



# Deep learning-based approach for landform classification from the integrated data sources of digital elevation model and imagery

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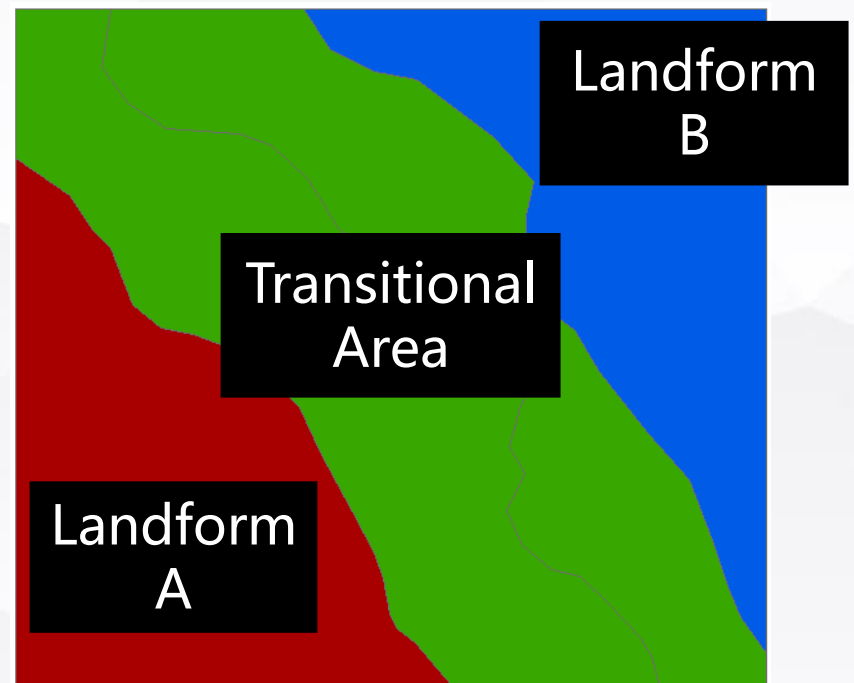
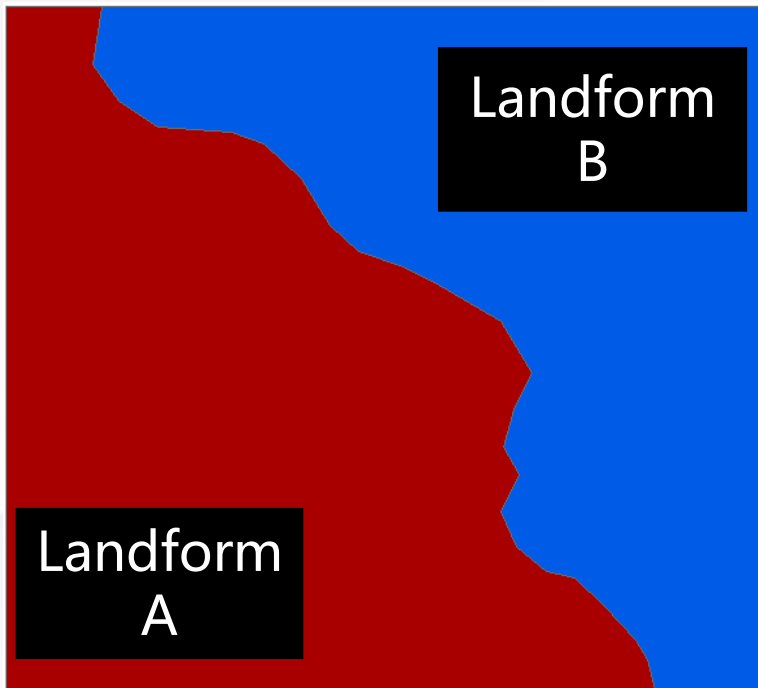
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# Classification of transitional landform areas

- The gradual changing surface leads to similar terrain features, and increase the difficulty to obtain the clear boundary and classification results.
- It is difficult to do quantitative analysis in these areas.



# Target Transformation

“Area”



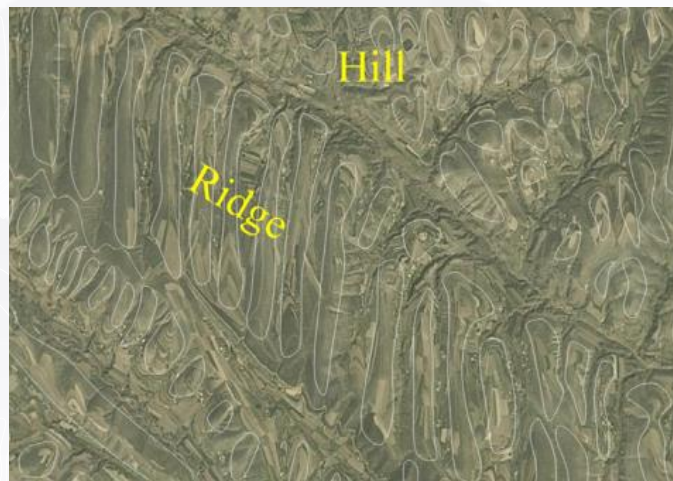
“Unit”



(which can indicate the stage of landform development)

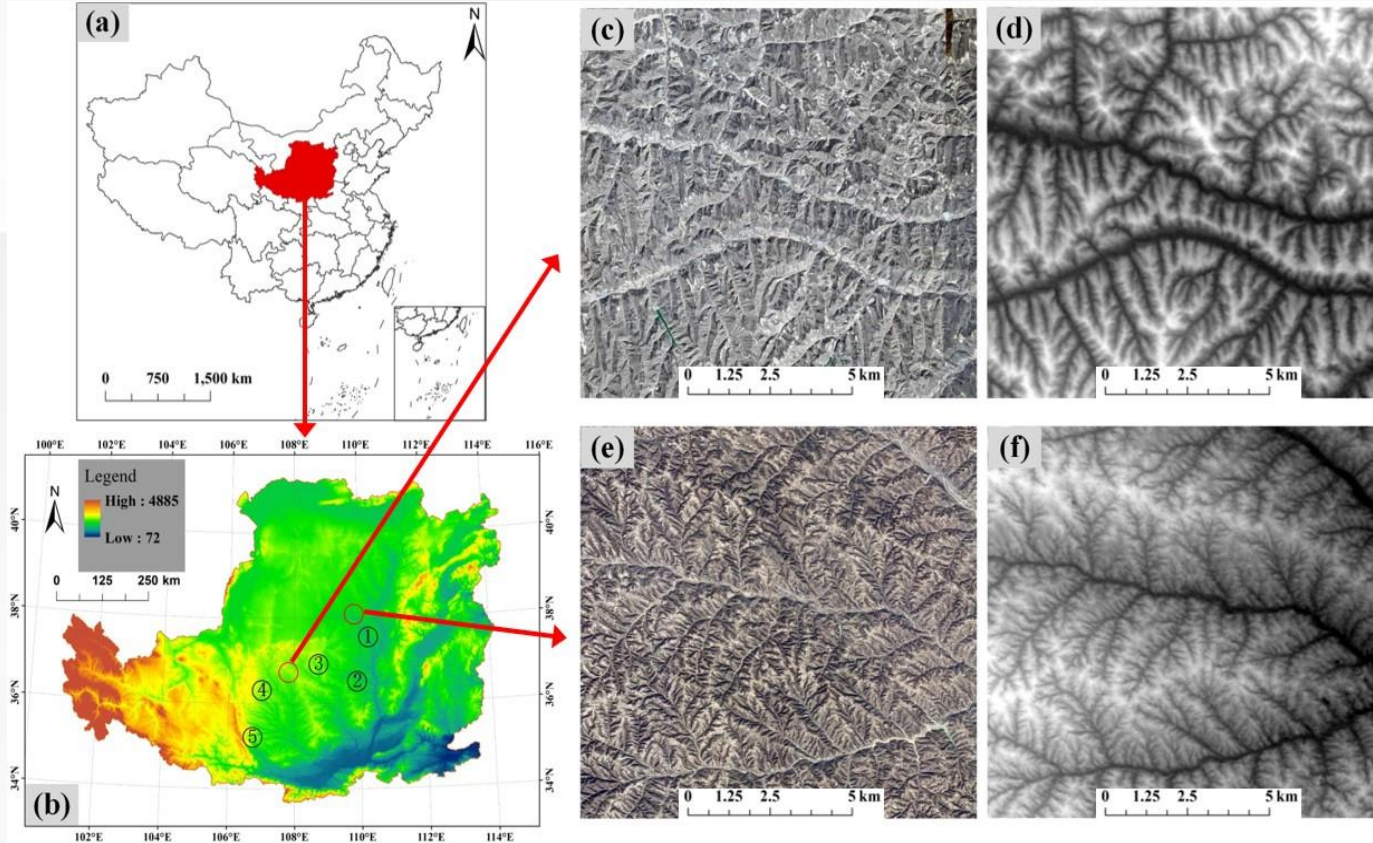
**Expected  
Result**

(manually drawing)



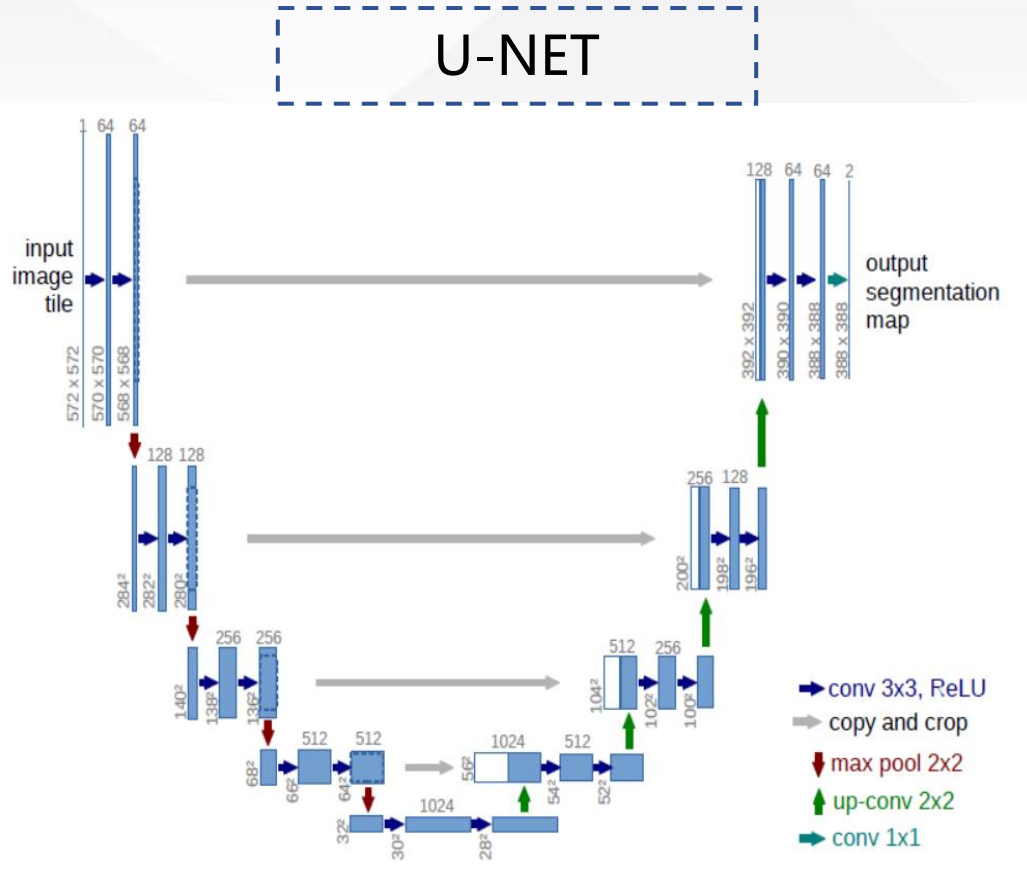
**Loess landform area**  
In this study, we only discuss in the Loess landform area.

# Study Area



1. Training data came from 5 areas marked by black circle and number (Fig (b)).
2. Areas marked by red circle (Fig (b)) were used as the test areas.
3. Fig. (c), (e) are imagery of test areas, and (d), (f) are the corresponding DEMs.

# Method

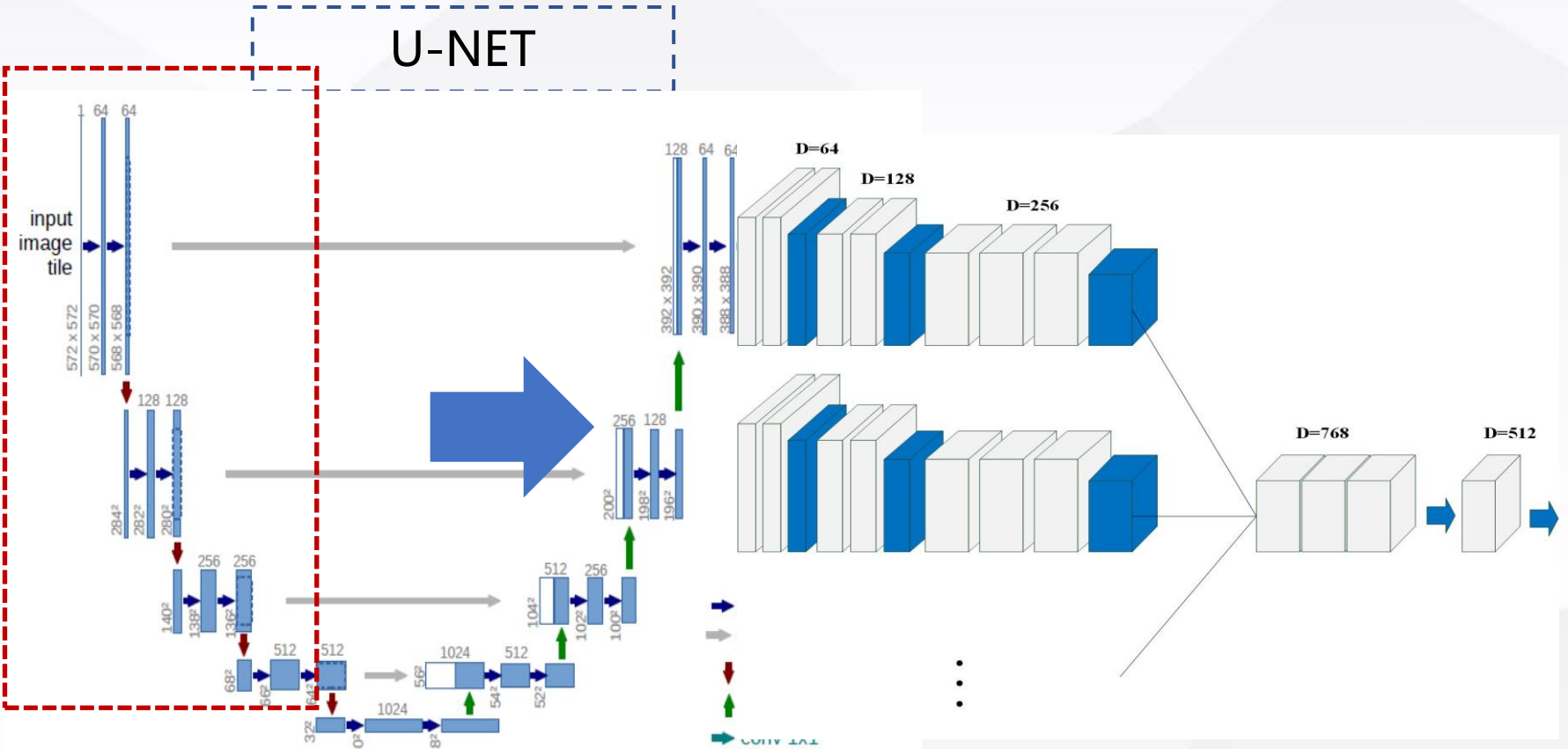


(Ronneberger et al., 2015).

**data augmentation by applying elastic deformation**

1. It can help to generate more training data on the basis of the existing data, which means this network is suitable to the small training dataset.
2. It can simulate a part of unregular and unpredictable landform changes and enhance the classification ability of the network.

# Method



(Ronneberger et al., 2015).

Modify the structure of input layer.  
The modified input structure can be  
used to receive multiple data at the  
same time.

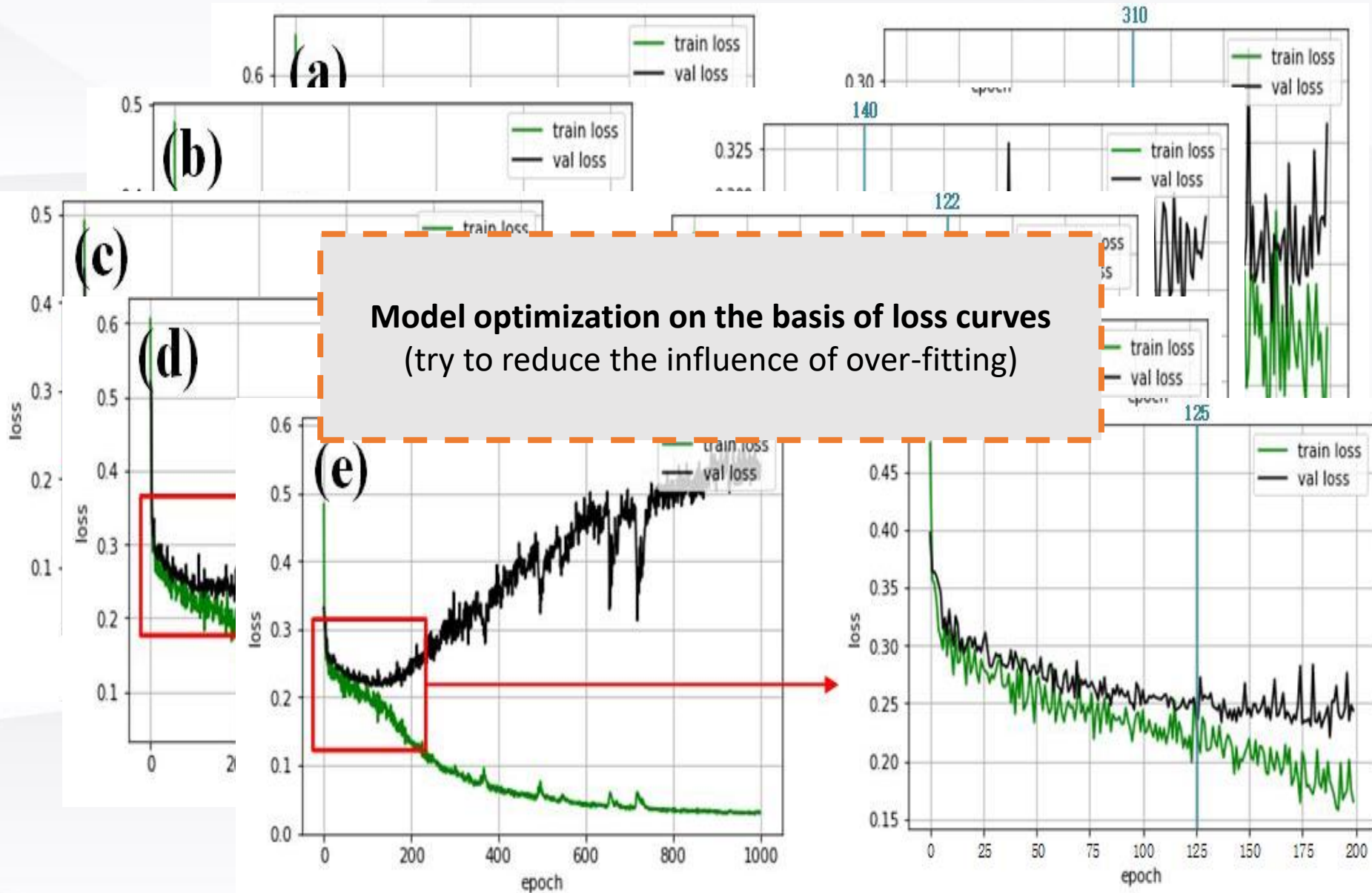
# Method

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| Case Number | Data                  |
|-------------|-----------------------|
| Case 1      | Imagery               |
| Case 2      | Imagery + DEM         |
| Case 3      | Imagery + DEM+ Aspect |
| Case 4      | Imagery + DEM + Slope |
| Case 5      | All data              |

Design different data combination to discuss the influence of training dataset.

# Model optimization

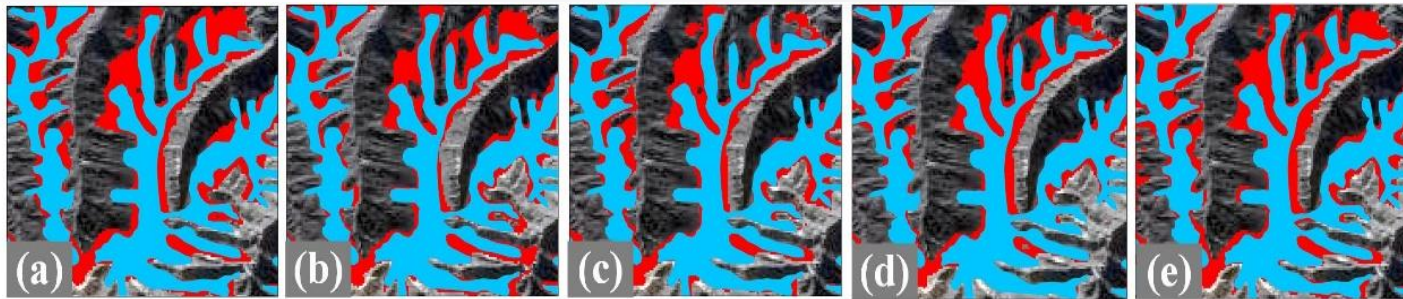




# Accuracy Assessment

| Loess Hill | Precision | Recall | Overall Accuracy |
|------------|-----------|--------|------------------|
| Case 1     | 0.76      | 0.59   | 0.50             |
| Case 2     | 0.86      | 0.78   | 0.69             |
| Case 3     | 0.74      | 0.53   | 0.45             |
| Case 4     | 0.66      | 0.53   | 0.42             |
| Case 5     | 0.77      | 0.75   | 0.62             |

| Loess Ridge | Precision | Recall | Overall Accuracy |
|-------------|-----------|--------|------------------|
| Case 1      | 0.63      | 0.76   | 0.52             |
| Case 2      | 0.82      | 0.85   | 0.71             |
| Case 3      | 0.59      | 0.77   | 0.50             |
| Case 4      | 0.66      | 0.81   | 0.57             |
| Case 5      | 0.77      | 0.82   | 0.66             |



Legend ■ Actual Boundary ■ Predicted Boundary

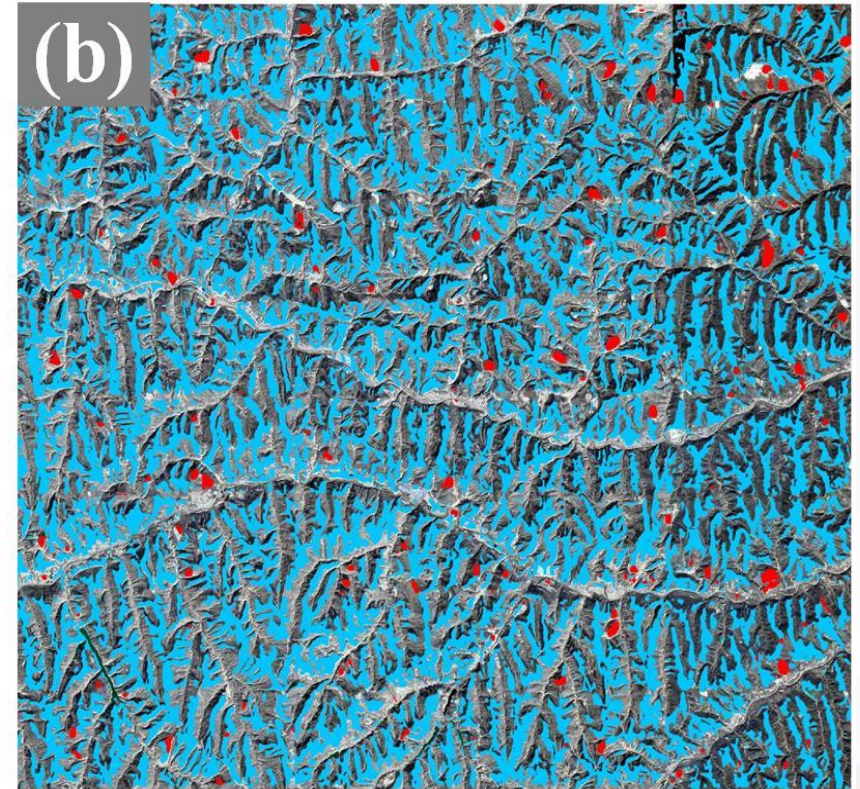
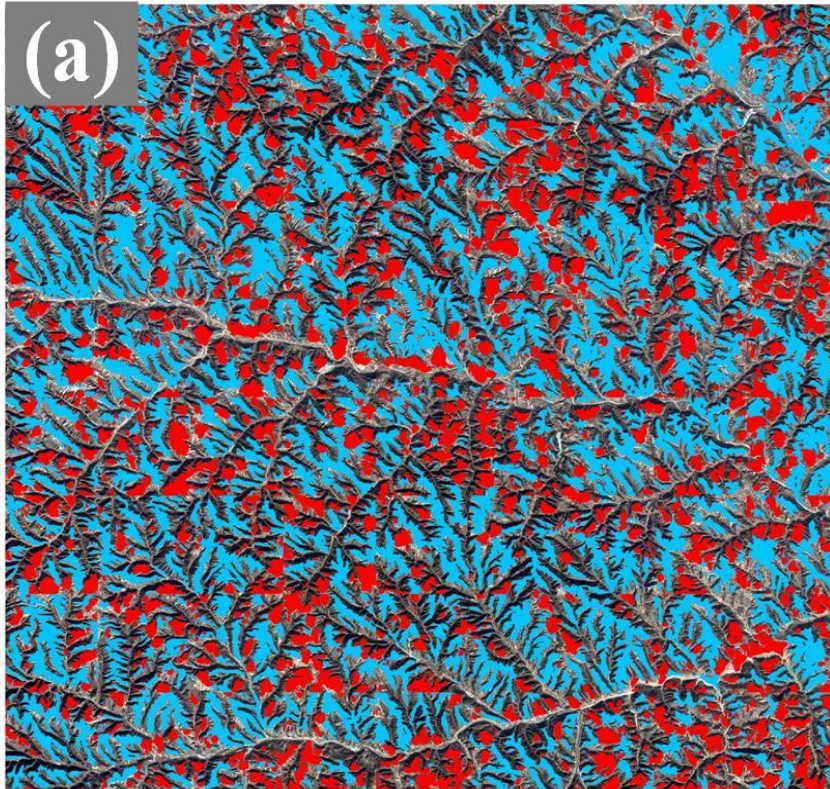
0 250 500 m





(a)-(e) respectively represent results of 5 case study with different data combinations.

# Results of test areas


More quantitative analyses can be completed based on the current result.



## Legend

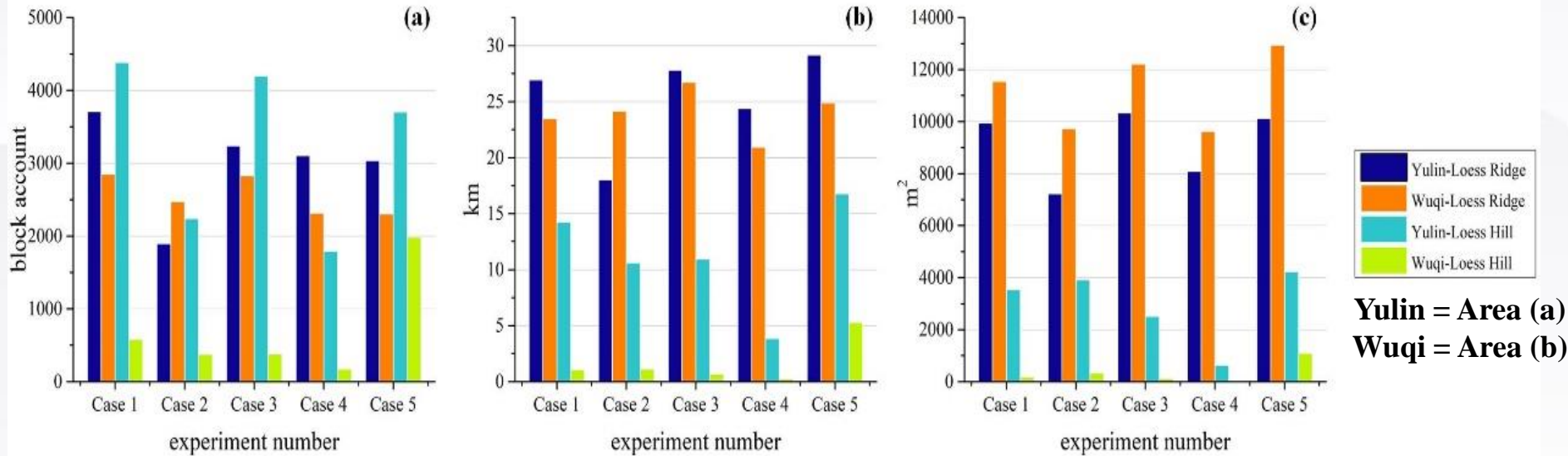
-  loess ridge
-  loess hill

0 1.5 3 6 km

A horizontal scale bar with four segments, labeled 0, 1.5, 3, and 6 km.

**(loess hill is a more mature landform unit and suffer more intense erosion compared with loess ridge)**

# Analysis



1. Area (a) contains more loess hills, which means Area (a) has a more mature landform development stage than that of Area (b).
2. The block number of loess ridge in Area (a) is more than that in Area (b) (Fig. a), while the total area of loess ridge in Area (a) is less than that in Area (b) (Fig. c). This phenomenon indicates that the surface of Area (a) is more broken than surface of Area (b).

# Conclusions

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1. The DL method was used for landform classification and demonstrates good performance.
2. Constructing several data combinations and the accuracies based on the different data layers were assessed.
3. On the basis of the comparison with the RF approach, the performance of the DL approach is better than the RF approach.
4. The final results can indicate the stage of landform development.

**Outlook:** if it can be used in other landform areas?



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Thanks!

