Detecting deforestation in the Amazon rainforest using unsupervised K-medoids clustering on satellite imagery

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Introduction

Deforestation around the world has reached a critical level, causing irreversible damage to environmental sustainability that is contributing to climate change around the world. Widespread forest fires, from the Amazon Basin in Brazil, to the west coast of the United States, are raging all year-round. This notebook will allow us to detect deforested areas in the Brazilian Amazon rainforest, using satellite imagery.

Imports

```
%matplotlib inline

import pandas as pd
from datetime import datetime
from IPython.display import Image
from IPython.display import HTML
import matplotlib.pyplot as plt

from sklearn.preprocessing import MinMaxScaler
from datetime import datetime as dt

import arcgis
from arcgis.gis import GIS
from arcgis.learn import MLModel, prepare_tabulardata
from arcgis.raster import Raster

from fastai.vision import *
```

Connecting to ArcGIS

```
gis = GIS("home")
gis_enterp = GIS("https://pythonapi.playground.esri.com/portal", "arcgis_python", "amazing_arcgis_123")
```

Accessing & Visualizing datasets

Here, we use Sentinel-2 imagery, which has a high resolution of 10m and 13 bands. This imagery is accessed from the ArcGIS Enterprise portal, where it is sourced from the AWS collection.

```
# get image
s2 = gis.content.get('fd61b9e0c69c4e14bebd50a9a968348c')
sentinel = s2.layers[0]
s2
```

Sentinel-2 Views
Sentinel-2, 10m Multispectral, Multitemporal, 13-band images with visual renderings and indices. This Imagery Layer is sourced from the Sentinel-2 on AWS collections and is updated daily with new imagery. This layer is in beta release.
Imagery Layer by esri
Last Modified: May 28, 2020
21 comments, 1,513,352 views

Data Preparation

Define Area of Interest in the Amazon

The area of interest is defined using the four latitude and longitude values from a certain region of the Amazon rainforest where a considerable area of forest has been deforested, as can be seen from the images above.

```
#  extent in 3857 for amazon rainforest
amazon_extent = {
    "xmin": -6589488.51,
    "ymin": -325145.08,
    "xmax": -6586199.09,
    "ymax": -327024.74,
    "spatialReference": {"wkid": 3857}
}
```

Here, we select all the scenes from the sentinel imagery containing the area of interest for our study.

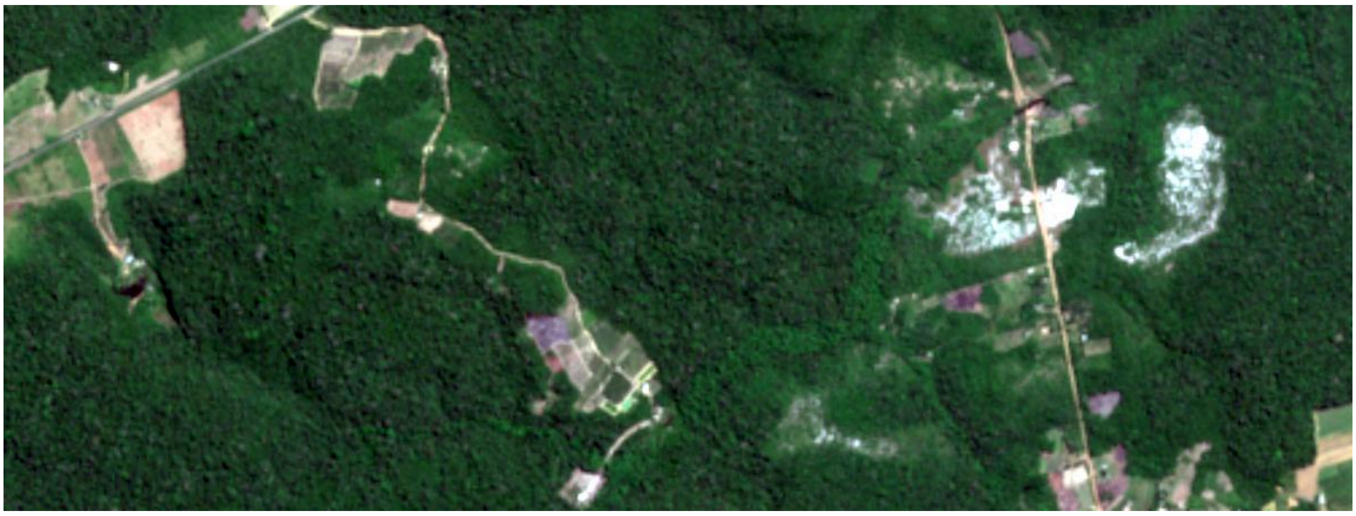
```
# The respective scene having the above area is selected
selected = sentinel.filter_by(where="(Category = 1) AND (cloudcover <=0.05)",
                              geometry=arcgis.geometry.filters.intersects(amazon_extent))
df = selected.query(out_fields="AcquisitionDate, GroupName, CloudCover, DayOfYear",
                   order_by_fields="AcquisitionDate").sdf

df['AcquisitionDate'] = pd.to_datetime(df['acquisitiondate'], unit='ms')
df
```

	objectid	acquisitiondate	groupname	cloudcover	dayofyear	SHAPE	AcquisitionDate
0	2459960	2020-06-21 14:23:37	20200621T142337_21MTS_0	0.0359	173	{"rings": [[[-6535992.3057, -302418.3759999983...	2020-06-21 14:23:37
1	3343176	2020-07-06 14:23:39	20200706T142339_21MTS_0	0.0037	188	{"rings": [[[-6535992.3057, -302418.3759999983...	2020-07-06 14:23:39
2	3620096	2020-07-21 14:23:37	20200721T142336_21MTS_0	0.0091	203	{"rings": [[[-6535992.3057, -302418.3759999983...	2020-07-21 14:23:37
3	3596177	2020-07-26 14:23:40	20200726T142340_21MTS_0	0.0020	208	{"rings": [[[-6535992.3057, -302418.3759999983...	2020-07-26 14:23:40
4	1584818	2020-07-31 14:23:38	20200731T142337_21MTS_0	0.0000	213	{"rings": [[[-6535992.3057, -302418.3759999983...	2020-07-31 14:23:38
5	776568	2020-08-10 14:23:38	20200810T142338_21MTS_0	0.0039	223	{"rings": [[[-6535992.3057, -302418.3759999983...	2020-08-10 14:23:38

The satellite imagery with the least cloud cover is selected and visualized for further processing.

```
# The scene is selected with the least cloud cover and extracted using the amazon extent
amazon_scene = sentinel.filter_by('OBJECTID=1584818')
amazon_scene.extent = amazon_extent
amazon_scene
```



In the above scene, the brown patches are the deforested areas that are to be identified. This selected scene is then published to the portal.

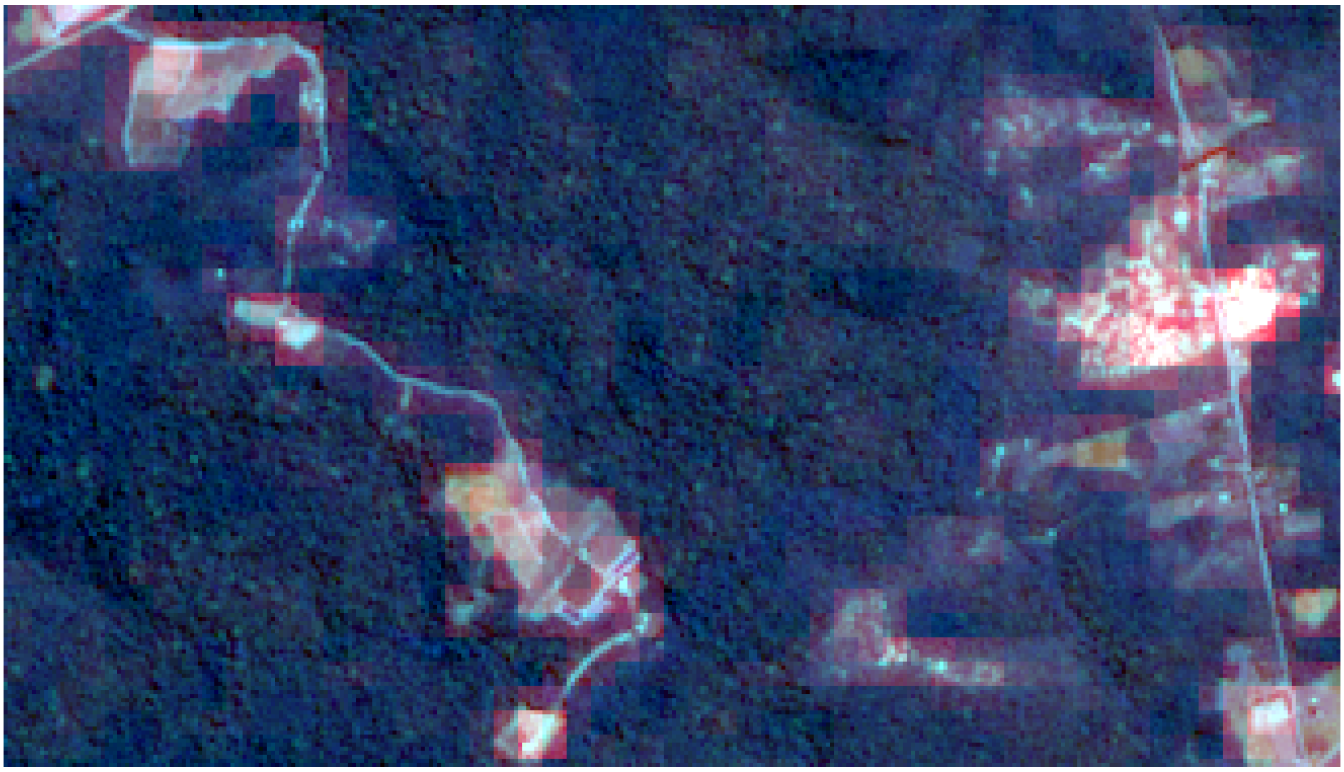
```
# publish the scene to the portal
amazon_scene.save('amazon_scene'+ str(dt.now().microsecond), gis=gis_enterp)
```

amazon_scene331940
Analysis Image Service generated from GenerateRaster Imagery Layer by arcgis_python
Last Modified: July 21, 2021
0 comments, 0 views

The published imagery of the Amazon rainforest is exported back to an image file on disk for further processing.

```
raster_amazon_13bands = Raster("https://pythonapi.playground.esri.com/ra/rest/services/Hosted/amazon_scene_may26/ImageServer",
                               gis=gis_enterp,
                               engine="image_server")
```

```
# visualizing the image
raster_amazon_13bands.export_image(size=[3330,1880])
```



Model Building

The first part of model building consists of defining the preprocessors, which will be used to scale the bands before feeding them into the model. The band names use the conventional naming method of the imagery name with an id number appended at the end as follows:

Sentinel-2 imagery has 13 bands, of which 4 bands, namely the blue, green, red, and near infrared bands, we will use here for modelling. These bands work well for differentiating green forested areas from barren land. The band information, along with the band name and their respective ids, are obtained for selecting the required bands.

```
# get the band names and their ids, sentinel images have 13 bands
pd.DataFrame(amazon_scene.key_properties()['BandProperties'])
```

	BandName	WavelengthMin	WavelengthMax
0	B1_Aerosols	433	453
1	B2_Blue	458	522
2	B3_Green	543	577
3	B4_Red	650	680
4	B5_RedEdge	698	712
5	B6_RedEdge	733	747
6	B7_RedEdge	773	793
7	B8_NearInfraRed	784	899
8	B8A_NarrowNIR	855	875
9	B9_WaterVapour	935	955
10	B10_Cirrus	1360	1390
11	B11_ShortWaveInfraRed	1565	1655
12	B12_ShortWaveInfraRed	2100	2280

```
# get the imagery name to define the band names
raster_amazon_13bands.name
```

```
'Hosted/amazon_scene_may26'
```

Here, the imagery name is 'Hosted/amazon_scene_april9'. Subsequently, the names of the blue, green, red, and near infrared bands would be 'Hosted/amazon_scene_april9_1', 'Hosted/amazon_scene_april9_2', 'Hosted/amazon_scene_april9_3', 'Hosted/amazon_scene_april9_7' respectively. These bands will be used for defining the preprocessors.

Data Pre-processing

```
from sklearn_extra.cluster import KMedoids
from sklearn.preprocessing import MinMaxScaler
```

The four bands are listed in the preprocessors for scaling, with the last item as the designated scaler as follows.

```
preprocessors = [('Hosted/amazon_scene_may26_1',
                  'Hosted/amazon_scene_may26_2',
                  'Hosted/amazon_scene_may26_3',
                  'Hosted/amazon_scene_may26_7', MinMaxScaler())]
```

Here, in the explanatory raster, we pass the name of the explanatory raster and the selected bands by their id's — 1 for blue, 2 for green, 3 for red, and 7 for NIR, as follows:

```
# Data is prepared for the MLModel using the selected scene and the preprocessors
data = prepare_tabulardata(explanatory_rasters=[(raster_amazon_13bands,(1,2,3,7))], preprocessors=preprocessors)
```

```
# visualization of the data to be processed by the model
data.show_batch()
```

	Hosted/amazon_scene_may26_1	Hosted/amazon_scene_may26_2	Hosted/amazon_scene_may26_3	Hosted/amazon_scene_may26_7
647	820	695	406	2508
5345	1144	1155	1181	2303
28764	818	707	389	2901
42042	1201	1252	1257	2596
61515	802	700	388	2410

Model Initialization

Once the data is prepared, an unsupervised model of k-means clustering from scikit-learn is used for clustering the pixels into deforested areas and forested areas. The clustering model is passed inside MLModel as follows, with the number of clusters set as three in the parameters.

```
from arcgis.learn import MLModel, prepare_tabulardata
```

```
# Model Initialization with KMedoids
model = MLModel(data, 'sklearn_extra.cluster.KMedoids', n_clusters=3, random_state=43)
```

Model Training

Now the model is ready to be trained, and will label the pixels as being one of three classes, either forested, slightly deforested, or highly deforested.

```
# here model is trained which would label the pixels into the designated classes
model.fit()
```

```
# the labelled pixels can be visualized as follows with the last column returning the predicted labels by the model
model.show_results()
```

	Hosted/amazon_scene_may26_1	Hosted/amazon_scene_may26_2	Hosted/amazon_scene_may26_3	Hosted/amazon_scene_may26_7	predicti
25429	811	709	391	3294	
30113	829	730	397	3261	
31345	835	767	419	2783	
32640	986	1015	780	3028	
55783	815	708	421	2958	

Deforestation Clusters Prediction

Next, the trained model is used to predict clusters within the entire selected scene of the Amazon rainforest. This is passed as the explanatory raster, with the prediction type as raster and a local path provided for output. The `output_layer_name` parameter can also be used for publishing.

```
pred_new = model.predict(explanatory_rasters=[raster_amazon_13bands],
                         prediction_type='raster',
                         output_layer_name=('deforest_predicted2'+str(dt.now().microsecond)),
                         output_raster_path=r"/tmp/result5.tif")
```

```
The Published Item ID is :  3df30cd12a48421dade893490c967c62
```

Result Visualization

The resulting raster with the predicted classes of deforested areas and forested areas is now read back for visualization. The predicted local raster can be accessed here.

```
amazon_predict = gis.content.get('b81b89aac4cd4e08bcd7cd400fac558f')
amazon_predict
```

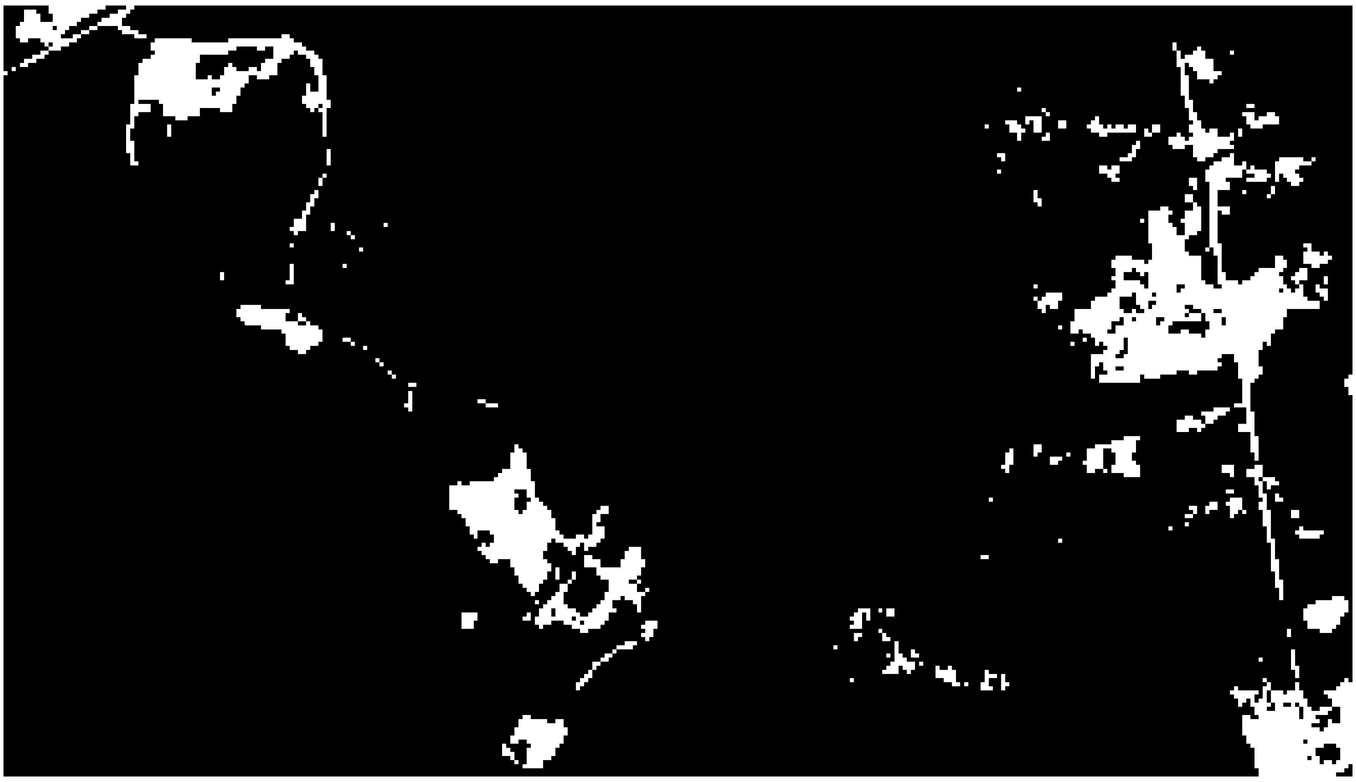
amazon_deforest_result
Image Collection by arcgis_python
Last Modified: April 16, 2021
0 comments, 12 views

```
import os, zipfile
```

```
filepath_new = amazon_predict.download(file_name=amazon_predict.name)
with zipfile.ZipFile(filepath_new, 'r') as zip_ref:
    zip_ref.extractall(Path(filepath_new).parent)
output_path = Path(os.path.join(os.path.splitext(filepath_new)[0]))
output_path = os.path.join(output_path, "result5.tif")
```

```
raster_predict = Raster(output_path)
```

```
raster_predict.export_image(size=[3290,1880])
```



The model has correctly labelled the deforested areas in white, distinguishing them from the rest of the forested areas in black.

The boundaries of the detected deforested areas could be further extracted into polygons using the convert raster to feature function.

Conclusion

In conclusion, this notebook demonstrated the process of detecting deforestation in the Amazon rainforest using unsupervised K-means clustering on satellite imagery. The key steps involved in this process were as follows:

1. **Data Preparation**: The area of interest in the Amazon rainforest was defined, and satellite imagery containing this area was selected and visualized.
2. **Model Building**: Preprocessing steps were performed to scale the relevant bands of the satellite imagery, and an unsupervised K-medoids clustering model was initialized and trained using the prepared data.
3. **Deforestation Clusters Prediction**: The trained model was then used to predict clusters within the entire selected scene of the Amazon rainforest, resulting in the identification of deforested areas.
4. **Result Visualization**: The resulting raster with the predicted classes of deforested areas and forested areas was visualized to observe the effectiveness of the model.

Throughout the process, the ArcGIS API for Python was utilized for accessing, processing, and analyzing the satellite imagery, showcasing its capabilities in geospatial analysis and machine learning tasks. This methodology can be further extended and refined to monitor deforestation trends over time, contributing to environmental conservation efforts in the Amazon rainforest and beyond.

Summary of methods used

Method	Description	Examples
prepare_tabulardata	prepare data including imputation, normalization and train-test split	prepare data ready for fitting a MLModel
MLModel()	select the ML algorithm to be used for fitting	any supervised and unsupervised models from scikit learn can be used
model.fit()	train a model	training the unsupervised model with suitable input
model.score()	find the appropriate model metric of the trained model	returns suitable value after training the unsupervised MLModel
model.predict()	predict on a test set	predict values using the trained models on the trained data itself

Data resources

Dataset	Source	Link
sat imagery	sentinel2	https://registry.opendata.aws/sentinel-2/