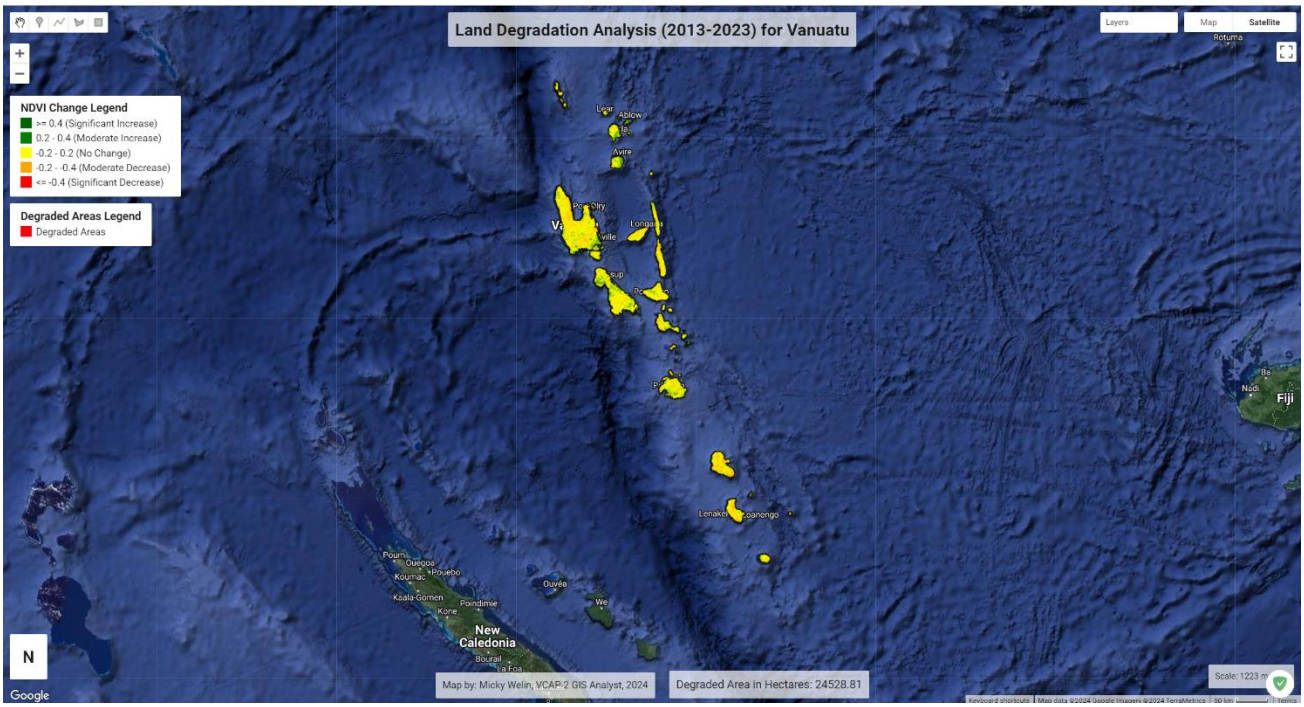
Documentation for Land Degradation Analysis Script using Google Earth Engine.



The provided script, designed for Google Earth Engine, conducts a comprehensive land degradation analysis for Vanuatu using the Normalized Difference Vegetation Index (NDVI) derived from Landsat 8 satellite images over a 10-year period (2013-2023). This analysis, created by Micky Welin, the GIS Analyst for the Vanuatu Coastal Adaptation Project - Phase II (VCAP-2), on July 14, 2024, identifies areas where vegetation health has declined, providing valuable insights for environmental management and conservation efforts.

The analysis begins by defining Vanuatu as the region of interest using a geographic boundary file and collects Landsat 8 satellite images covering this area within the specified date range. For each year, the script calculates the NDVI using the formula:

$$\mathrm{NDVI} = \frac{NIR - R}{NIR + R}$$

where **NIR** is the reflectance in the near-infrared band and **R** is the reflectance in the red band. This index measures vegetation health by comparing the red and near-infrared light reflected by the vegetation. The NDVI values are then averaged to create yearly composites. By comparing the NDVI values from 2013 to 2023, the script

identifies areas where vegetation health has significantly declined, termed degraded areas.

To visualize these changes, the script generates a map that highlights NDVI variations using a color-coded palette. Green indicates areas where vegetation has improved, yellow shows areas with no significant change, and red marks areas where vegetation has deteriorated. Additional elements, such as legends explaining the color codes, a title, a scale bar, a north arrow, and labels for the map creator and the total area of degradation in hectares, ensure that the map is informative and user-friendly.

Google Earth Engine (GEE), a powerful cloud-based platform, facilitates this analysis by providing access to a vast collection of satellite imagery and geospatial data. GEE enables users to filter, process, and analyze these datasets without needing specialized hardware, making complex analyses accessible and efficient.

Understanding land degradation is crucial for developing effective conservation strategies and making informed decisions about land use. This analysis helps identify areas in Vanuatu that require attention and supports efforts to protect and restore the environment. By visualizing and quantifying land degradation, stakeholders can take proactive measures to address these issues and promote the resilience of ecosystems in Vanuatu.

The results of this analysis can be particularly useful for various government departments in Vanuatu. The Department of Forestry can use the data to identify areas where reforestation efforts are needed, prioritize resources, and monitor the effectiveness of their programs. The Department of Agriculture can benefit from understanding how land degradation affects agricultural productivity, allowing them to implement sustainable farming practices and develop strategies to combat soil erosion and other degradation factors. The Department of Environment, Protection, and Conservation can leverage the findings to focus on areas requiring conservation efforts, develop policies for sustainable land use, and engage in restoration projects to preserve biodiversity and ecosystem health.

This script exemplifies how advanced satellite imagery and cloud-based computing can monitor environmental changes and support sustainable development initiatives. By providing a clear, data-driven understanding of land degradation patterns, it enables informed decision-making and effective management of Vanuatu's natural resources.

Overview

Region of Interest: Vanuatu
Time Range: 2013-07-01 to 2023-07-01
Satellite Data: Landsat 8 Collection 2, Level-2
Main Index: NDVI (Normalized Difference Vegetation Index)
Output: NDVI change map, degraded areas map, area of degradation in hectares

Script Breakdown

1. Define the Region of Interest

```
var vanuatu = ee.FeatureCollection("FAO/GAUL/2015/level1")
  .filter(ee.Filter.eq('ADM0_NAME', 'Vanuatu'));
```

Description: *Filters the FAO GAUL dataset to include only the features corresponding to Vanuatu.*

2. Define the Time Range

```
var startDate = ee.Date('2013-07-01');
var endDate = ee.Date('2023-07-01');
```

Description: *Sets the start and end dates for the analysis period (10 years).*

3. Load Landsat 8 Data

```
var landsat8 = ee.ImageCollection('LANDSAT/LC08/C02/T1_L2')
  .filterBounds(vanuatu)
  .filterDate(startDate, endDate);
```

Description: *Loads the Landsat 8 Collection 2, Level-2 image collection, filters it by the region of interest (Vanuatu), and the defined time range.*

4. Function to Add NDVI Band

```
var addNDVI = function(image) {
  var ndvi = image.normalizedDifference(['SR_B5', 'SR_B4']).rename('NDVI');
  return image.addBands(ndvi);
};
```

Description: *Defines a function to calculate the NDVI for each image and add it as a new band.*

5. Calculate Yearly NDVI

```
var yearlyNDVI = ee.ImageCollection(
  ee.List.sequence(2013, 2023).map(function(year) {
    var start = ee.Date.fromYMD(year, 1, 1);
    var end = start.advance(1, 'year');
    var composite = landsat8.filterDate(start, end).map(addNDVI).mean();
    return composite.set('year', year).select('NDVI');
  })
);
```

Description: *Calculates the mean NDVI for each year from 2013 to 2023 and creates an image collection with yearly NDVI images.*

6. Calculate NDVI Change

```
var ndvi2013 = yearlyNDVI.filter(ee.Filter.eq('year', 2013)).first();
var ndvi2023 = yearlyNDVI.filter(ee.Filter.eq('year', 2023)).first();
var ndviChange = ndvi2023.subtract(ndvi2013).rename('NDVI_Change');
```

Description: *Computes the change in NDVI between the years 2013 and 2023.*

7. Identify and Clip Degraded Areas

```
var degradationThreshold = -0.2;
var degradedAreas = ndviChange.lte(degradationThreshold);

var ndviChangeClipped = ndviChange.clip(vanuatu);
var degradedAreasClipped = degradedAreas.clip(vanuatu);
```

Description: *Identifies areas where NDVI has significantly decreased (threshold set to -0.2) and clips the NDVI change and degraded areas to the boundaries of Vanuatu.*

8. Visualization Parameters and Map Display

```
var ndviChangeVis = {
  min: -0.5,
  max: 0.5,
  palette: ['red', 'orange', 'yellow', 'green', 'darkgreen']
};
```

Add Layers to Map

```
Map.centerObject(vanuatu, 7);

var title = ui.Label({
  value: 'Land Degradation Analysis (2013-2023) for Vanuatu',
  style: {
    fontWeight: 'bold',
    fontSize: '24px',
    margin: '10px',
    padding: '10px',
    backgroundColor: 'rgba(255, 255, 255, 0.7)'
  }
});
Map.add(title);

Map.addLayer(vanuatu, {}, 'Vanuatu');
Map.addLayer(ndviChangeClipped, ndviChangeVis, 'NDVI Change (2013-2023)');
Map.addLayer(degradedAreasClipped.updateMask(degradedAreasClipped), {palette: 'red'}, 'Degraded Areas');
```

Description: *Sets up visualization parameters for NDVI change, centers the map on Vanuatu, and adds layers to display NDVI change and degraded areas. It also adds a title to the map.*

9. Legends for NDVI Change and Degraded Areas

NDVI Change Legend

```
var legendNDVIChange = ui.Panel({
  style: {
    position: 'top-left',
    padding: '8px 15px'
  }
});

var legendTitleNDVIChange = ui.Label({
  value: 'NDVI Change Legend',
  style: {
    fontWeight: 'bold',
    fontSize: '16px',
    margin: '0 0 4px 0',
    padding: '0'
  }
});
legendNDVIChange.add(legendTitleNDVIChange);

var makeRowNDVIChange = function(color, label) {
  var colorBox = ui.Label({
    style: {
      backgroundColor: color,
      padding: '8px',
      margin: '0 0 4px 0'
    }
  });
  var description = ui.Label({
    value: label,
    style: {margin: '0 0 4px 6px'}
  });
  return ui.Panel({
    widgets: [colorBox, description],
    layout: ui.Panel.Layout.Flow('horizontal')
  });
};

var paletteLabelsNDVIChange = [
  {color: 'darkgreen', label: '>= 0.4 (Significant Increase)'},
  {color: 'green', label: '0.2 - 0.4 (Moderate Increase)'},
  {color: 'yellow', label: '-0.2 - 0.2 (No Change)'},
  {color: 'orange', label: '-0.2 - -0.4 (Moderate Decrease)'},
  {color: 'red', label: '<= -0.4 (Significant Decrease)'}
];

paletteLabelsNDVIChange.forEach(function(item) {
  legendNDVIChange.add(makeRowNDVIChange(item.color, item.label));
});

Map.add(legendNDVIChange);
```

Description: *Creates and adds a legend for the NDVI change map.*

Degraded Areas Legend

```
var legendDegradedAreas = ui.Panel({
  style: {
    position: 'top-left',
    padding: '8px 15px'
  }
});

var legendTitleDegradedAreas = ui.Label({
  value: 'Degraded Areas Legend',
  style: {
    fontWeight: 'bold',
    fontSize: '16px',
    margin: '0 0 4px 0',
    padding: '0'
  }
});
legendDegradedAreas.add(legendTitleDegradedAreas);

var makeRowDegradedAreas = function(color, name) {
  var colorBox = ui.Label({
    style: {
      backgroundColor: color,
      padding: '8px',
      margin: '0 0 4px 0'
    }
  });
  var description = ui.Label({
    value: name,
    style: {margin: '0 0 4px 6px'}
  });
  return ui.Panel({
    widgets: [colorBox, description],
    layout: ui.Panel.Layout.Flow('horizontal')
  });
};

legendDegradedAreas.add(makeRowDegradedAreas('red', 'Degraded Areas'));

Map.add(legendDegradedAreas);
```

Description: *Creates and adds a legend for the degraded areas map.*

10. Calculate and Display Area of Degraded Regions

```
var pixelArea = ee.Image.pixelArea().divide(10000); // Convert m^2 to hectares
var degradedAreaHectares = degradedAreasClipped.multiply(pixelArea).reduceRegion({
  reducer: ee.Reducer.sum(),
  geometry: vanuatu.geometry(),
  scale: 30,
  maxPixels: 1e13
});

degradedAreaHectares.evaluate(function(result) {
  var degradedAreaLabel = ui.Label({
    value: 'Degraded Area in Hectares: ' + result.NDVI_Change.toFixed(2),
    style: {
      position: 'bottom-center',
      fontSize: '16px',
      margin: '10px',
      padding: '10px',
      backgroundColor: 'rgba(255, 255, 255, 0.7)'
    }
  });
  Map.add(degradedAreaLabel);
});
```

Description: *Calculates the total area of degraded regions in hectares and displays it on the map.*

11. Add Map Metadata

Map Creator and Organization

```
var mapCreatorLabel = ui.Label({
  value: 'Map by: Micky Welin, VCAP-2 GIS Analyst, 2024',
  style: {
    position: 'bottom-center',
    fontSize: '14px',
    margin: '10px',
    padding: '10px',
    backgroundColor: 'rgba(255, 255, 255, 0.7)'
  }
});
Map.add(mapCreatorLabel);
```

Scale Bar

```
var scaleBar = ui.Label({
  value: 'Scale: ' + Map.getScale().toFixed(0) + ' meters',
  style: {
    position: 'bottom-right',
    padding: '10px',
    fontSize: '12px',
    backgroundColor: 'rgba(255, 255, 255, 0.7)'
  }
});
Map.add(scaleBar);
```

North Arrow

```
var northArrow = ui.Panel({
  widgets: [
    ui.Label('N', {fontWeight: 'bold', fontSize: '24px'})
  ],
  style: {
    position: 'bottom-left',
    padding: '10px'
  }
});
Map.add(northArrow);
```

Description: *Adds metadata to the map including the map creator's information, a scale bar, and a north arrow.*

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How to Run the Script

1. Open Google Earth Engine Code Editor: Visit [Google Earth Engine Code Editor] (https://code.earthengine.google.com/).

2. Create a New Script by clicking on the "New" button.

3. Copy the provided code and paste it into the script editor.

4. Click the "Run" button to execute the script and visualize the results.