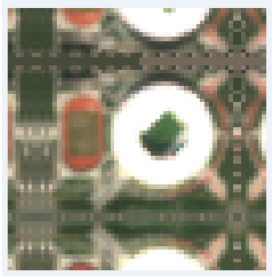
Minimum circumscribed rectangle



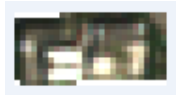
49 X 38

Fill null value

Mirror padding



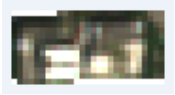
64 X 64



27 X 13

Rotation and clip

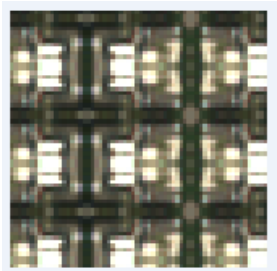
Minimum circumscribed rectangle



27 X 13

Fill null value

Mirror padding

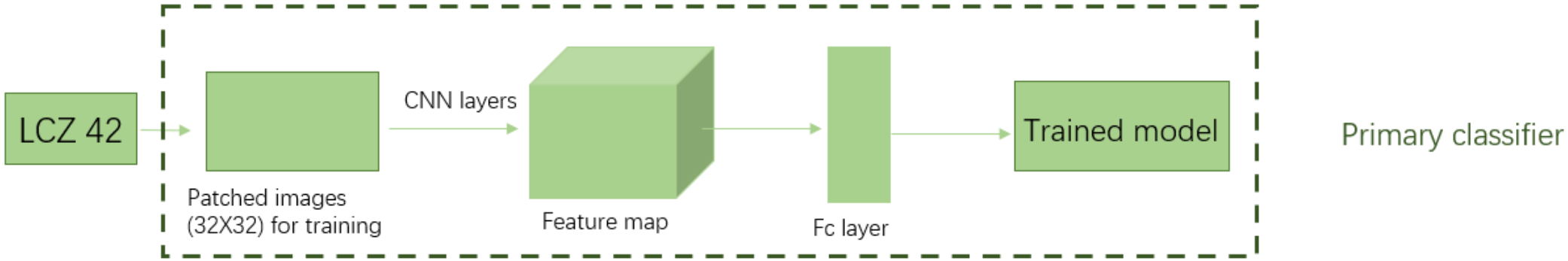


64 X 64

Methodology

- Primary classifier

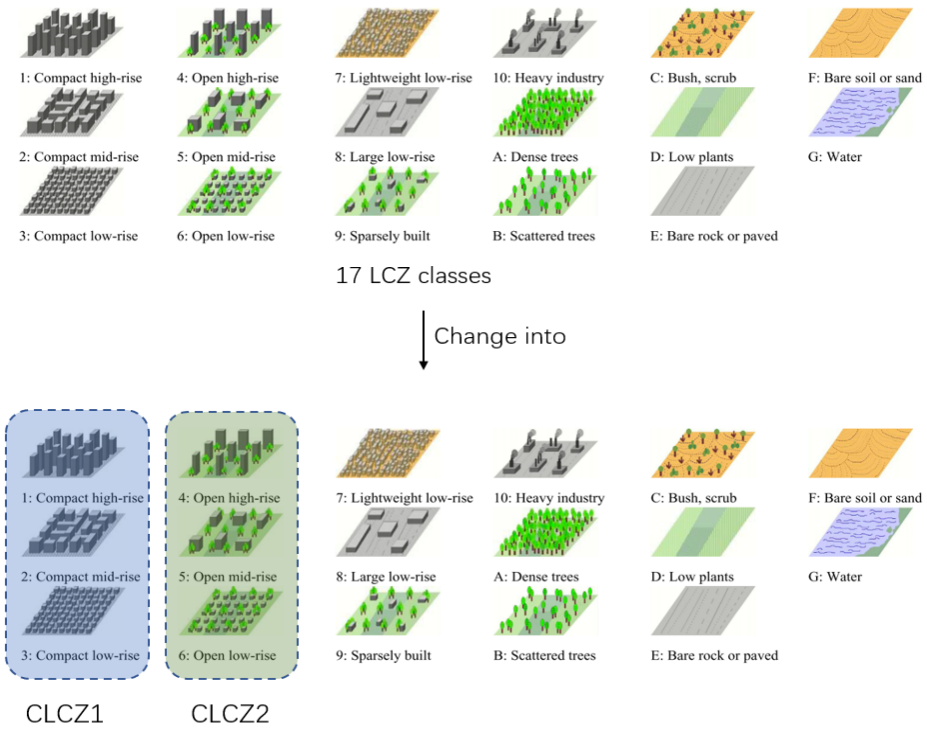
1. For input data, merge LCZ1, LCZ2, LCZ3 as CLCZ1 and LCZ4, LCZ5, LCZ6 as CLCZ2.
2. Structure of CNN model



Methodology

- Input Data

- The main difference between LCZ1, LCZ2 and LCZ3 comes from the height of the building. So does LCZ 4, LCZ 5, LCZ 6.
- The secondary classifier classifies CLCZ1 and CLCZ2 with the building elevation data.



Methodology

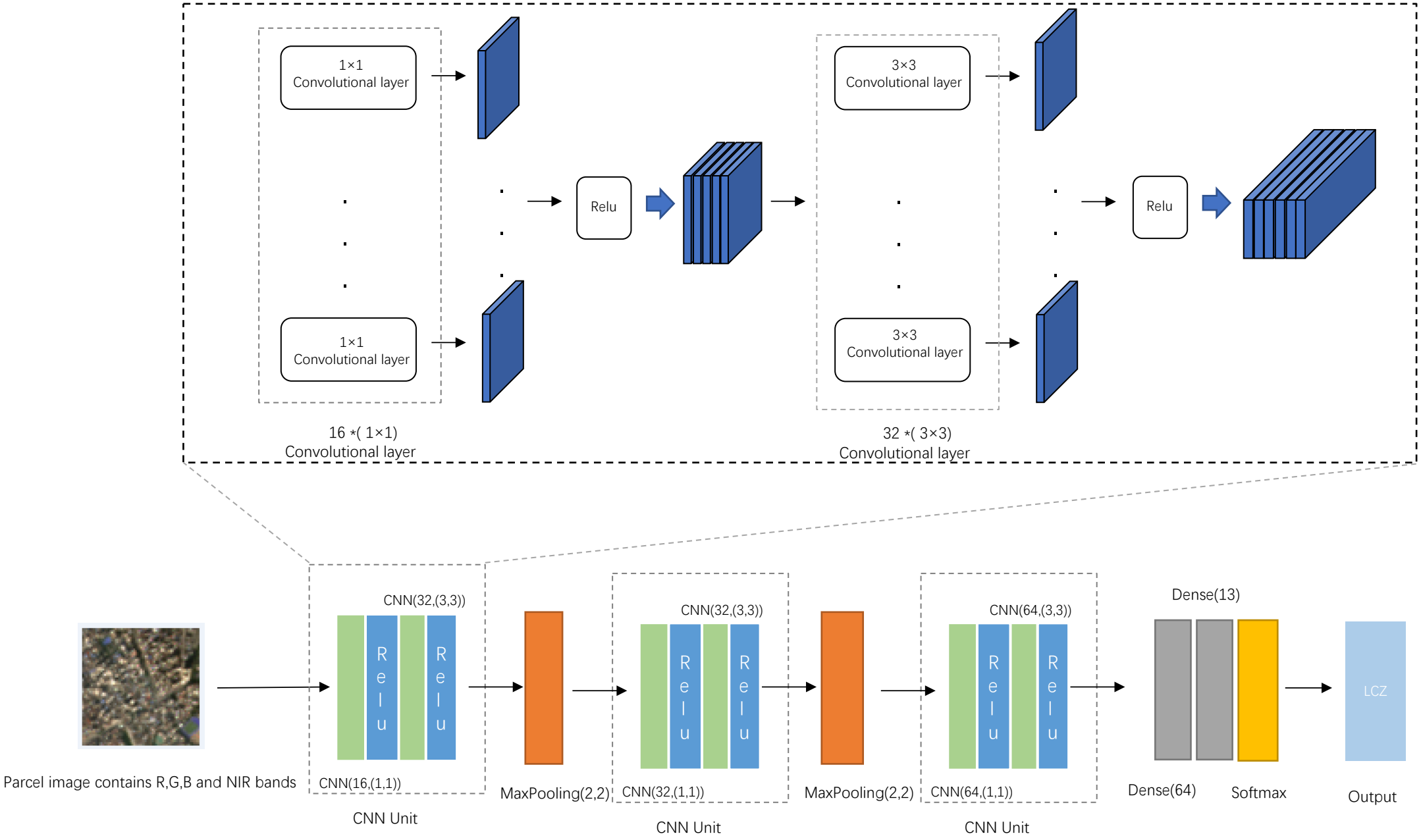
- Structure of CNN model

- This CNN model consists of 3 CNN units.

- Each CNN unit consists of 2 convolutional layers and 2 Relu activation layer. Max pooling layer connect every two CNN units. Finally, the classification results are output by the FC layer and softmax functions.

- In order to preserve the information of the input image as much as possible, we have selected a small window size for each component Layer. Our input image size is 32*32 relatively small.

Methodology

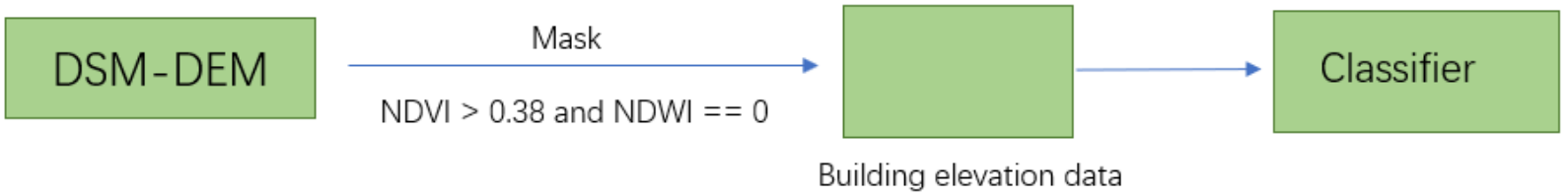


Structure of CNN model

Methodology

- Secondary classifier

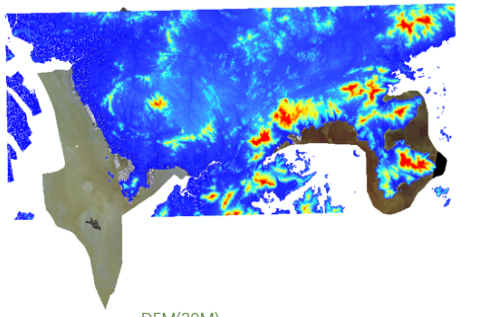
1. Use DEM, DSM data combined with NDVI, NDWI data to get the elevation data of buildings.
2. Use the elevation data of the building to divide CLCZ1 into LCZ1, LCZ2, LCZ3 and CLCZ2 into LCZ4, LCZ5, LCZ6.



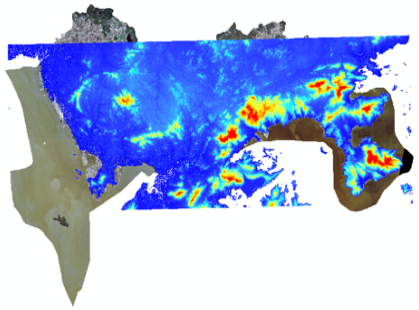
Secondary classifier

Methodology

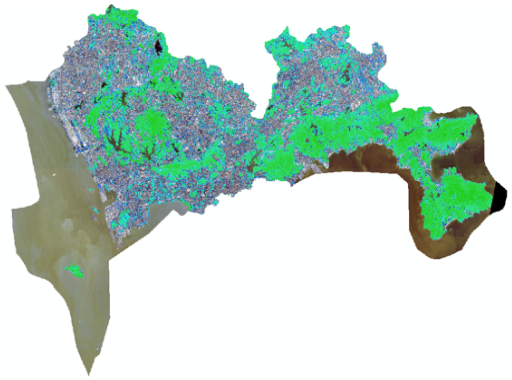
- Secondary classifier



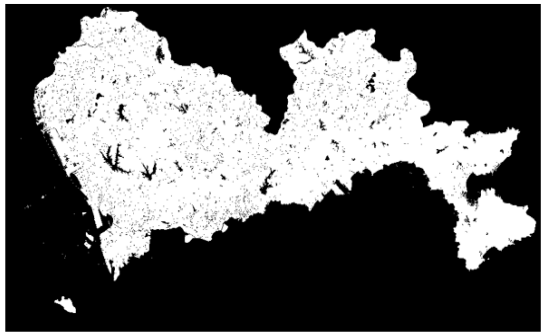
DEM(30M)



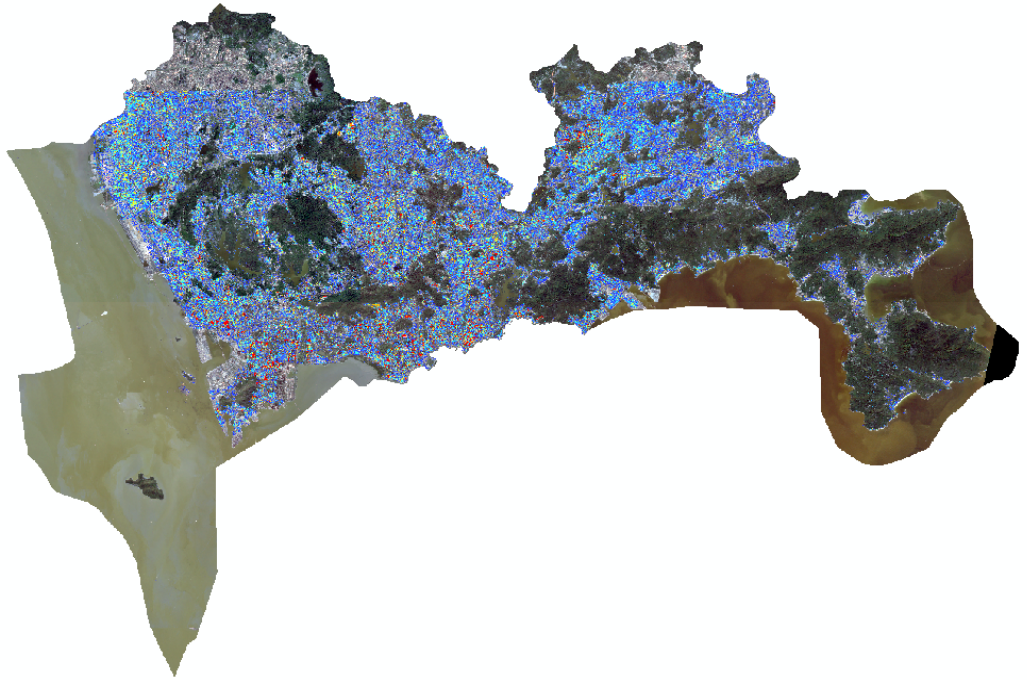
DSM(30M)



NDVI >= 0.38



NDWI == 0



DEM DSM NDVI mask NDWI mask

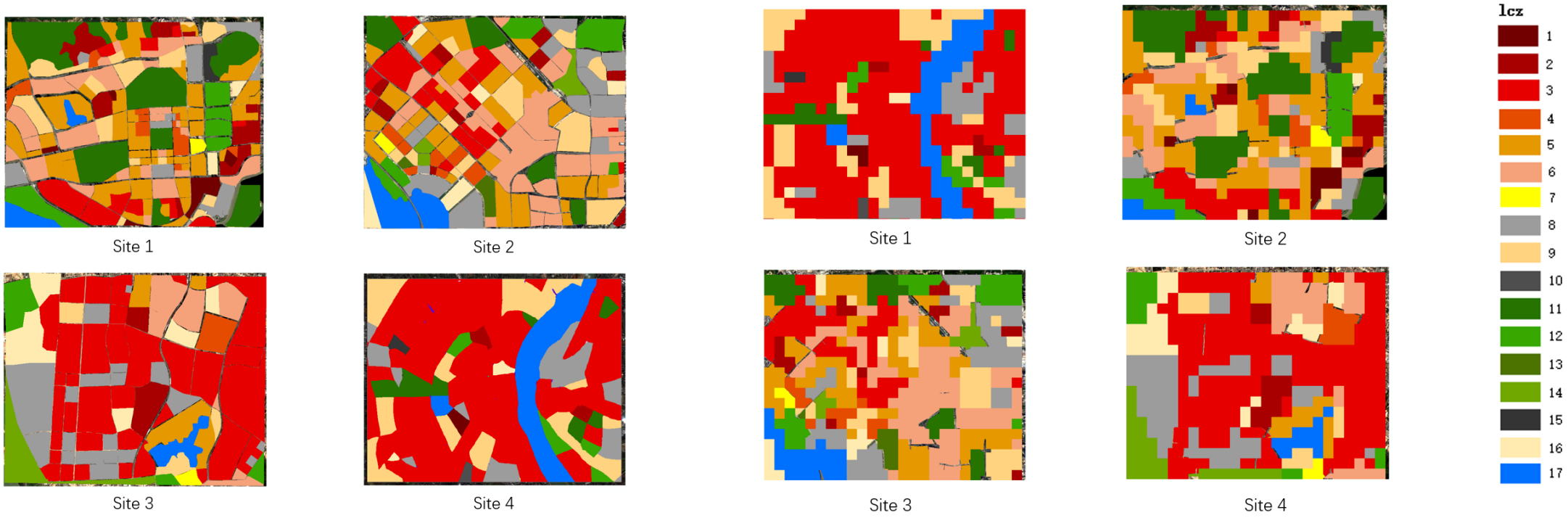
Building elevation data

Contents

Result

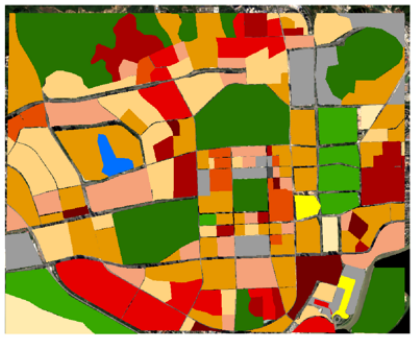
- Reference Data

1. Combining high-resolution google earth images and building elevation data, we manually labeled the study area. Use the labeled data as reference data.
2. Resample the reference data to get the window-based reference data.

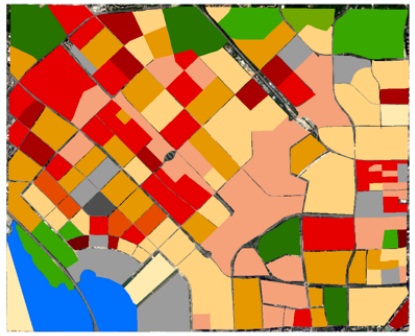


Result

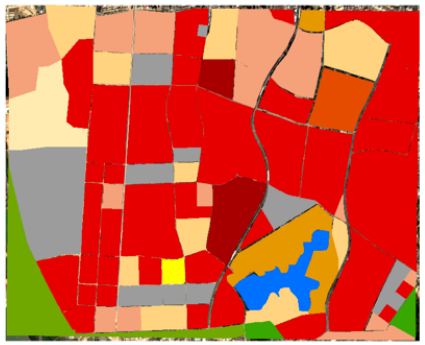
- Result Data
- Classification results based on Parcel-based method
- Classification results based on Window-based method



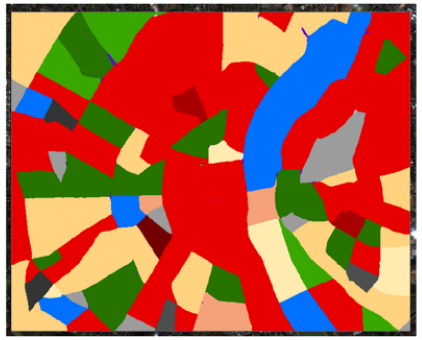
Site 1



Site 2

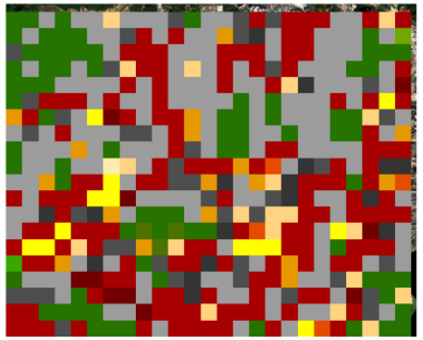


Site 3



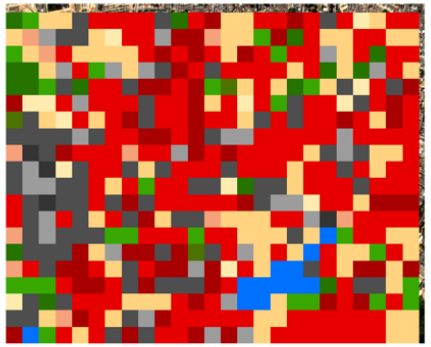
Site 4

Parcel-based

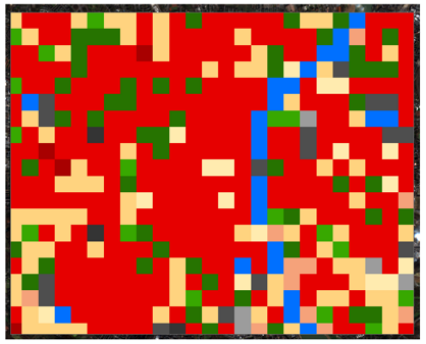


Site 1

Site 2

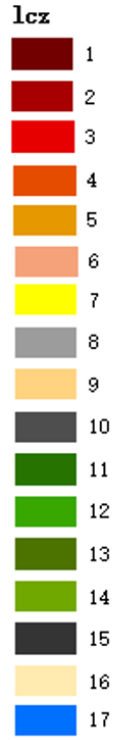


Site 3



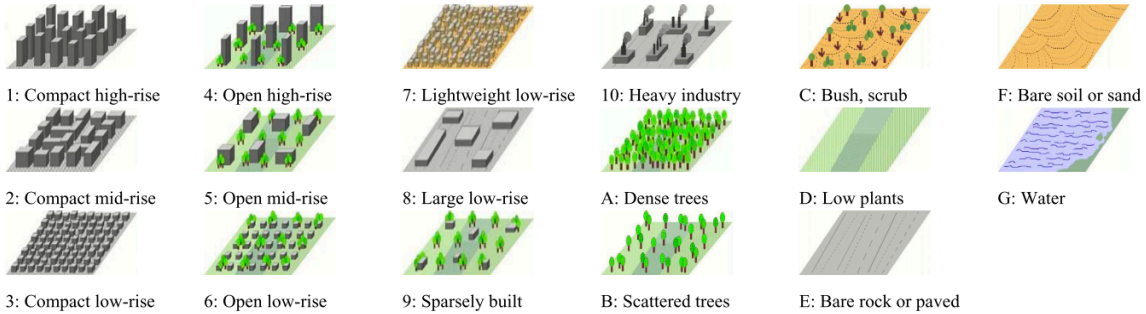
Site 4

Window-based



Result

- **Confusion matrix**
  - Classification errors concentrated in LCZ1-LCZ10
  - The errors of LCZ1 and LCZ4, LCZ2 and LCZ5, LCZ3 and LCZ6 are that vegetation information is not captured perfectly.
  - From the error of LCZ9,whether the buildings are regularly and orderly arranged is not sensitive in our classifier.



Parcel-based result

Reference

LCZ	1	2	3	4	5	6	7	8	9	10	A	B	C	D	E	F	G
1	**6**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	**23**	1	0	4	0	0	0	4	0	0	0	0	0	0	0	0
3	1	2	**90**	0	0	6	0	1	3	0	0	0	0	0	0	0	0
4	2	0	0	**15**	1	0	0	0	3	1	0	0	0	0	0	0	0
5	0	8	0	0	**80**	2	0	1	15	0	0	1	0	0	0	0	0
6	0	0	15	0	1	**52**	0	1	15	0	0	0	0	0	0	0	0
7	0	0	1	0	0	0	**1**	0	1	0	0	0	0	0	0	0	0
8	0	0	5	0	0	3	2	**35**	6	0	0	0	0	1	0	0	0
9	0	0	0	0	0	0	0	0	**28**	0	0	0	0	0	0	0	0
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A	0	0	0	0	0	0	0	0	0	0	**14**	0	0	0	0	0	0
B	0	0	0	0	0	1	0	0	0	0	0	**12**	0	0	0	0	0
C	0	0	0	0	0	0	0	0	2	0	0	1	**0**	0	0	0	0
D	0	0	1	0	0	1	0	0	0	1	0	0	0	**1**	0	0	0
E	0	0	0	0	0	0	0	1	0	0	0	0	0	0	**0**	0	0

Result

- **PA(Producer Accuracy), UA(User Accuracy)**

- LCZ10, LCZC and LCZE have no corresponding areas in our sites.

- LCZA – LCZG are natural surface without buildings. There are less samples in our sites.

- In all categories, the parcel-based method have higher UA and PA than the window-based method.

- Especially for LCZ1-LCZ10, which is difficult to classify, parcel-based method achieves high accuracy.

UA, PA of Different Types of LCZ in Sites

Study Area	UA		PA	
Split Method	Parcel	Window	Parcel	Window
LCZ1	1	0.076	0.667	0.083
LCZ2	0.719	0.228	0.676	0.062
LCZ3	0.874	0.438	0.783	0.399
LCZ4	0.682	0	1	0
LCZ5	0.748	0.041	0.93	0.588
LCZ6	0.619	0.018	0.8	0.111
LCZ7	0.333	0	0.67	0.308
LCZ8	0.673	0.105	0.9	0.089
LCZ9	1	0.327	0.35	0.128
LCZ10	-	-	-	-
LCZA	1	0.341	1	0.406
LCZB	0.923	0.056	0.857	0.074
LCZC	-	-	-	-
LCZD	0.25	0	0.5	0
LCZE	-	-	-	-
LCZF	0.5	0.06	0.857	0.088
LCZG	0.8	0.693	1	0.944
AA	**0.72**	**0.15**	**0.79**	**0.23**

Result

- OA(Overall Accuracy), AA(Average Accuracy)

- $OA = \frac{num.(Correctly\ classified\ units)}{num.(units)}$

- $AA = \frac{sum(accuracy\ of\ each\ category)}{num.(categories)}$

- OA and AA of the parcel-based method are maintained at around 0.75 on each site.

- The window-based method is unstable in our sites. OA and AA of the window-based method get around 0.2 on site1,site2 and site3. Although it achieves 0.47 on site4, which cannot reach the application requirement.

Accuracy Assessment of Different Methods

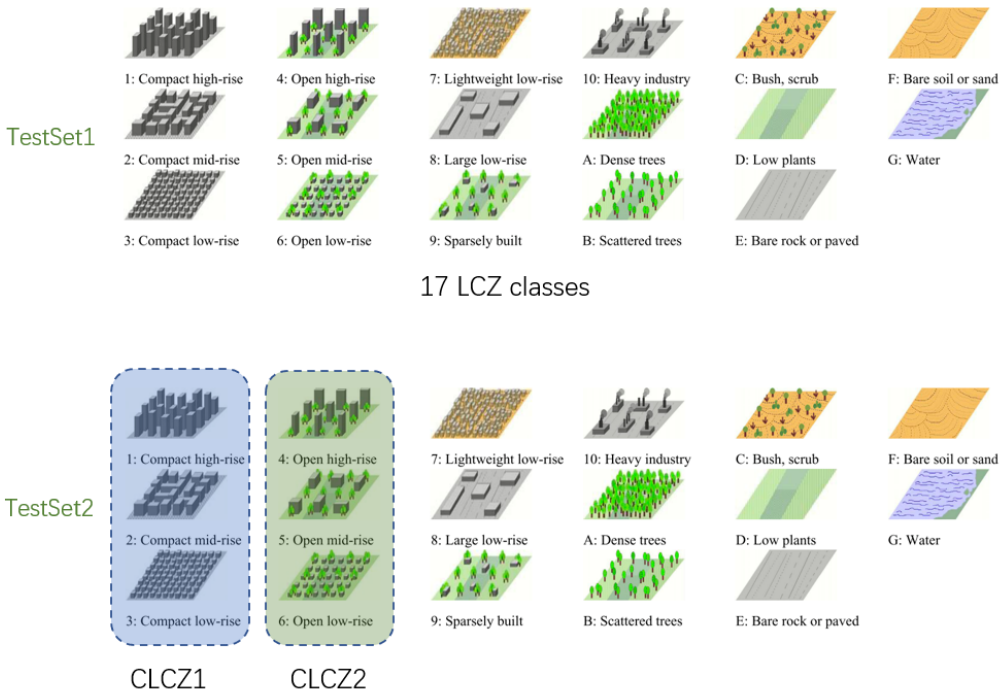
Study area	OA		AA	
Split Method	Parcel	Window	Parcel	Window
Site1	0.77	0.14	0.77	0.14
Site2	0.71	0.17	0.71	0.18
Site3	0.78	0.29	0.74	0.15
Site4	0.75	0.47	0.75	0.47

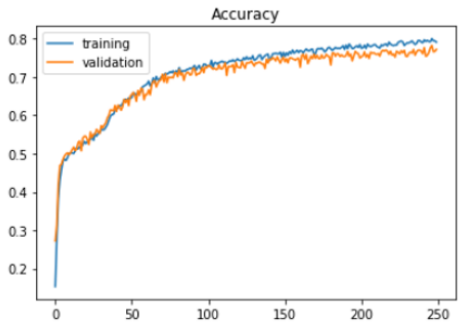
Contents

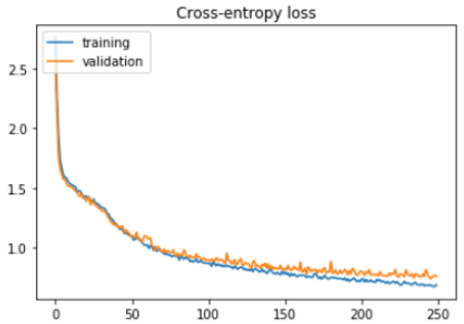
Discussion

- Simulation 1

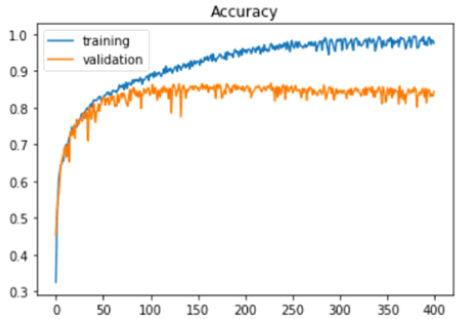
- Examining the effect of combined data sets on training effectiveness
- TestSet2 got a higher accuracy rate but overfitting. Because the TestSet2 task is simpler than the TestSet1, the over-complex model will cause overfitting. We end the training early and add regularization to reduce overfitting.

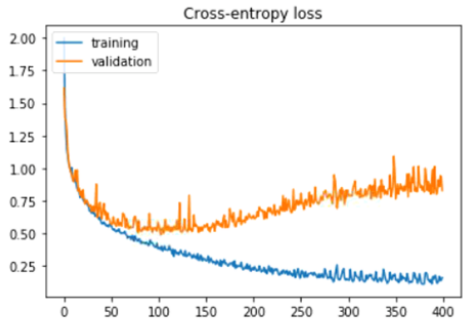






TestSet1





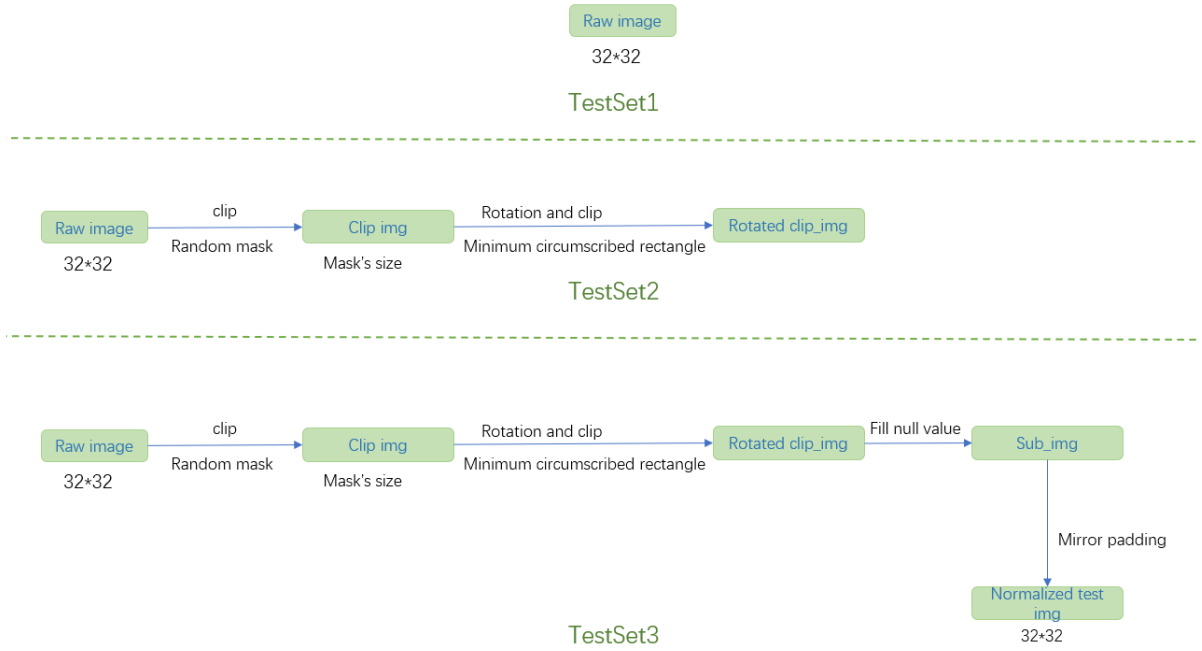
TestSet2

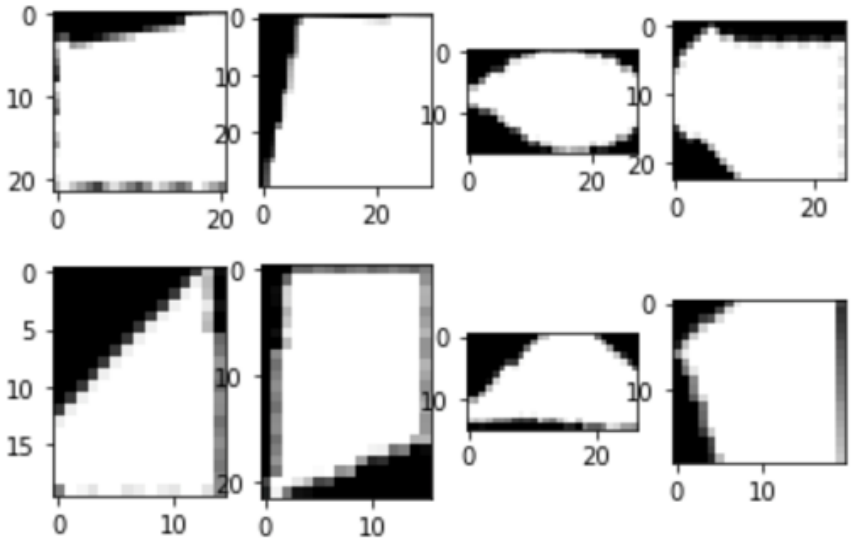
(LCZ 1,LCZ 2 and LCZ 3 as CLCZ1)+ (LCZ 4,LCZ 5 and LCZ 6 as CLCZ2)+ (the rest) = 13 LCZ classes

Discussion

- Simulation 2

- Examining the effect of Image-Normalization process.
- For TestSet1, we use original images as validation data.
- For TestSet2, original images cropped by mask without any process as validation data.
- For TestSet3, TestSet2 data preprocessed by Image-Normalization is used as validation data.

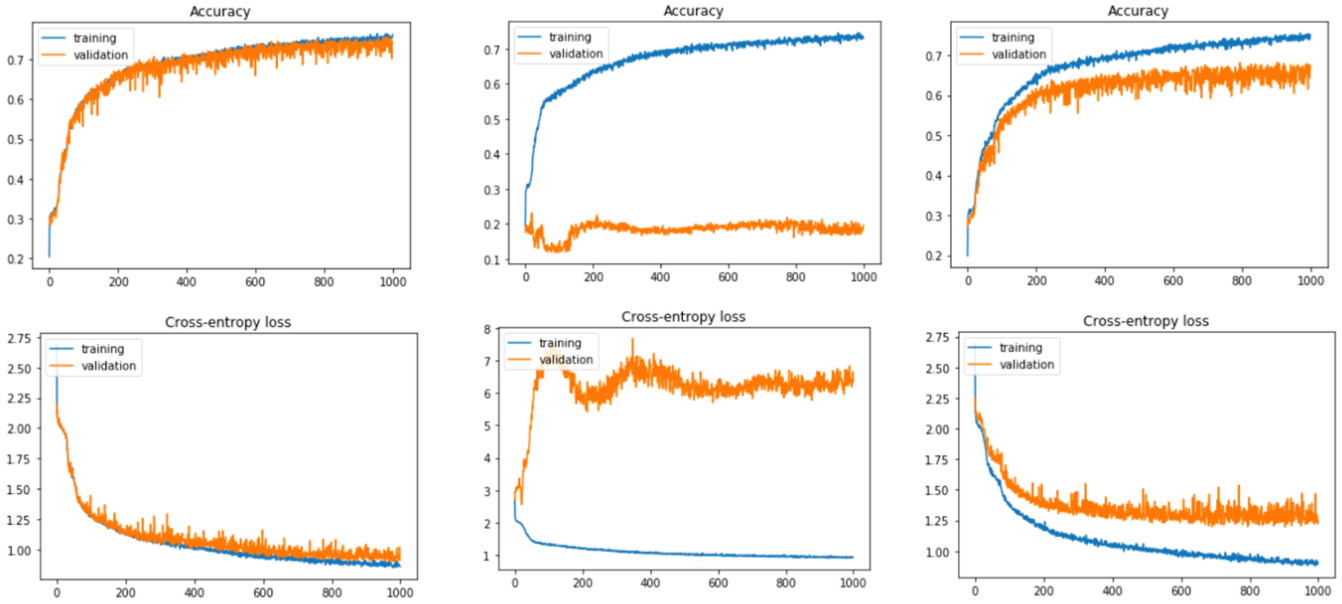




Discussion

- Simulation 2

- By comparing the results of TestSet1 and TestSet3, we found that the accuracy of TestSet3 has decreased. There are some information loss after cropping and filling.
- By comparing the results of TestSet2 and TestSet3, the effect of image training without Image-Normalization is too bad.
- Image-Normalization module try to recover image information which is necessary.



TestSet1 TestSet2 TestSet3

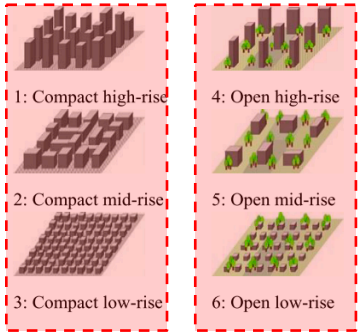
Discussion

- Advantages

- The road network divides the city into different functional areas. The same functional area contains similar surface characteristics. This helps our LCZ classification.

- In the definition of LCZ, LCZ is described as an area with the same climatic characteristics, and regular segmentation will destroy the completeness of LCZ.

- The secondary classifier improves the accuracy of the categories that are highly sensitive to building height information.



LCZ	1	2	3	4	5	6
1	**6**	0	0	0	0	0
2	0	**23**	1	0	4	0
3	1	2	**90**	0	0	6
4	2	0	0	**15**	1	0
5	0	8	0	0	**80**	2
6	0	0	15	0	1	**52**

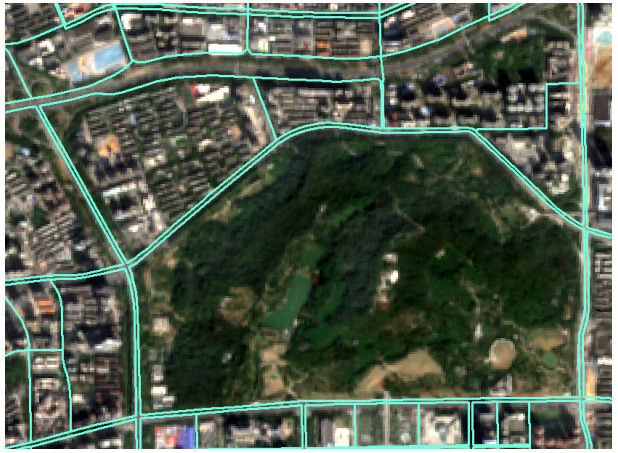
Confusion matrix of LCZ1-LCZ6

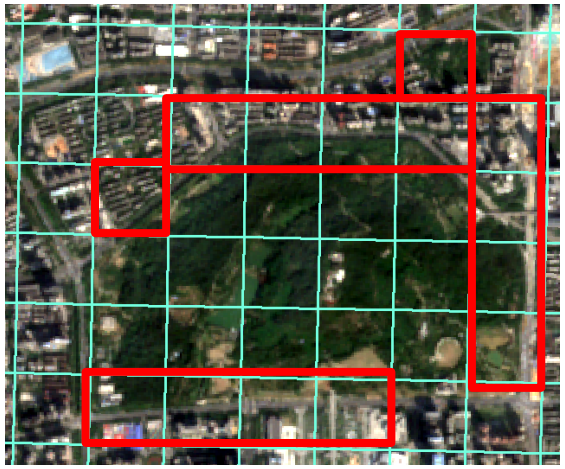
Discussion

- Advantages

- Road network segmentation reduces the impact of mixed units. Using a fixed grid segmentation will produce a large number of mixed units.

- In the method exploration stage, selecting high-purity images for training has achieved good classification results. However, in practical applications, the classification accuracy is greatly reduced due to the influence of mixed pixels.





Discussion

- Limitations

- Relatively more LCZ9 classification errors indicate that our classification model is insensitive to whether urban buildings are regularly distributed.

- The migration ability of the model

- From the results of simulation2, it is found that although the Image-normalization module uses the original image for recovery, there is still some loss of image information. Here are some ideas worth trying:

  a. Combined with PCA to crop and fill the segmented image.

  b. Use Generative Adversarial Networks (GAN) to synthesize and repair the information of segmented images.

Thank you !

A Parcel-Based Local Climate Zone Classification

Method Using CNN Model

June 2020