Environmental Change of Lake Naivasha and its Surrounding Areas

Introduction

Lake Naivasha is expanding and it has enormous implications for the regions surrounding it. River Malewa and Gilgil river flow into the Lake and carry large sediments into the lake in the rainy season. As a result, the sediments carried into the lake reduces the depth of the lake. This leads to the current water level rise being experienced which has displaced populations nearby the Lake.

Section 1: Examining the features of Lake Naivasha

1.1 - 1.3: Observing the surface area of the water

It is well known that Lake Naivasha is expanding and we will examine if satellite imagery around surface water will tell the same story. We use two different datasets to display this info.

1.4 - 1.5 Looking at the Normalized Difference Vegetation Index (NDVI)

Our objective is to understand where Lake Naivasha might be losing or gaining in vegetation. There is an agricultural industry around the Lake which is dependent on the lake waters itself for irrigation. Examining the NDVI in the buffer zone around Lake Victoria might explain the impact Lake Naivasha rising level has on local development.

Section 2: Examining the symbiotic impact on areas around Lake Naivasha through a few datasets

2.1: Global Human Settlement Layers
2.2: Degree of Urbanization
2.3: Human Modification
2.4: Night-time lighting

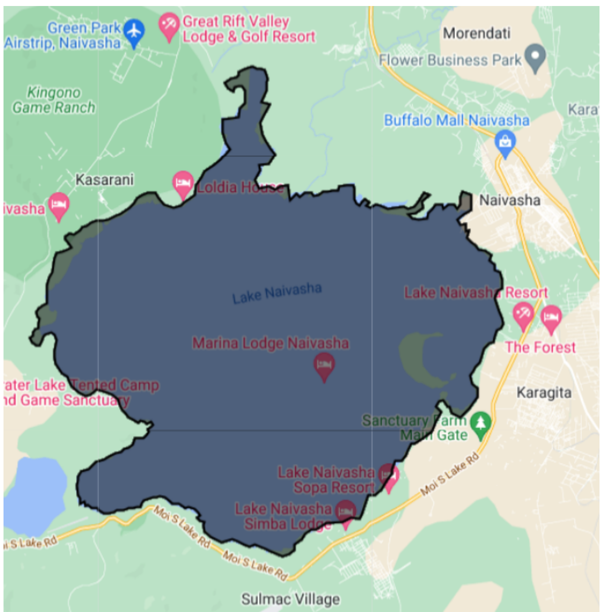
Conclusion: Environmental and Political Ramifications of Lake Naivasha and its surrounding areas

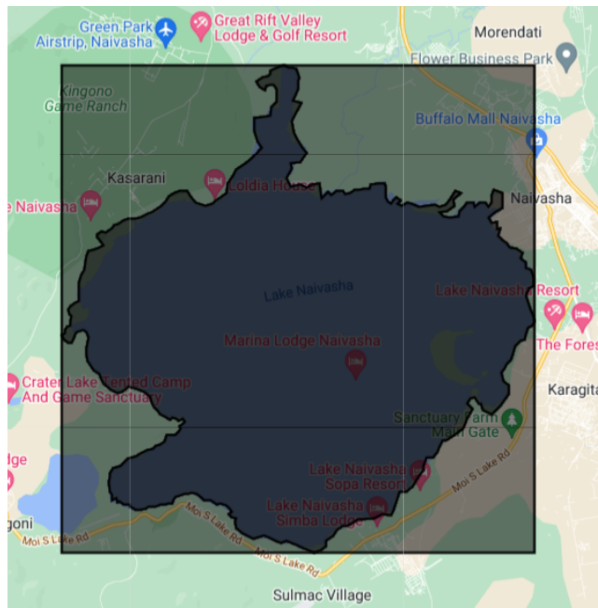
Study Area

Lake Naivasha and its surrounding area is at the following latitude and longitude ((0° 46 N, 36° 21'E))

The lake is well known for not having a visible outlet; it is assumed that its outlet is an underground one.

The study area was created from Google Earth Engine 2022 version where the satellite image was used to create a shapefile in ArcGIS pro.





Step 1.1 Surface Water Area

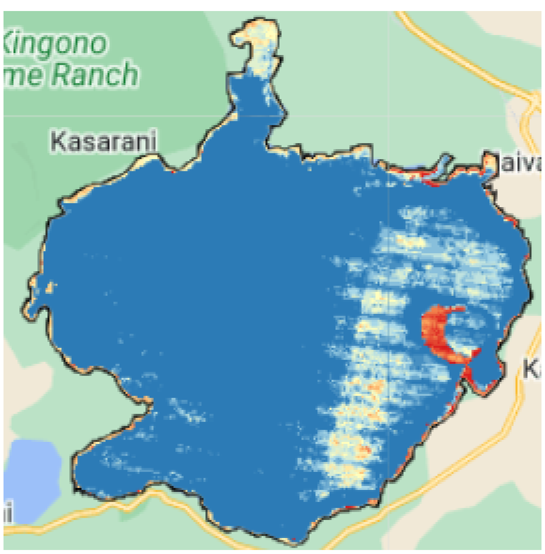
First, we examine a dataset that contains maps on surface water between 1984-2019. We can see a considerable change across a 35 year span.
We can point out the gain of surface water around the eastern, northern and western edge of the area across all images.

Left: Surface water absolute change
Right: Normalized change in occurrence

Dataset: JRC Global Surface Water Mapping Layers, v1.2

Step 1.2 Difference in Surface Water Area

Next we subtract the current image from the baseline image featured in the above image. The image below is the result which shows areas that have gained surface water in blue and areas that have lost water in red.The red crescent area of surface water loss on the west is actually an island known as crescent island which has even wild animals. The island is easily visible from the other images which means that it had neither been submerged and covered by water.



In addition to visualizing the gain of water through color, my script also calculates the gain of surface water in square meters. The difference image above shows that there is a major increase in surface water area which is shown also in the numbers that there is an 84% increase.

```
Surface Water Area of Baseline 2001 - 2003 155985731.55696854
```

```
Surface Water Area of Current 2019 - 2021 287364035.26921725
```

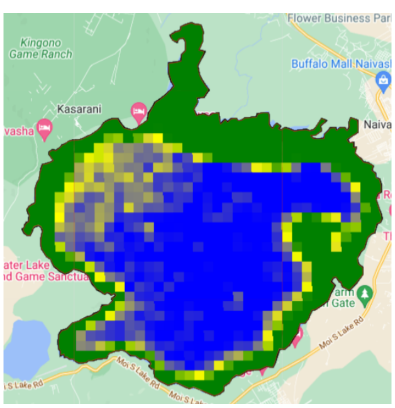
```
84.22456490148087 Percent change difference in Surface Water Area
```

```
131378303.71224871 Difference in Surface Water Area
+ Code  + Text
```

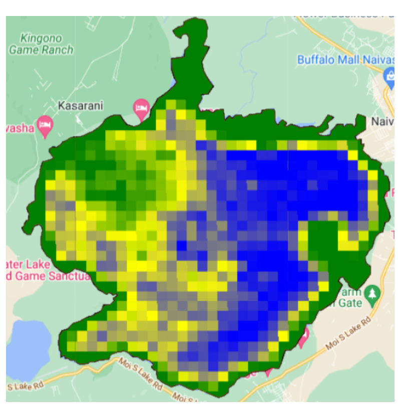
Step 1.3: NDVI of Lake Naivasha

Presented here is a visualization of Lake Naivasha's NDVI in 2001 - 2003, 2019 - 2021 and the difference in change between those years. The values range from a min of .08 in blue to a maximum of .267 in green (with yellow as a middle value). We can see that indeed the NDVI value has grown from the baseline year to the current year. It appears that the Lake has gained an NDVI value especially around the middle part of the lake.

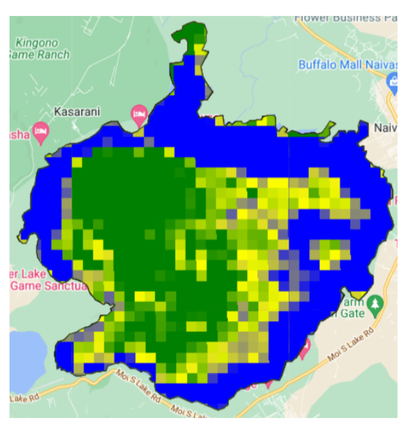
2001 -2003



2019 - 2021



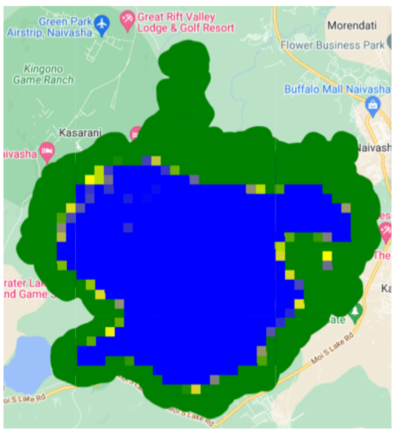
Difference



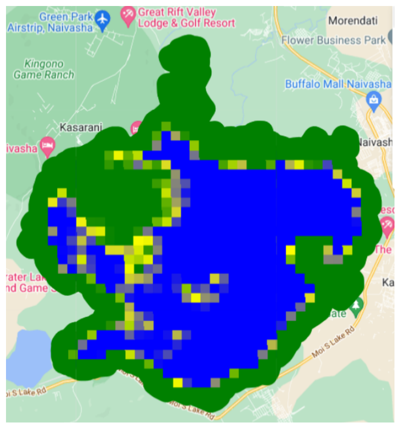
Section 1.4: NDVI of the area around Lake Naivasha

This section we examine the NDVI of the buffer zone around Lake Naivasha which was set to 500 meters. In the first two images we see a slight increase in green values which represent the maximum amount. In the difference image, we see an increase in NDVI in the middle of the lake. Around the edge of the lake we see a huge reduction in NDVI, this is due to the water level rise in the lake which wiped out all the vegetation along the lake.

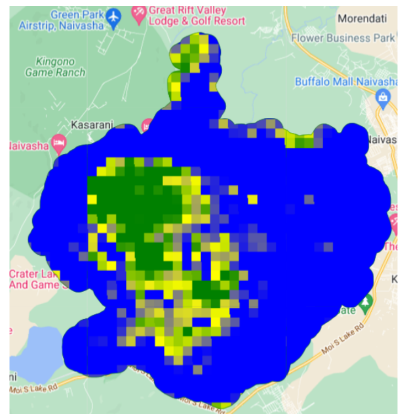
NDVI in 2001 -2003 (min: .05, max: .17)



NDVI in 2019 - 2021 (min: .05, max: .17)



Difference in the images (min: -.008, max: 0.009)



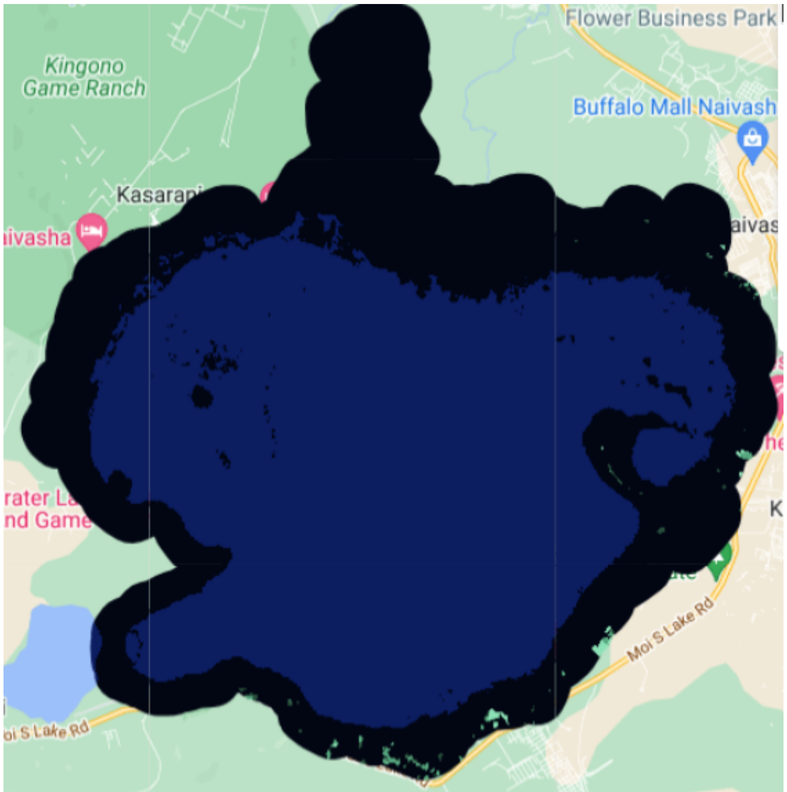
Range (Min: Blue, Yellow, Max: Green)

Section 2: Man Made Development

In this section, we examine a few different datasets to see if there is a connection between Lake Naivasha expansion and the locations of developments.

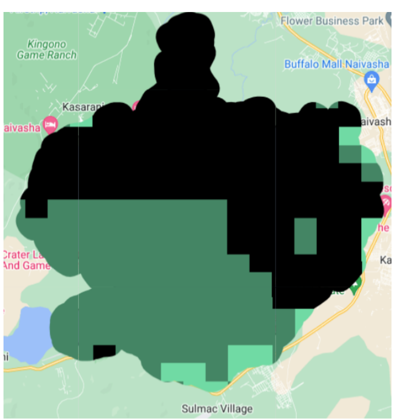
Section 2.1: Human Settlement

Using the dataset of Global Human Settlement Layers, we first examine the area of built up presence along the lake. We see that most of the older development exists in the East and Southern part of the lake.

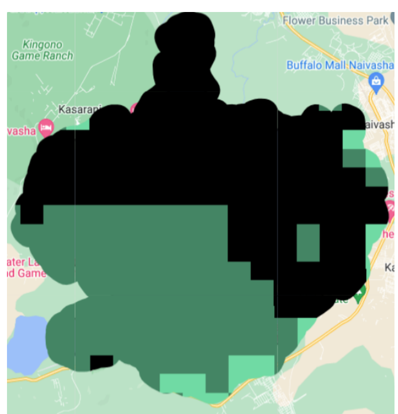


Section 2.2: Degree of Urbanization

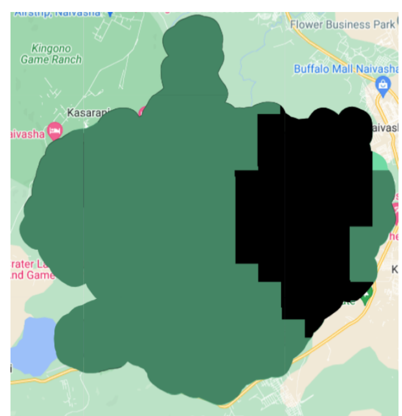
2000



2014

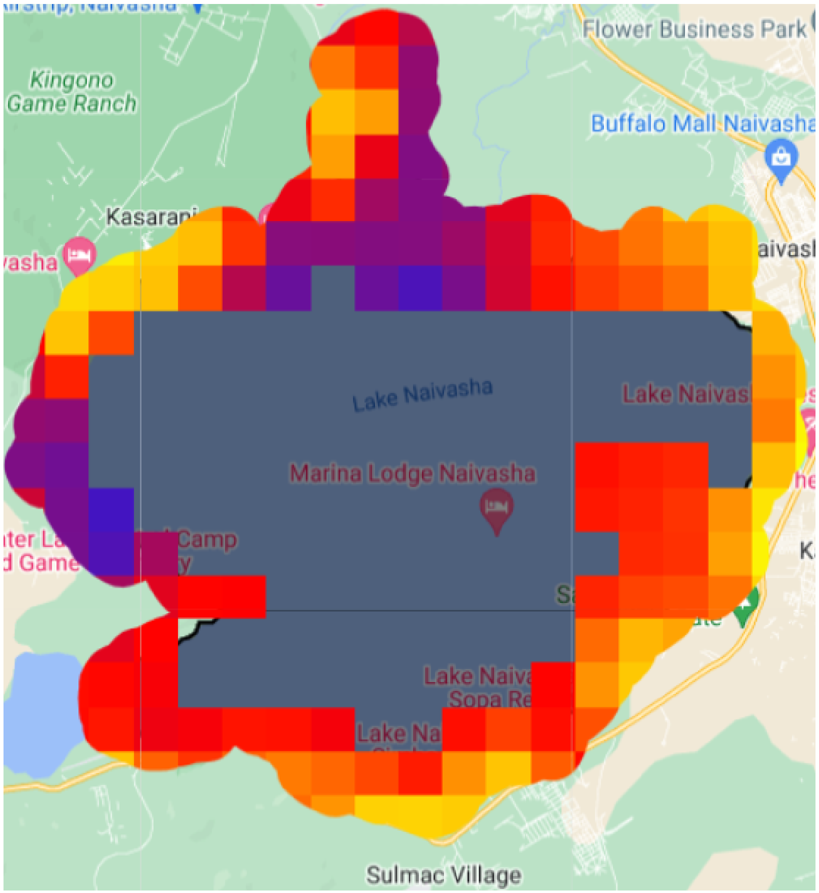


1975



In this slide, we examine a dataset that shows human population by clusters. We filtered out for our dates of interest which are the years 2000 and 2014 (this was the last date) to see if any change occurred within this 15 period but cannot see anything visually.
For comparison we added the basemap of the year 1975. We see the growth development in the Southern and Eastern parts with high density clusters.

Section 2.3: Human Modification

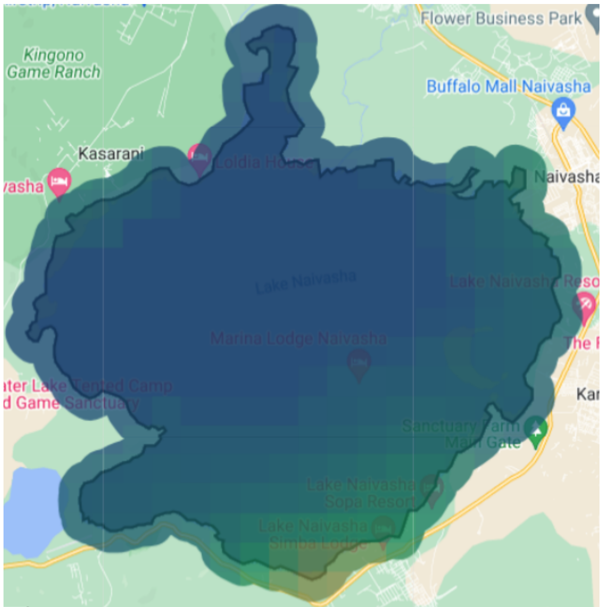


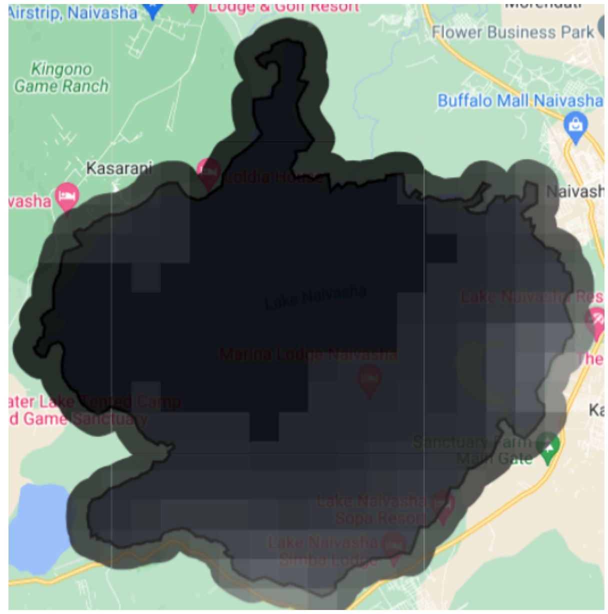
I also used a dataset that observes human modification on the Earth. I added this buffer area to Lake Naivasha and observed the strongest areas of modification.
The values of human modification go from 0 to 1 and dark blue to a bright yellow. Human modification has taken part all along the lake with the most development on the Eastern and Southern side.

Section 2.4: Night-Time Lighting

In addition to datasets that explicitly look at development and population growth, nighttime lighting is often used as a proxy to show where people and places are. I used a dataset specifically of a 2000 satellite to see the persistent lighting in that year and then to see the persistent lighting in 2013 (the last year available) to see if anything has changed within our study period.
We see an increase in lights on the water, perhaps light emitted from boats.

2000	2013





Conclusion

This project has demonstrated the environmental change occurring in and around Lake Naivasha through the exploration of various datasets around surface water area, NDVI, human settlement patterns, human modification, and nighttime lighting imagery.
As it relates to Lake Naivasha, the same areas which are experiencing gain of water are losing in vegetation.

In order to move forward to regulating Lake Naivasha's expansion, more effort is needed to regulate the cutting down of trees and vegetation alongside River Malewa and Gilgil which carry large amounts of sediments into the lake in the rainy season. The sediments deposited into the lake have been the biggest factor causing the lake expansion.

In [51]:

```
pip install geopandas
```

```
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheels/publi
c/simple/
Requirement already satisfied: geopandas in /usr/local/lib/python3.7/dist-packages (0.10.
2)
Requirement already satisfied: shapely>=1.6 in /usr/local/lib/python3.7/dist-packages (fr
om geopandas) (1.8.2)
Requirement already satisfied: fiona>=1.8 in /usr/local/lib/python3.7/dist-packages (from
geopandas) (1.8.21)
Requirement already satisfied: pandas>=0.25.0 in /usr/local/lib/python3.7/dist-packages (
from geopandas) (1.3.5)
Requirement already satisfied: pyproj>=2.2.0 in /usr/local/lib/python3.7/dist-packages (f
rom geopandas) (3.2.1)
Requirement already satisfied: munch in /usr/local/lib/python3.7/dist-packages (from fion
a>=1.8->geopandas) (2.5.0)
Requirement already satisfied: click-plugins>=1.0 in /usr/local/lib/python3.7/dist-packag
es (from fiona>=1.8->geopandas) (1.1.1)
Requirement already satisfied: setuptools in /usr/local/lib/python3.7/dist-packages (from
fiona>=1.8->geopandas) (57.4.0)
Requirement already satisfied: click>=4.0 in /usr/local/lib/python3.7/dist-packages (from
fiona>=1.8->geopandas) (7.1.2)
Requirement already satisfied: certifi in /usr/local/lib/python3.7/dist-packages (from fi
ona>=1.8->geopandas) (2022.6.15)
Requirement already satisfied: cligj>=0.5 in /usr/local/lib/python3.7/dist-packages (from
fiona>=1.8->geopandas) (0.7.2)
Requirement already satisfied: attrs>=17 in /usr/local/lib/python3.7/dist-packages (from
fiona>=1.8->geopandas) (21.4.0)
Requirement already satisfied: six>=1.7 in /usr/local/lib/python3.7/dist-packages (from f
iona>=1.8->geopandas) (1.15.0)
Requirement already satisfied: python-dateutil>=2.7.3 in /usr/local/lib/python3.7/dist-pa
ckages (from pandas>=0.25.0->geopandas) (2.8.2)
Requirement already satisfied: pytz>=2017.3 in /usr/local/lib/python3.7/dist-packages (fr
om pandas>=0.25.0->geopandas) (2022.1)
Requirement already satisfied: numpy>=1.17.3 in /usr/local/lib/python3.7/dist-packages (f
rom pandas>=0.25.0->geopandas) (1.21.6)
```

In [52]:

```
import numpy as np
import pandas as pd
import geopandas as gpd
import json

try:
    import geemap, ee
    import seaborn as sns
    import matplotlib.pyplot as plt
except ModuleNotFoundError:
    if 'google.colab' in str(get_ipython()):
        print("package not found, installing w/ pip in Google Colab...")
        !pip install geemap seaborn matplotlib

    import geemap, ee
    import seaborn as sns
    import matplotlib.pyplot as plt
```

In [53]:

```
try:
  ee.Initialize()
except Exception as e:
  ee.Authenticate()
  ee.Initialize()
```

In [54]:

```
# path = '/content/glwd_1.shp'
# path = '/content/KEN_Lakes.shp'
path = '/content/lake_naivasha.shp'
# path = '/content/ke_waterbodies.shp'
roi_gdf = gpd.read_file(path)

roi_gdf = roi_gdf.loc[roi_gdf.index == 0]
# roi_gdf = roi_gdf.loc[roi_gdf.LAKE == "Lake Naivasha"]
# roi_gdf = roi_gdf.loc[roi_gdf.index == 82]

roi_gdf
```

Out[54]:

	Id	geometry
0	0	POLYGON ((36.29363 -0.80432, 36.29589 -0.80354...

In [55]:

```
def shp_to_ee_fmt(geodf):
    data = json.loads(geodf.to_json())
    return data['features'][0]['geometry']['coordinates']

# create the ee object
lakenaivasha = ee.Geometry.MultiPolygon(shp_to_ee_fmt(roi_gdf))
```

In [56]:

```
map = geemap.Map()
map.centerObject(lakenaivasha, 12)
map.addLayer(lakenaivasha, {}, 'Lake Naivasha')
```

In [57]:

```
bounding_box = lakenaivasha.bounds()
map.addLayer(bounding_box, {}, 'Bounding Box')
```

In [58]:

```
# buffer zone

buffer = lakenaivasha.buffer(700)

# find area of Lake Naivasha
area = ee.Number(lakenaivasha.area())
print("Area of Lake Naivasha in sq. metres", area.getInfo())
```

```
Area of Lake Naivasha in sq. metres 160315324.14867967
```

In [59]:

```
# examine surface water from 1898 to 2019 using an image
surfacewater = ee.Image("JRC/GSW1_3/GlobalSurfaceWater").clip(lakenaivasha).select('chan
ge_abs')
surfacewater_norm_change = ee.Image("JRC/GSW1_3/GlobalSurfaceWater").clip(lakenaivasha).
select('change_norm')
surfacewater_occurrence = ee.Image("JRC/GSW1_3/GlobalSurfaceWater").clip(lakenaivasha).s
elect('occurrence')
# map.addLayer(surfacewater, {"min": -100, "max": 75, "palette": ["#fc8d59","#ffffbf","#9
1bfdb"]}, "Surface water from change_abs")
# map.addLayer(surfacewater_norm_change, {"min": -100, "max": 75, "palette": ["#fc8d59","
#ffffbf","#91bfdb"]}, "Surface water from change_norm")
# map.addLayer(surfacewater_occurrence, {"min": -100, "max": 75, "palette": ["#fc8d59","#
ffffbf","#91bfdb"]}, "Surface water from occurrence")
```

In [60]:

```
waterorno = ee.ImageCollection("JRC/GSW1_3/MonthlyHistory").filter(ee.Filter.date("2001-
```

```
01-01", "2003-12-31")).mean().clip(lakenaivasha)
# multiply by ee.image to get the sq metres of each pixel area
wateronoBaseline = waterorno.multiply(ee.Image.pixelArea())
map.addLayer(wateronoBaseline, {"min": 1000, "max": 10000, "palette": ["#d7191c", "#fdae
61","#ffffbf","#abd9e9","#2c7bb6"]}, "Water Area Baseline")

waterornoCurr = ee.ImageCollection("JRC/GSW1_3/MonthlyHistory").filter(ee.Filter.date("2
019-01-01", "2021-12-31")).mean().clip(lakenaivasha).multiply(ee.Image.pixelArea())
map.addLayer(waterornoCurr, {"min": 1000, "max": 10000, "palette": ["#d7191c", "#fdae61",
"#ffffbf","#abd9e9","#2c7bb6"]}, "Water Area Current")

waterornoDiff = waterornoCurr.subtract(wateronoBaseline)
map.addLayer(waterornoDiff, {"min": 1500, "max": 4000, "palette": ["#d7191c", "#fdae61","
#ffffbf","#abd9e9","#2c7bb6"]}, "Water Area Difference")
```

In [61]:

```
# def Naivasha_mean(feature):
#   # calculate spatial sum value for each area
#   reduced1 = wateronoBaseline.reduceRegion(reducer = ee.Reducer.sum(), geometry = featu
re, scale= 500)
#   reduced2 = waterornoCurr.reduceRegion(reducer= ee.Reducer.sum(), geometry= feature, s
cale= 500)

#   return feature.set(waterorno_base = reduced1.get('water'), waterorno_curr = reduced2.
get('water'))

reduced1 = wateronoBaseline.reduceRegion(reducer = ee.Reducer.sum(), geometry = lakenaiv
asha, scale = 500)
waterorno_base = ee.Number(reduced1.get('water'))
reduced2 = waterornoCurr.reduceRegion(reducer = ee.Reducer.sum(), geometry = lakenaivash
a, scale = 500)
waterorno_curr = ee.Number(reduced2.get('water'))

print("Surface Water Area of Baseline 2001 - 2003", waterorno_base.getInfo())
```

```
Surface Water Area of Baseline 2001 - 2003 155985731.55696854
```

In [62]:

```
print("Surface Water Area of Current 2019 - 2021", waterorno_curr.getInfo())
```

```
Surface Water Area of Current 2019 - 2021 287364035.26921725
```

In [63]:

```
waterorno_percentage = (waterorno_curr.subtract(waterorno_base)).divide(waterorno_base).m
ultiply(100)
waterorno_percentage = ee.Number(waterorno_percentage).getInfo()
print((waterorno_percentage), "Percent change difference in Surface Water Area")
```

```
84.22456490148087 Percent change difference in Surface Water Area
```

In [64]:

```
waterorno_difference = waterorno_curr.subtract(waterorno_base)
waterorno_difference = ee.Number(waterorno_difference).getInfo()
print(waterorno_difference, "Difference in Surface Water Area")
```

```
131378303.71224871 Difference in Surface Water Area
```

NDVI

In [65]:

```
modis = ee.ImageCollection("MODIS/061/MOD13A1").select('NDVI')
# multiply each pixel by scaling factor to get the NDVI values
ndvi_naivasha_baseline = modis.filter(ee.Filter.date("2001-01-01", "2003-12-31")).mean()
.multiply(0.0001).clip(lakenaivasha)
map.addLayer(ndvi_naivasha_baseline, {"min": -.08, "max": .267, "palette":["blue", "yell
```

```
ow", "green"]}, "NDVI Lake Naivasha Baseline")

ndvi_naivasha_current = modis.filter(ee.Filter.date("2019-01-01", "2021-12-31")).mean().
multiply(0.0001).clip(lakenaivasha)
map.addLayer(ndvi_naivasha_current, {"min": -.08, "max": .267, "palette":["blue", "yello
w", "green"]}, "NDVI Lake Naivasha Currrent")

ndvi_naivasha_difference = ndvi_naivasha_current.subtract(ndvi_naivasha_baseline)
map.addLayer(ndvi_naivasha_difference, {"min": -.05, "max": .1, "palette":["blue", "yell
ow", "green"]}, "NDVI Lake Naivasha Difference")
```

In [66]:

```
# Mean
reduced1 = ndvi_naivasha_baseline.reduceRegion(reducer = ee.Reducer.sum(), geometry = la
kenaivasha, scale = 500)
ndvi_base = ee.Number(reduced1.get('NDVI'))
reduced2 = ndvi_naivasha_current.reduceRegion(reducer = ee.Reducer.sum(), geometry = lak
enaivasha, scale = 500)
ndvi_curr = ee.Number(reduced2.get('NDVI'))

print(ndvi_base.getInfo(), "Area of Baseline NDVI (2001 - 2003)")
```

```
90.9447032509237 Area of Baseline NDVI (2001 - 2003)
```

In [67]:

```
print(ndvi_curr.getInfo(), "Area of Current NDVI (2019 - 2021)")
```

```
73.19780325751778 Area of Current NDVI (2019 - 2021)
```

In [68]:

```
ndvi_percentage = (ndvi_curr.subtract(ndvi_base)).divide(ndvi_base).multiply(100)
print(ndvi_percentage.getInfo(), "NDVI Percentage change") # Large percentage change does
not mean anything
```

```
-19.513945682400884 NDVI Percentage change
```

In [69]:

```
ndvi_difference = ndvi_curr.subtract(ndvi_base)
print(ndvi_difference.getInfo(), "NDVI Difference")
```

```
-17.74689999340592 NDVI Difference
```

In [70]:

```
# Plot a histogram to show the NDVI difference
```

In [71]:

```
# NDVI of buffer zone 500m around the lake

ndvi_bb_baseline = modis.filter(ee.Filter.date("2001-01-01", "2003-12-31")).mean().multi
ply(0.0001).clip(buffer)
map.addLayer(ndvi_bb_baseline, {"min": .05, "max": .17, "palette": ["blue", "yellow", "g
reen"]}, "NDVI Buffer Baseline")

ndvi_bb_current = modis.filter(ee.Filter.date("2019-01-01", "2021-12-31")).mean().multip
ly(0.0001).clip(buffer)
map.addLayer(ndvi_bb_current, {"min": .05, "max": .17, "palette": ["blue", "yellow", "gr
een"]}, "NDVI Buffer Current")

bb_difference = (ndvi_bb_current.subtract(ndvi_bb_baseline))
map.addLayer(bb_difference, {"min": .05, "max": .17, "palette": ["blue", "yellow", "gree
n"]}, "NDVI Buffer Difference")
```

Man-Made Development

In [72]:

```
builtUpMultitemporal = ee.Image("JRC/GHSL/P2016/BUILT_LDSMT_GLOBE_V1").select('built').c
lip(buffer)
visParams = {"min": 1.0, "max": 6.0, "palette": ["0c1d60", "000000", "448564", "70daa4",
"ffffff"]}
map.addLayer(builtUpMultitemporal, visParams, "Built_UP Multitemporal")

# Year 2000
# settlementInit = ee.ImageCollection("JRC/GHSL/P2016/SMOD_POP_GLOBE_V1").filter(ee.Filte
r.date('2000-01-01', '2013-12-31')).map(
#     def ClipImage(image):
#       return image.clip(buffer)
# )
settlementInit = ee.ImageCollection("JRC/GHSL/P2016/SMOD_POP_GLOBE_V1").filter(ee.Filter
.date('2000-01-01', '2000-12-31')).median().clip(buffer)
visParams = {"min": 0.0, "max": 3.0, "palette": ["000000", "448564", "70daa4", "ffffff"]}
map.addLayer(settlementInit, visParams, "Degree of Urbanization Initial (2000)")

# Year 2013
settlementInit = ee.ImageCollection("JRC/GHSL/P2016/SMOD_POP_GLOBE_V1").filter(ee.Filter
.date('2013-01-01', '2013-12-31')).median().clip(buffer)
visParams = {"min": 0.0, "max": 3.0, "palette": ["000000", "448564", "70daa4", "ffffff"]}
map.addLayer(settlementInit, visParams, "Degree of Urbanization Current (2013)")

# Year 1975
settlementInit = ee.ImageCollection("JRC/GHSL/P2016/SMOD_POP_GLOBE_V1").filter(ee.Filter
.date('1975-01-01', '1975-12-31')).median().clip(buffer)
visParams = {"min": 0.0, "max": 3.0, "palette": ["000000", "448564", "70daa4", "ffffff"]}
map.addLayer(settlementInit, visParams, "Degree of Urbanization 1975")
```

Global Human Modification

In [73]:

```
modification = ee.ImageCollection("CSP/HM/GlobalHumanModification").select('gHM').median
().clip(buffer)
visualization = {"min": 0.0, "max": 1.0, "palette": ["0c0c0c", "071aff", "ff0000", "ffbd0
3", "fbff05", "fffdfd"]}
map.addLayer(modification, visualization, "Human Modification")
```

Night Time Lights

In [74]:

```
nightLightImages = ee.ImageCollection("NOAA/DMSP-OLS/NIGHTTIME_LIGHTS").select('stable_l
ights')

# Persistent lighting from the 2000 dataset
nighttime2000 = nightLightImages.filter(ee.Filter.date('2000-01-01', '2000-12-31')).media
n().clip(buffer)
map.addLayer(nighttime2000, {"min": 0, "max": 63, "palette": ['1d4877','1b8a5a','f68838',
'ee3e32'], "opacity": 0.9}, "Night Time Lights 2000")

# Persistent lighting from the 2013 dataset
nighttime2013 = nightLightImages.filter(ee.Filter.date('2013-01-01', '2013-12-31')).media
n().clip(buffer)
map.addLayer(nighttime2013, {"min": 0, "max": 63,  "opacity": 0.9}, "Night Time Lights 2
013")
```

In [75]:

```
map
```

In [75]:

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```