# Earth Observation for Land and Water Challenge Leveraging

# DUNIA Platforms & Resources

**Forest Change in the Aberdare Forest and Its Impact on Air Quality**

**Summary Report**

**Team 2**

# Forest Change Analysis in the Aberdare Forest and its Impact on Air Quality

## Introduction

The Aberdare Forest is a crucial ecological region in Kenya, it plays a significant role in maintaining biodiversity, regulating the climate, and ensuring water supply. This study aims to analyze the forest change in the Aberdare Forest from 2018 to 2024 and its relationship with air quality, focusing on nitrogen dioxide ($NO_2$) levels. Nitrogen dioxide is a significant pollutant that contributes to smog formation and acid rain which turn have adverse effects on human health such as respiratory issues. It also affects agricultural production due to leaching of soil nutrients caused by acidic rain. It is therefore necessary to look at how forests relate to $NO_2$ concentrations in the atmosphere, forests can help regulate these levels through direct absorption and soil interactions where soil microbes play a significant role in the Nitrogen cycle.

## Problem Statement

The Aberdare Forest is very dynamic especially with the frequent occurrences of forest fires which reduce the forest cover. These events lead to the changes in forest cover which also affects $NO_2$ levels by reducing the number of trees regulating it as well as by increasing the amount of $NO_2$ in the atmosphere through the combustion of biomass. This necessitates the need for a mechanism to monitor the forest change in order to show forest losses as well as its recovery after fire events and its role when it comes to controlling air pollution.

## Goal

The objective of this exercise was to take note of the forest change that has occurred between 2018 and 2024 and to compare the change to the amount of $NO_2$ present in the atmosphere at those instances. The change is evaluated in terms of whether it is a gain, loss or no change occurred in that time period.

## Data and Tools

The following datasets were used in the analysis;

### *Sentinel 2 Level 2A*

The Sentinel-2 Level 2A dataset is part of the Copernicus Programme managed by the European Space Agency (ESA). It provides medium resolution satellite imagery of Earth's surface. This dataset is primarily used for land monitoring applications, including agriculture, forestry, land cover classification, and disaster management. The dataset offers a spatial resolution of 10 meters for visible and near-infrared (VNIR) bands, 20 meters for red-edge and short-wave infrared (SWIR) bands, and 60 meters for atmospheric correction bands. The temporal resolution is 5 days due to the constellation of Sentinel 2A and 2B satellites which makes it ideal for monitoring applications such as agriculture and forestry.

The data was accessed through the Copernicus Dataspace Hub for the years 2018, 2021 and 2024.The chosen date was around February 17$^{th}$ to the 23$^{rd}$ in order to deal with clouds which present a huge problem in forested areas due to the high moisture facilitating cloud formation. The images were downloaded for further analysis.

***Sentinel 5P***

Sentinel-5 Precursor (Sentinel-5P) is part of the European Space Agency's (ESA) Copernicus Programme, dedicated to monitoring the Earth's atmosphere. Sentinel-5P since its launch in 2017 primarily performs atmospheric measurements with high precision and resolution, aiding in environmental monitoring and climate research. It makes use of the TROPOMI instrument which is a multispectral imaging spectrometer used atmospheric measurements. It provides daily global coverage at a spatial resolution of 7x3.5 $km^{2,}$ some of the parameters measured include Ozone ($O_3$), Nitrogen Dioxide ($NO_2$), Sulfur Dioxide ($SO_2$), Carbon Monoxide (CO), Methane ($CH_4$), Formaldehyde (HCHO and the Aerosol Index.

The data was accessed through Google Earth Engine as it allows for computation of yearly composite through the mean and median functionalities. This process ensures that one is able to get the data for their area of study easily as well as in geotiff format which is friendlier to work with compared to the netcdf format provided through the Copernicus Dataspace Hub.

The tools used were;

***Dunia Platform***

The Dunia platform is an all-in-one, user-friendly digital solution designed for processing and disseminating Earth observation data over Africa. It makes use of virtual machine environments hosting jupyter notebooks, desktop capability which comes with GIS software such as QGIS and SNAP making it quite convenient in data analysis involving earth observation data.

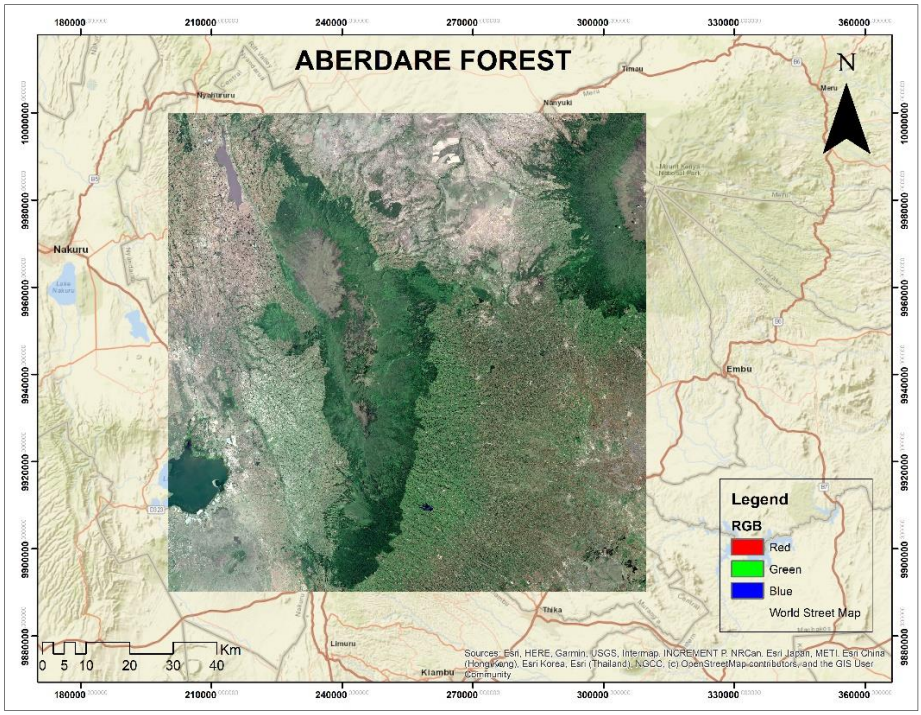
***Google Earth Engine***

Google Earth Engine (GEE) is a cloud-based platform designed for planetary-scale environmental data analysis. It enables users to analyze and visualize and download datasets, facilitating a wide range of applications in environmental monitoring, research, and policy-making.

## Study Area

The focus area was the Aberdare Forest region and included a part of the Mt Kenya Forest. This region is dominated by the Aberdare Range, a mountain range that forms part of the eastern rim of the Great Rift Valley. The area is characterized by its high-altitude forests, moorlands, and diverse wildlife, making it a vital conservation area and a popular destination for eco-tourism.

The Aberdare Forest experiences regular forest fires which causes changes in the forest cover as well as has an influence on the air quality. This is because combustion of biomass leads to release of simple organic elements such as Carbon and Nitrogen which combined with oxygen leads to formation of pollutants such as Nitrogen Dioxide.




## Methodology

### *Data Collection*

- Sentinel 2 images
  The images were obtained through the Copernicus Dataspace Hub, the download period was between February 17th – 23rd for the years 2018, 2021 and 2024.
  The product of interest was the Sentinel 2 Level2A image which shows the surface reflectance
- Sentinel 5P $NO_2$
  The S5P $NO_2$ images were exported from google earth engine for each of the years of interest mentioned above. This link provides access to the script that was used to perform the data access as well as export.

### *Image Classification*

- Sen2classification algorithm
  Land cover classification was carried out to identify the forest extents, due to the complexity of collecting ground data to train models which may be time consuming especially for large datasets we used the sen2classification library in python. The library is designed for automatic land cover classification of Sentinel 2 images using machine learning. The library computes vegetation indices such as NDVI, BAEI, AWEI and NDTI for thresholding and uses either ALCC or gradient boosting for classification. The output

classes are as follows; 0 = no data 1 = water 2 = low vegetation 3 = high vegetation 4 = soil 5 = built up more details are given in the PyPi website

***Forest Mask Creation***

The classified images were uploaded into Dunia Platform for processing. The process involved creating a binary image of forest and non-forest areas, this was done by reclassifying the image so that the forest class was assigned a value of 1 and the rest of the classes a value of zero.

***Forest Difference Image Computations***

The binary images for the years 2018, 2021 and 2024 were then subtracted to obtain the forest gains and losses. The first difference image was obtained by subtracting the 2018 image from the 2021 image, the second one was obtained by subtracting the 2021 image from 2024. The difference images were then plotted and area calculation was carried out to determine the area in hectares of either forest loss or forest gain.

***Visualization of $NO_2$ images***

The downloaded $NO_2$ images were also uploaded into Dunia and visualized to see the distribution of $NO_2$ within the area of study generating three images showing the levels in 2018, 2021 and 2024.

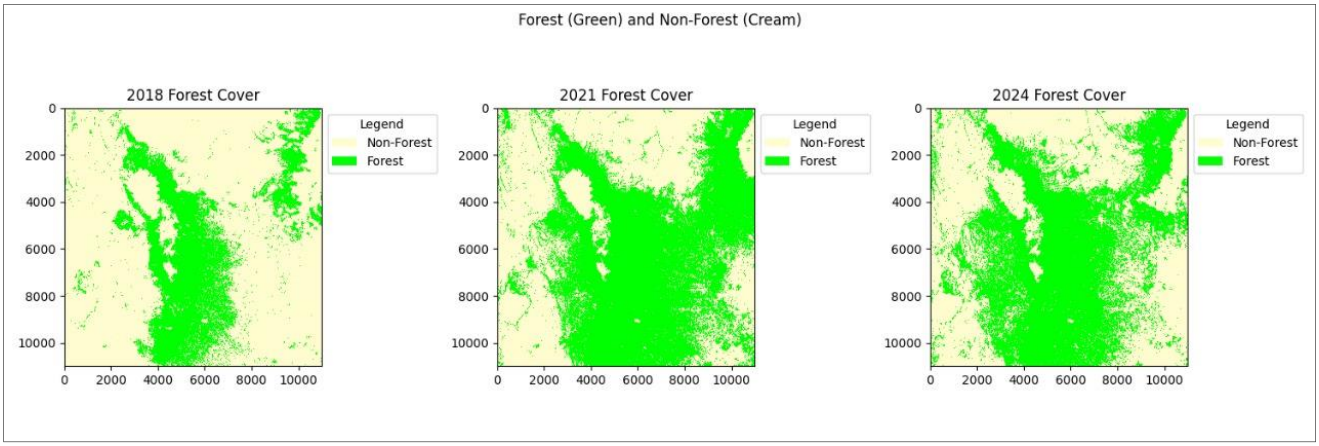
***$NO_2$ Difference Image Computations***

In this case the difference images were also computed by subtracting the 2018 from 2021 and 2021 from 2024 to get the changes in $NO_2$ level distribution.

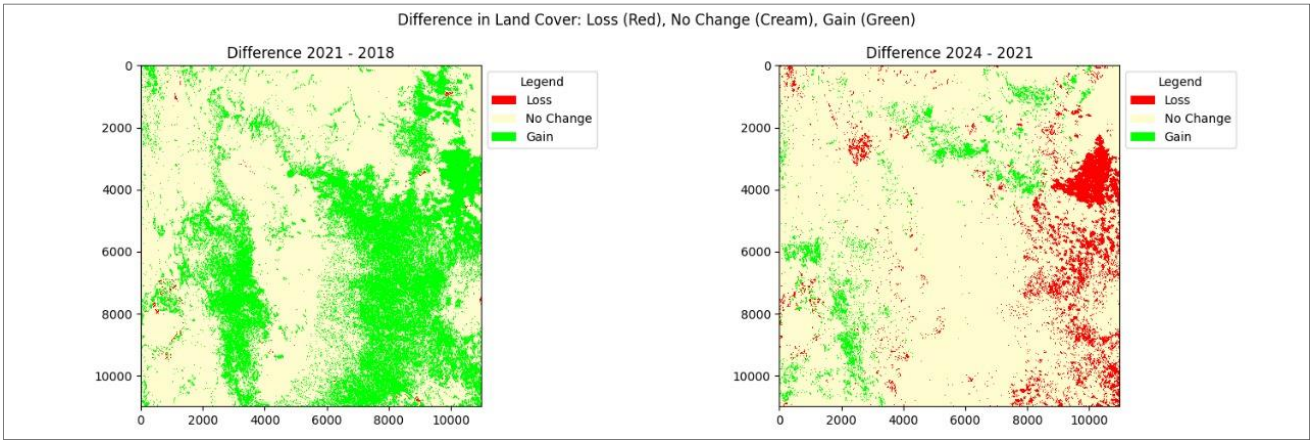
***Visual Inspection of the relationship between forest change and air quality and reporting***

The images for both forest cover and $NO_2$ levels were compared visually to determine the influence of forest change on air quality.

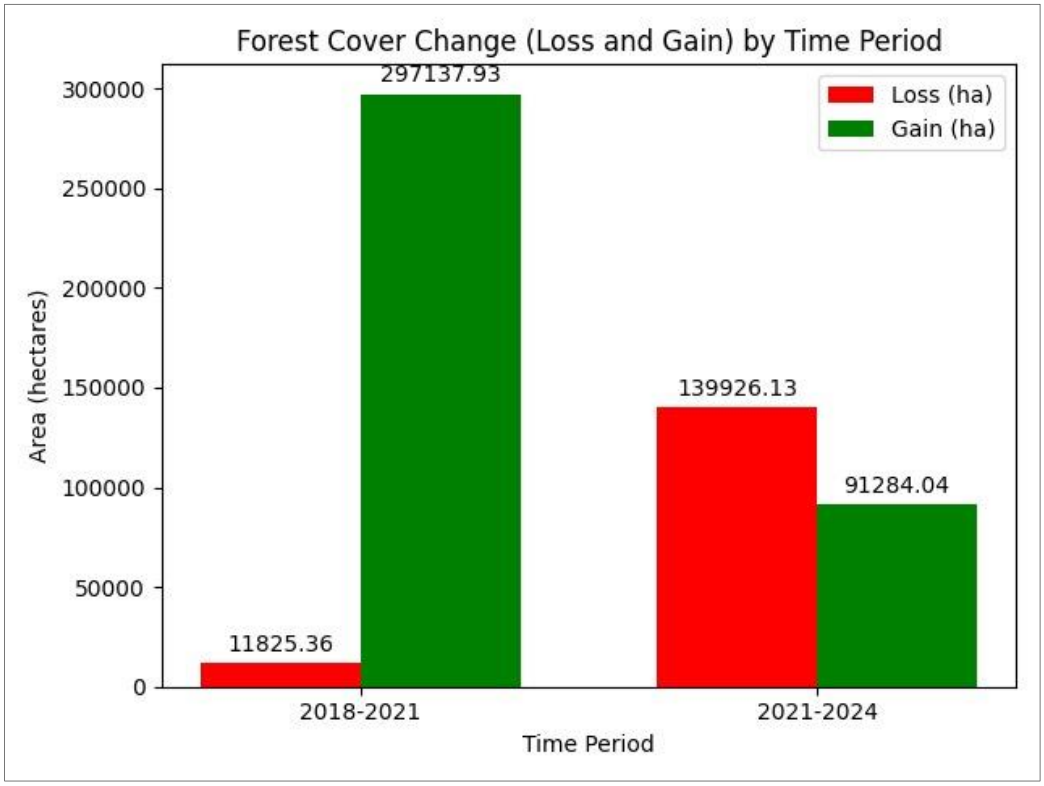
## Results



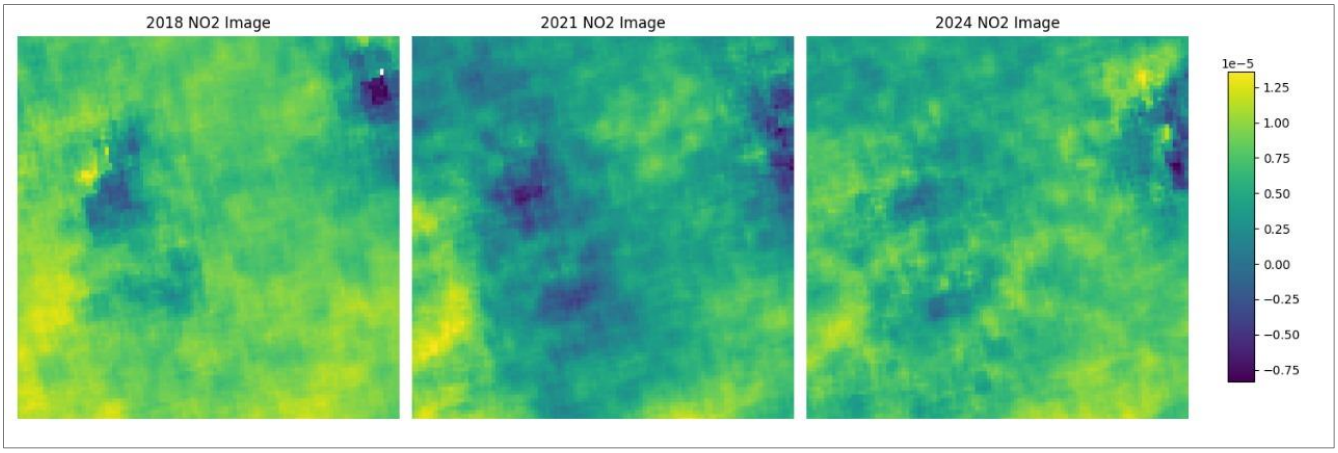

*Forest Cover for the years 2018, 2021 and 2024*




*Forest Difference Images for the time periods 2021-2018 and 2024-2021*

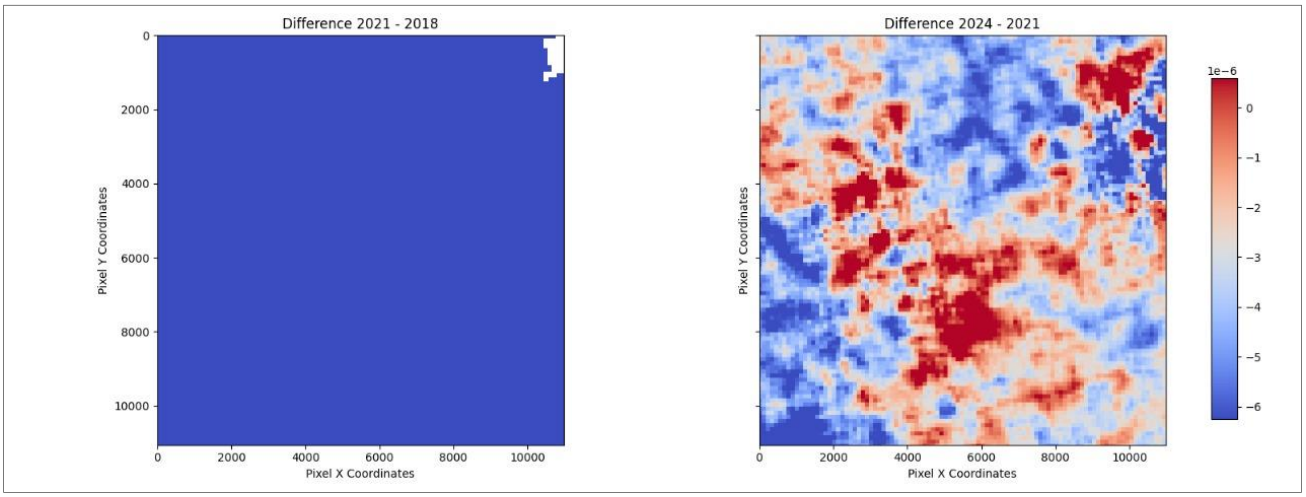



*Forest Gain and Loss Graph for the time periods 2018-2021 & 2021-2024*




*NO2 Levels for the years 2018, 2021 and 2024*

NO2 Levels Difference Images 2018-2021 and 2021-2024




**Discussion**

From the above results we see that there was an increase in forest cover from the year 2018 to the year 2021, from the year 2021 to the year 2024 there was a decrease in forest cover. We see from the graphs that for the period 2018-2021 the forest loss was 11,825.36 hectares while the gain was 297,137.93 hectares. On the other hand, we see that the forest loss was 139,926.13 hectares and the forest gain was 91,284.04 hectares. For the time period 2021-2024 the major forest loss may be attributed to the forest fire events that occurred in the years 2023, 2022 and 2024.

When the forest change is compared to the $NO_2$ levels we see that an increase in forest cover from 2018 to 2021 lead to a decrease in the amounts of $NO_2$ in the atmosphere while the decrease in forest area in 2021-2024 led to an increase in $NO_2$ levels considering the contribution of the forest fires to processes

that increase NO2 in the atmosphere. It is clear that forest change has an impact in the quality of air in the area.

## Recommendations

- Strengthen Forest Conservation Efforts

Implement stricter protection measures for existing forests to prevent illegal logging, encroachment, and other destructive activities. This includes increasing patrolling and monitoring activities in vulnerable areas.

Initiate and support reforestation and afforestation programs to restore degraded forest areas and expand forest cover.

Engage local communities in forest conservation efforts by providing education and incentives for sustainable land use practices, and involve them in monitoring and protecting forest areas.

- Fire Management and Prevention

Develop and implement comprehensive fire prevention strategies. This includes creating firebreaks, conducting controlled burns in a safe manner, and removing combustible materials from forest floors.

Establish and enhance early warning systems for forest fires. Utilize satellite data and ground-based sensors to detect fires early and respond promptly to prevent widespread damage.

Ensure adequate resources and training for firefighting personnel as well as investing in equipment and infrastructure to improve the efficiency and effectiveness of fire response teams.

- Air Quality Monitoring and Mitigation

Enhance air quality monitoring by continuously tracking $NO_2$ levels and using this data to identify trends and sources of pollution.

Conduct public awareness campaigns to educate citizens about the impact of air pollution and the importance of forests in regulating the air quality.

## Conclusions

The analysis of forest cover changes between 2018 and 2024 highlights the significant impact of these changes on environmental quality, in relation to $NO_2$ levels in the atmosphere. The increase in forest cover from 2018 to 2021, resulted in a net gain of 285,312.57 hectares, which positively influenced air quality by reducing $NO_2$ levels. However, the subsequent period from 2021 to 2024 saw a net forest loss of 48,642.09 hectares, largely due to devastating forest fires in 2022, 2023, and 2024. This loss of forest cover contributed to an increase in $NO_2$ levels, underscoring the critical role forests play in air purification and climate regulation.

The findings emphasize the urgent need for robust forest conservation strategies, improved fire management practices, and sustainable land use planning to mitigate further environmental degradation.