PROBLEM STATEMENT

- Comparative analysis to find the most optimized method in finding the change in multi temporal satellite images.
- Classification of satellite images into a desired labeled dataset.

Model training-(Classification) (Supervised Learning) ResNet50 Model

```
Epoch 1/10
101/101 [==============================] - 2469s 24s/step - loss: 1.6674 - accuracy: 0.6438 - val_loss: 0.9265 - val_accuracy: 0.6335
Epoch 2/10
101/101 [==============================] - 631s 6s/step - loss: 0.9933 - accuracy: 0.6692 - val_loss: 1.0030 - val_accuracy: 0.6907
Epoch 3/10
101/101 [==============================] - 626s 6s/step - loss: 0.7909 - accuracy: 0.6962 - val_loss: 0.8407 - val_accuracy: 0.6683
Epoch 4/10
101/101 [==============================] - 621s 6s/step - loss: 0.7274 - accuracy: 0.7068 - val_loss: 1.0872 - val_accuracy: 0.6994
Epoch 5/10
101/101 [==============================] - 605s 6s/step - loss: 0.6406 - accuracy: 0.7316 - val_loss: 0.6237 - val_accuracy: 0.7826
Epoch 6/10
101/101 [==============================] - 611s 6s/step - loss: 0.7361 - accuracy: 0.7148 - val_loss: 0.7497 - val_accuracy: 0.6211
Epoch 7/10
101/101 [==============================] - 616s 6s/step - loss: 0.8750 - accuracy: 0.6922 - val_loss: 0.7452 - val_accuracy: 0.7031
Epoch 8/10
101/101 [==============================] - 595s 6s/step - loss: 0.7010 - accuracy: 0.7154 - val_loss: 0.9345 - val_accuracy: 0.7665
Epoch 9/10
101/101 [==============================] - 591s 6s/step - loss: 0.6692 - accuracy: 0.7393 - val_loss: 0.8542 - val_accuracy: 0.7043
Epoch 10/10
101/101 [==============================] - 610s 6s/step - loss: 0.6987 - accuracy: 0.7278 - val_loss: 0.4850 - val_accuracy: 0.7727
```

ResNet50 model with optimiser(adam)

```
history = model.fit(train_dataset, validation_data=test_dataset, epochs=10, batch_size=32)
```

```
Epoch 1/10
101/101 [==============================] - 632s 6s/step - loss: 1.2980 - accuracy: 0.6631 - val_loss: 1.5225 - val_accuracy: 0.6484
Epoch 2/10
101/101 [==============================] - 351s 3s/step - loss: 0.8470 - accuracy: 0.6913 - val_loss: 0.9988 - val_accuracy: 0.7006
Epoch 3/10
101/101 [==============================] - 351s 3s/step - loss: 0.6660 - accuracy: 0.7387 - val_loss: 0.6026 - val_accuracy: 0.7739
Epoch 4/10
101/101 [==============================] - 350s 3s/step - loss: 0.6367 - accuracy: 0.7418 - val_loss: 0.8202 - val_accuracy: 0.6994
Epoch 5/10
101/101 [==============================] - 349s 3s/step - loss: 0.6299 - accuracy: 0.7443 - val_loss: 0.5192 - val_accuracy: 0.8050
Epoch 6/10
101/101 [==============================] - 352s 3s/step - loss: 0.5493 - accuracy: 0.7743 - val_loss: 0.4986 - val_accuracy: 0.7553
Epoch 7/10
101/101 [==============================] - 353s 3s/step - loss: 0.5506 - accuracy: 0.7855 - val_loss: 0.7973 - val_accuracy: 0.7776
Epoch 8/10
101/101 [==============================] - 352s 3s/step - loss: 0.5611 - accuracy: 0.7932 - val_loss: 0.6385 - val_accuracy: 0.7565
Epoch 9/10
101/101 [==============================] - 357s 4s/step - loss: 0.4634 - accuracy: 0.8180 - val_loss: 0.5272 - val_accuracy: 0.7665
Epoch 10/10
101/101 [==============================] - 352s 3s/step - loss: 0.4975 - accuracy: 0.8149 - val_loss: 0.5434 - val_accuracy: 0.7901
```

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DenseNet model (without optimiser)

```
print("Total time taken by the model:", total_time, "seconds")
```

```
Epoch 1/10
101/101 [==============================] - 2688s 26s/step - loss: 0.7034 - accuracy: 0.7415 - val_loss: 0.4657 - val_accuracy: 0.8211
Epoch 2/10
101/101 [==============================] - 11s 106ms/step - loss: 0.4126 - accuracy: 0.8149 - val_loss: 0.4958 - val_accuracy: 0.8224
Epoch 3/10
101/101 [==============================] - 11s 105ms/step - loss: 0.3202 - accuracy: 0.8571 - val_loss: 0.6496 - val_accuracy: 0.7826
Epoch 4/10
101/101 [==============================] - 11s 106ms/step - loss: 0.2427 - accuracy: 0.9014 - val_loss: 0.9986 - val_accuracy: 0.7739
Epoch 5/10
101/101 [==============================] - 10s 102ms/step - loss: 0.1984 - accuracy: 0.9194 - val_loss: 0.9814 - val_accuracy: 0.7540
Epoch 6/10
101/101 [==============================] - 11s 109ms/step - loss: 0.1550 - accuracy: 0.9402 - val_loss: 1.4511 - val_accuracy: 0.7466
Epoch 7/10
101/101 [==============================] - 11s 106ms/step - loss: 0.1294 - accuracy: 0.9507 - val_loss: 1.0420 - val_accuracy: 0.7354
Epoch 8/10
101/101 [==============================] - 11s 106ms/step - loss: 0.1147 - accuracy: 0.9616 - val_loss: 1.2843 - val_accuracy: 0.7540
Epoch 9/10
101/101 [==============================] - 11s 105ms/step - loss: 0.0930 - accuracy: 0.9671 - val_loss: 1.8285 - val_accuracy: 0.7217
Epoch 10/10
101/101 [==============================] - 11s 105ms/step - loss: 0.0855 - accuracy: 0.9699 - val_loss: 1.9735 - val_accuracy: 0.6969
Total time taken by the model: 2838.1581342220306 seconds
```

DenseNet model (with optimiser)

```
Epoch 1/10
101/101 [==============================] - 802s 8s/step - loss: 0.5626 - accuracy: 0.7616 - val_loss: 0.4111 - val_accuracy: 0.8037
Epoch 2/10
101/101 [==============================] - 11s 105ms/step - loss: 0.3744 - accuracy: 0.8292 - val_loss: 0.4154 - val_accuracy: 0.8273
Epoch 3/10
101/101 [==============================] - 10s 101ms/step - loss: 0.2885 - accuracy: 0.8723 - val_loss: 0.5264 - val_accuracy: 0.7925
Epoch 4/10
101/101 [==============================] - 10s 103ms/step - loss: 0.2233 - accuracy: 0.9086 - val_loss: 0.8865 - val_accuracy: 0.7627
Epoch 5/10
101/101 [==============================] - 10s 100ms/step - loss: 0.1777 - accuracy: 0.9275 - val_loss: 0.6794 - val_accuracy: 0.7590
Epoch 6/10
101/101 [==============================] - 10s 99ms/step - loss: 0.1455 - accuracy: 0.9473 - val_loss: 0.8133 - val_accuracy: 0.7379
Epoch 7/10
101/101 [==============================] - 10s 100ms/step - loss: 0.1155 - accuracy: 0.9551 - val_loss: 1.0163 - val_accuracy: 0.7578
Epoch 8/10
101/101 [==============================] - 10s 100ms/step - loss: 0.0818 - accuracy: 0.9709 - val_loss: 1.0706 - val_accuracy: 0.7839
Epoch 9/10
101/101 [==============================] - 11s 104ms/step - loss: 0.0768 - accuracy: 0.9715 - val_loss: 1.2101 - val_accuracy: 0.6832
Epoch 10/10
101/101 [==============================] - 10s 100ms/step - loss: 0.0690 - accuracy: 0.9771 - val_loss: 1.2956 - val_accuracy: 0.7031
Total time taken by the model: 912.7276697158813 seconds
```

Inception resnet (without optimizer)

```
Epoch 1/10
102/102 [==============================] - 1310s 13s/step - loss: 1.5030 - accuracy: 0.7010 - val_loss: 0.4473 - val_accuracy: 0.8463
Epoch 2/10
102/102 [==============================] - 22s 218ms/step - loss: 0.4986 - accuracy: 0.7891 - val_loss: 0.4059 - val_accuracy: 0.8315
Epoch 3/10
102/102 [==============================] - 22s 213ms/step - loss: 0.3588 - accuracy: 0.8476 - val_loss: 0.5111 - val_accuracy: 0.8265
Epoch 4/10
102/102 [==============================] - 22s 215ms/step - loss: 0.2808 - accuracy: 0.8878 - val_loss: 0.5334 - val_accuracy: 0.8030
Epoch 5/10
102/102 [==============================] - 23s 221ms/step - loss: 0.2053 - accuracy: 0.9246 - val_loss: 0.7353 - val_accuracy: 0.7819
Epoch 6/10
102/102 [==============================] - 24s 232ms/step - loss: 0.1765 - accuracy: 0.9419 - val_loss: 0.8133 - val_accuracy: 0.7807
Epoch 7/10
102/102 [==============================] - 23s 220ms/step - loss: 0.1416 - accuracy: 0.9539 - val_loss: 0.9409 - val_accuracy: 0.7943
Epoch 8/10
102/102 [==============================] - 23s 220ms/step - loss: 0.1268 - accuracy: 0.9576 - val_loss: 1.2106 - val_accuracy: 0.7794
Epoch 9/10
102/102 [==============================] - 23s 228ms/step - loss: 0.1100 - accuracy: 0.9666 - val_loss: 1.1047 - val_accuracy: 0.7968
Epoch 10/10
102/102 [==============================] - 23s 220ms/step - loss: 0.0955 - accuracy: 0.9706 - val_loss: 1.4298 - val_accuracy: 0.7770
Total time taken by the model: 1562.1777930259705 seconds
```

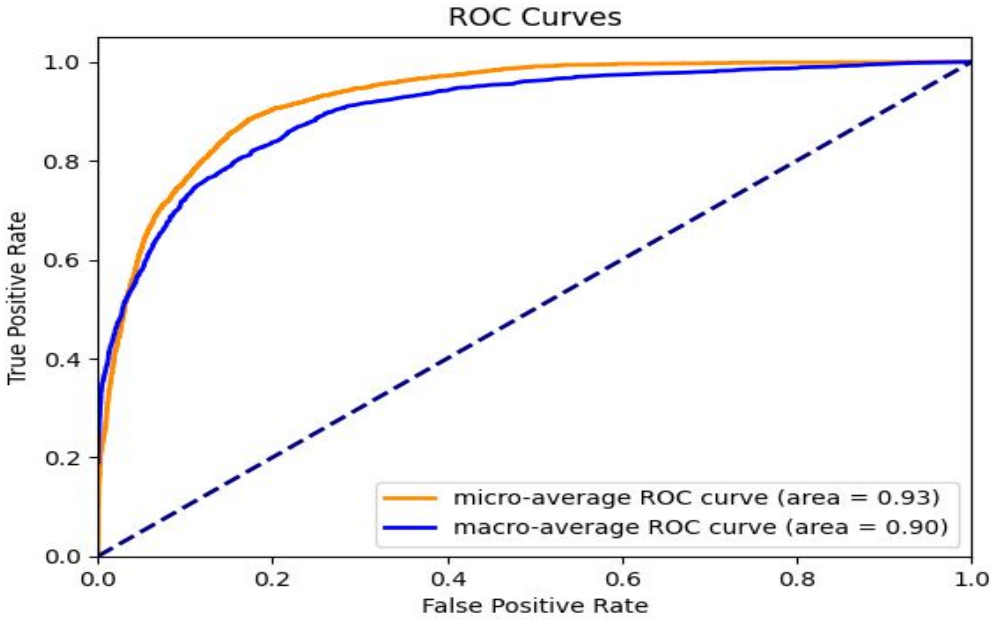
Inception resnet(with optimizer)

```
Epoch 1/10
102/102 [==============================] - 40s 254ms/step - loss: 1.0386 - accuracy: 0.7066 - val_loss: 0.5526 - val_accuracy: 0.7175
Epoch 2/10
102/102 [==============================] - 23s 221ms/step - loss: 0.4593 - accuracy: 0.7823 - val_loss: 0.4629 - val_accuracy: 0.8228
Epoch 3/10
102/102 [==============================] - 22s 216ms/step - loss: 0.3490 - accuracy: 0.8550 - val_loss: 0.6563 - val_accuracy: 0.7559
Epoch 4/10
102/102 [==============================] - 23s 225ms/step - loss: 0.2590 - accuracy: 0.8949 - val_loss: 0.5849 - val_accuracy: 0.7745
Epoch 5/10
102/102 [==============================] - 24s 235ms/step - loss: 0.2116 - accuracy: 0.9184 - val_loss: 0.6715 - val_accuracy: 0.7770
Epoch 6/10
102/102 [==============================] - 22s 217ms/step - loss: 0.2261 - accuracy: 0.9159 - val_loss: 0.7235 - val_accuracy: 0.7869
Epoch 7/10
102/102 [==============================] - 23s 222ms/step - loss: 0.1497 - accuracy: 0.9437 - val_loss: 0.8575 - val_accuracy: 0.7596
Epoch 8/10
102/102 [==============================] - 23s 227ms/step - loss: 0.1302 - accuracy: 0.9601 - val_loss: 1.0228 - val_accuracy: 0.7633
Epoch 9/10
102/102 [==============================] - 23s 220ms/step - loss: 0.0814 - accuracy: 0.9722 - val_loss: 1.0612 - val_accuracy: 0.7497
Epoch 10/10
102/102 [==============================] - 23s 222ms/step - loss: 0.1027 - accuracy: 0.9647 - val_loss: 1.1000 - val_accuracy: 0.7869
Total time taken by the model: 245.01757049560547 seconds
```

ResNet50 model metrics

	Without Optimizer	**With Optimizer(adam)**
Accuracy	0.764	**0.801**
Precision Score	0.900	**0.899**
Recall Score	0.856	**0.871**
F1 Score	0.865	**0.876**
Error Rate	0.235	**0.218**
Computational Time(in sec)	8121.742	**6101.651**

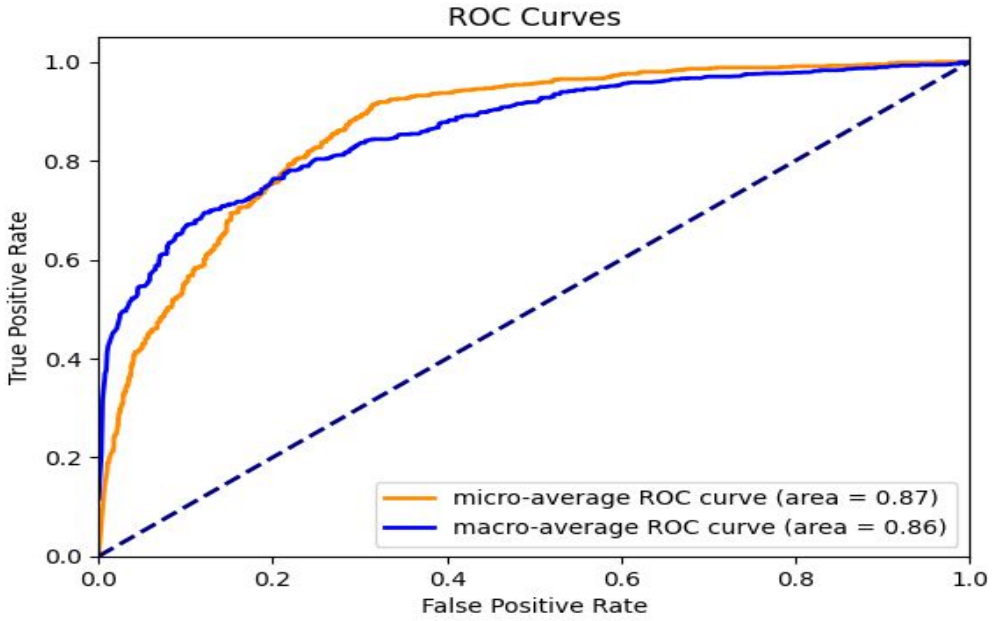
ROC Curve and AUC(ResNet50)



DenseNet model metrics

	Without Optimizer	**With Optimizer(adam)**
Accuracy	0.699	**0.720**
Precision Score	0.718	**0.871**
Recall Score	0.776	**0.843**
F1 Score	0.820	**0.836**
Error Rate	0.308	**0.300**
Computational Time(in secs)	2838.158	**912.727 seconds**

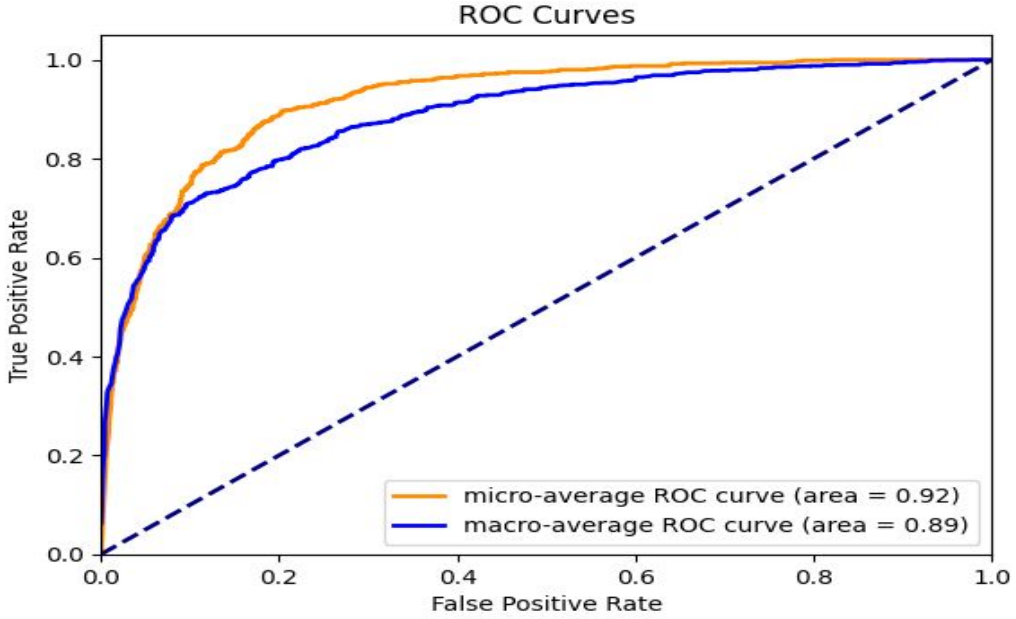
ROC Curve and AUC(DenseNet)



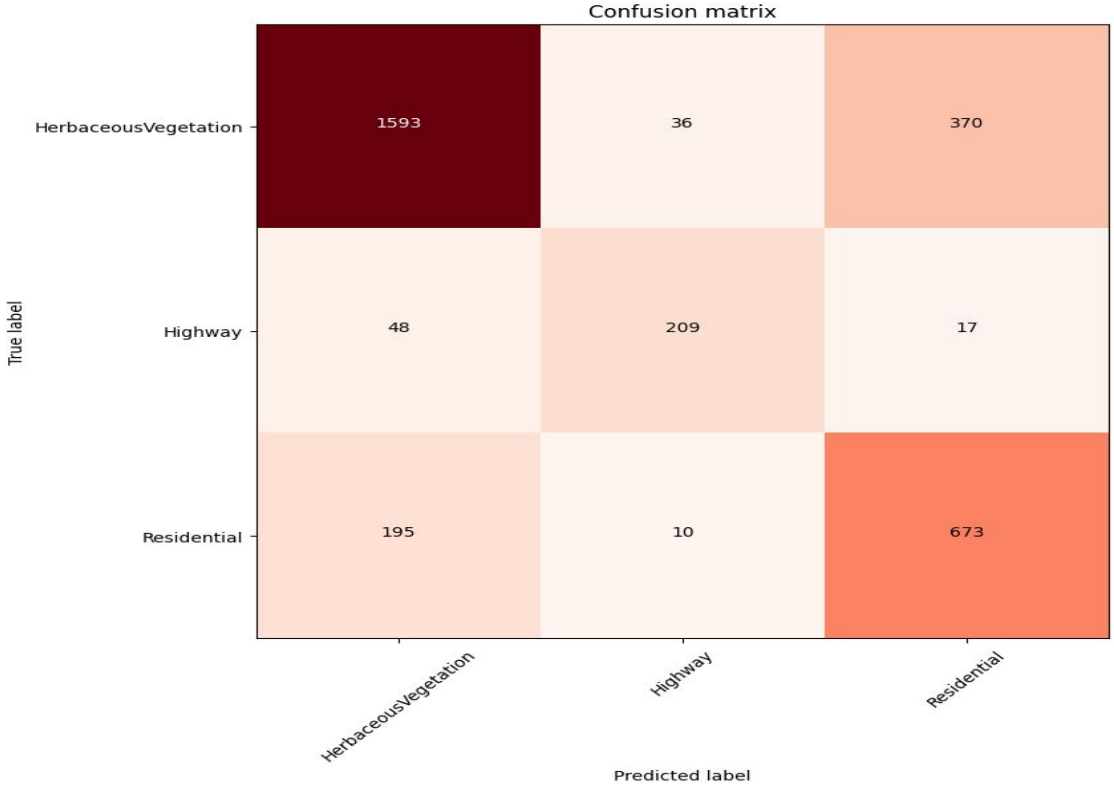
Inception resnet model metrics

	Without Optimizer	**With Optimizer(adam)**
Accuracy	0.777	**0.780**
Precision Score	0.842	**0.877**
Recall Score	0.828	**0.895**
F1 Score	0.865	**0.872**
Error Rate	0.277	**0.223**
Computational Time(in sec)	1562.177	**245.017**

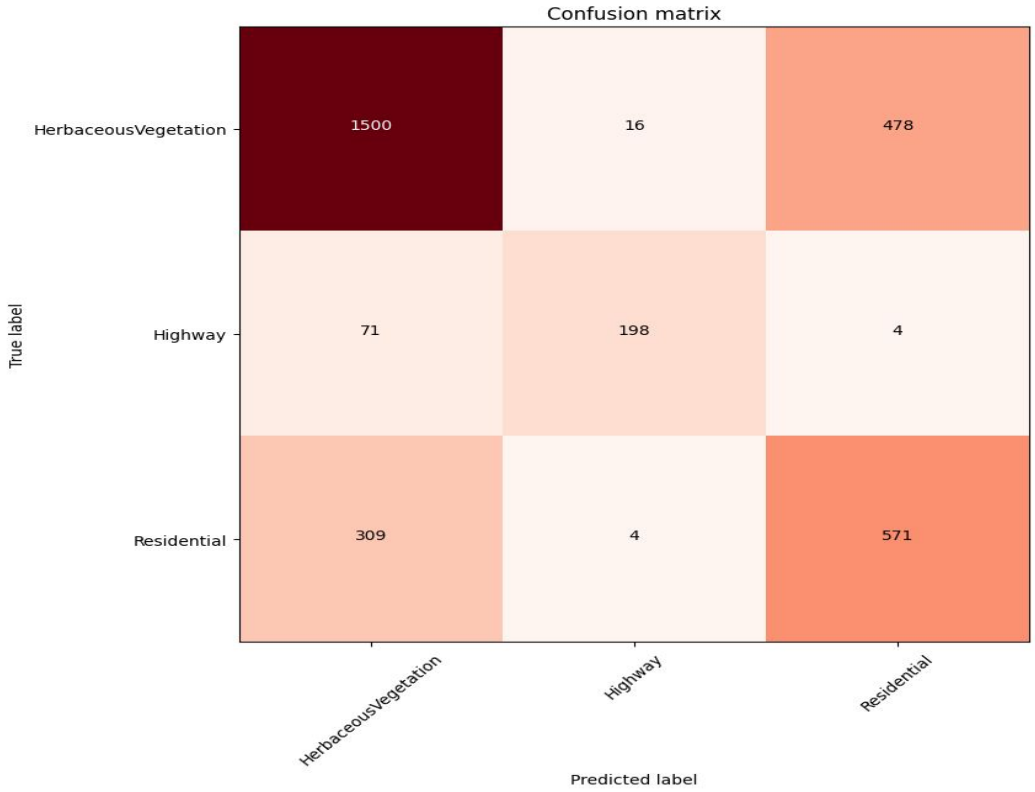
ROC Curve and AUC(Inception resnet)



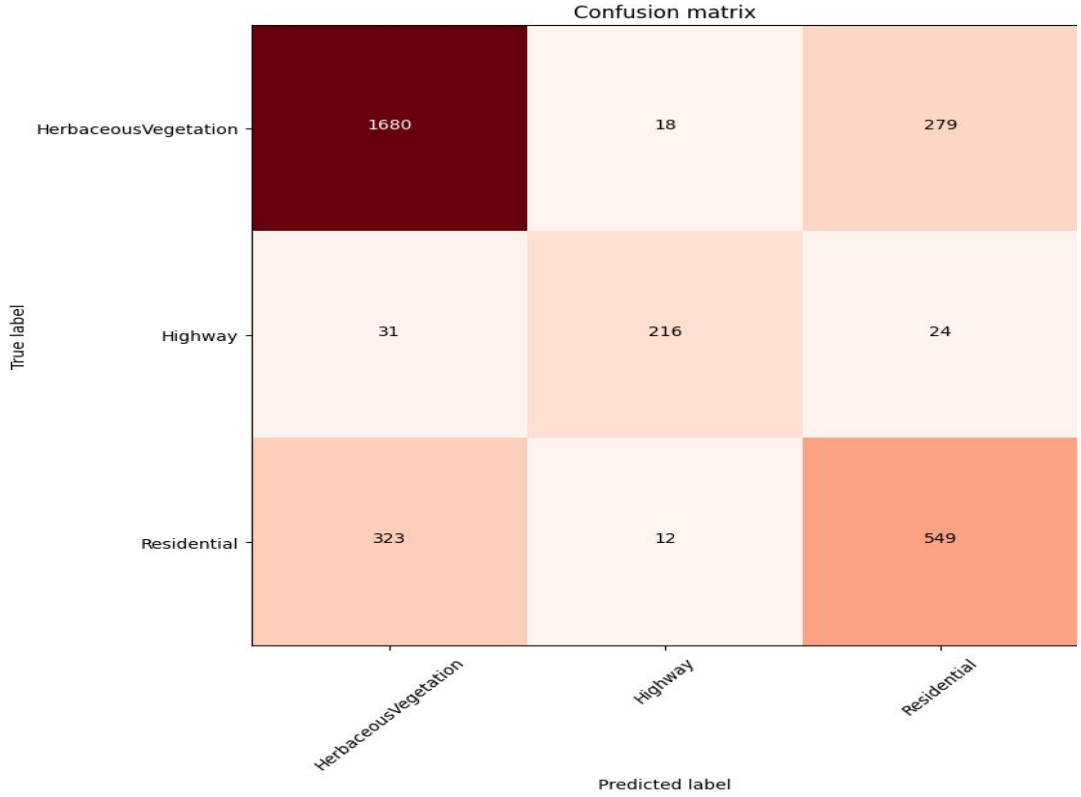
Confusion matrix (ResNet50)



Confusion matrix (DenseNet)



Confusion matrix (Inception)



RESULT ANALYSIS

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- The accuracies of 4 different clustering methods(K-Means, Mean Shift, DT-CWT, PSO) are compared using a table consisting of Pfa, Pma Pte as comparison metrics.
- In image clustering, the clustering method with least metric value is considered the most effective.
- In image classification, the input dataset is fed into a deep learning algorithm(ResNet model) for better effective and efficient classification.
- The accuracy at each epoch is varied and the final epoch's(10) accuracy of 81% is achieved.
- The accuracy follows an increasing trend when plotted against epoch.
- The loss over each epoch is significantly decreasing with increase in epoch.
- In the confusion matrix, the true positives(diagonal elements) are high implying the overall accuracy is maximum.

CONCLUSIONS

- From the histogram the PSO method has the least Pfa, Pte and Pma values, implying that it is the most effective method.
- In image classification, the accuracy is optimal considering the dataset size and number of parameters.
- The final change mask can also be used for image segmentation in order to quantify the individual changes.
- The classification output can be used in calculating land cover land change over the years.