National Aeronautics and Space Administration

Humanitarian Applications Using NASA Earth Observations

Part 3: Detecting Agricultural and Vegetation Changes In and Surrounding Refugee Settlements

June 21, 2022

Outline

This webinar series is scheduled around **World Refugee Day** on **June 20, 2022**, and includes four parts:

Part 1: Monitoring Urban Damage with InSAR (14 June)

Part 2: Mapping Refugee Settlement Growth and Population Change (16 June)

Part 3: Detecting Agricultural and Vegetation Changes In and Surrounding Refugee Settlements (21 June)

Part 4: Assessing Climate Hazards at Refugee Camps (23 June)

Each part is 2 hours long, including a question-and-answer session at the conclusion.

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Part 3: Detecting Agricultural and Vegetation Changes In and Surrounding Refugee Settlements

Motivation

- Ensuring refugee food security and protecting land quality is a central humanitarian goal
- Many refugee settlements are inhabited for years, and in some cases, generations, adding new pressures to land management
- Satellite data are useful for monitoring agricultural and vegetation condition especially when physical accessibility may be limited

Goals

- Map vegetation dynamics within and surrounding refugee settlements
- Visualize and measure changes in agricultural condition over time
- Measure changes in land degradation metrics before and following settlement establishment

Homework and Certificate

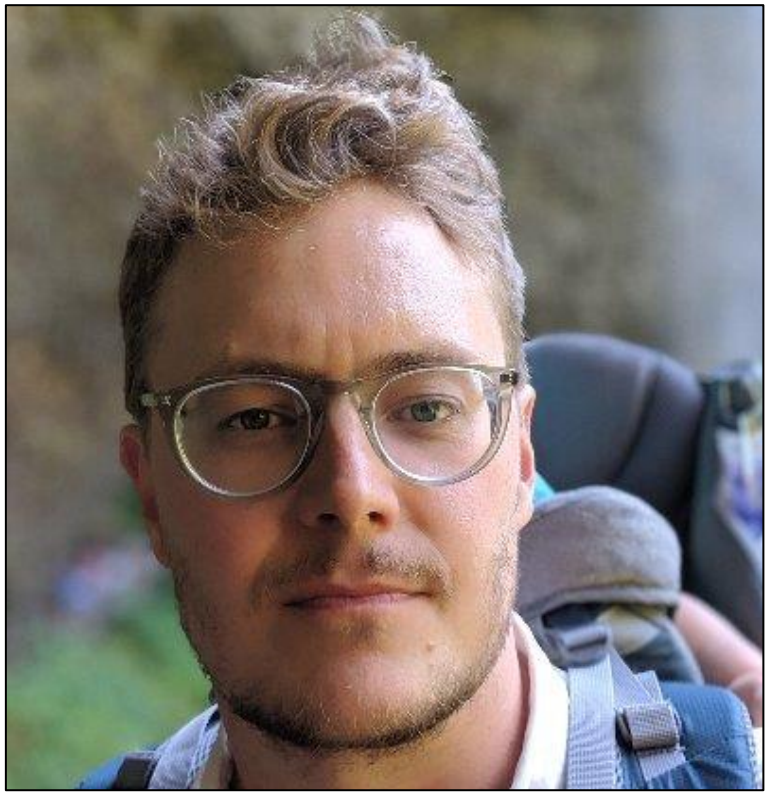
- **Homework Assignment:**
  - There will be one homework assignment for this webinar series
  - Answers must be submitted via Google Form found on training page
  - Due Date: July 7, 2022
- **A certificate of completion will be awarded to those who:**
  - Attend all live webinars
  - Complete the homework assignment by the deadline
  - You will receive a certificate approximately two months after the completion of the course from: marines.martins@ssaihq.com

Meet your presenters!

Hannah Friedrich

PhD student

University of Arizona



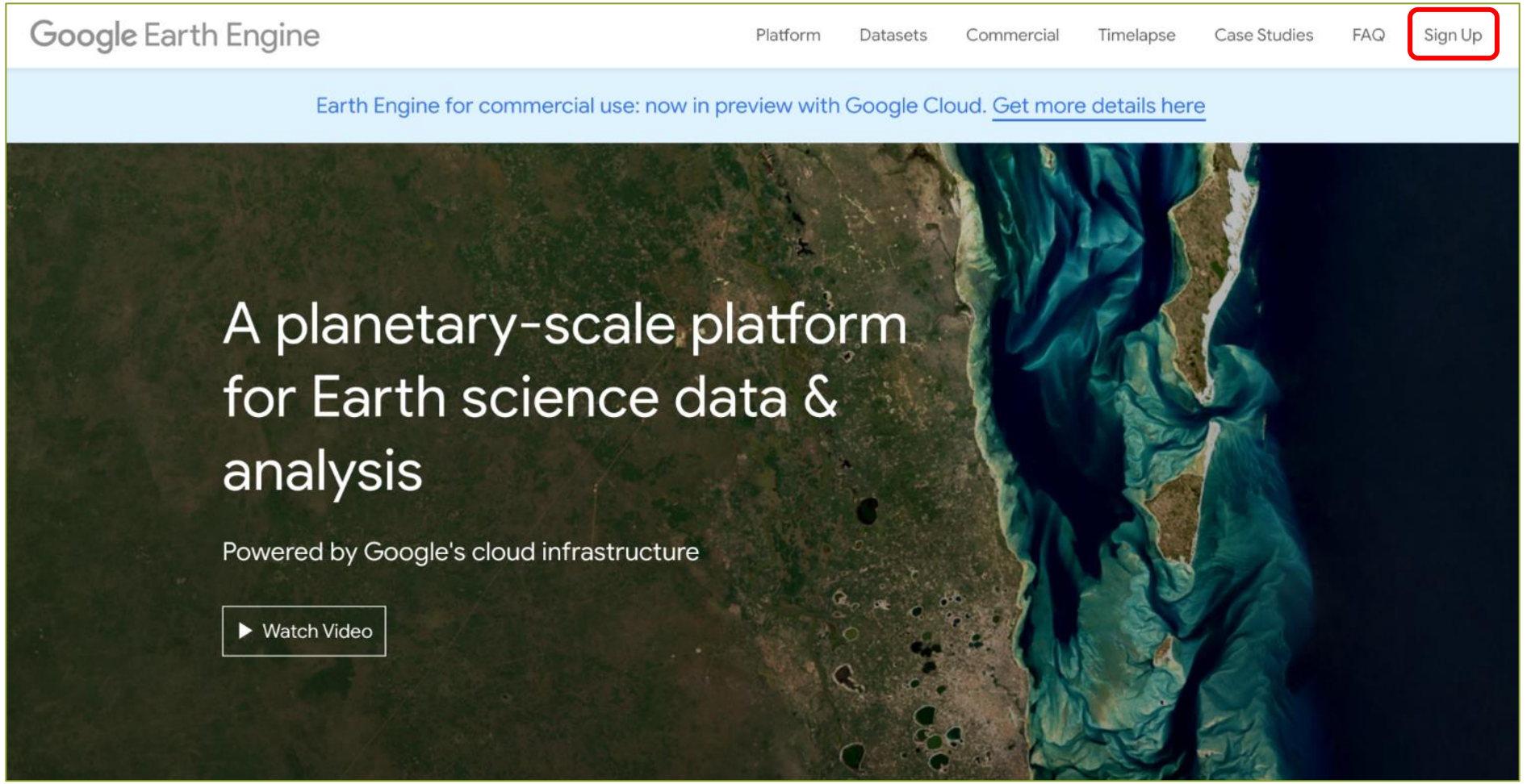
Jamon Van Den Hoek

Associate Professor of Geography

Oregon State University

We will be using Google Earth Engine for our analyses.

If you haven't already, navigate to the Google Earth Engine site, and click *Sign-Up*.



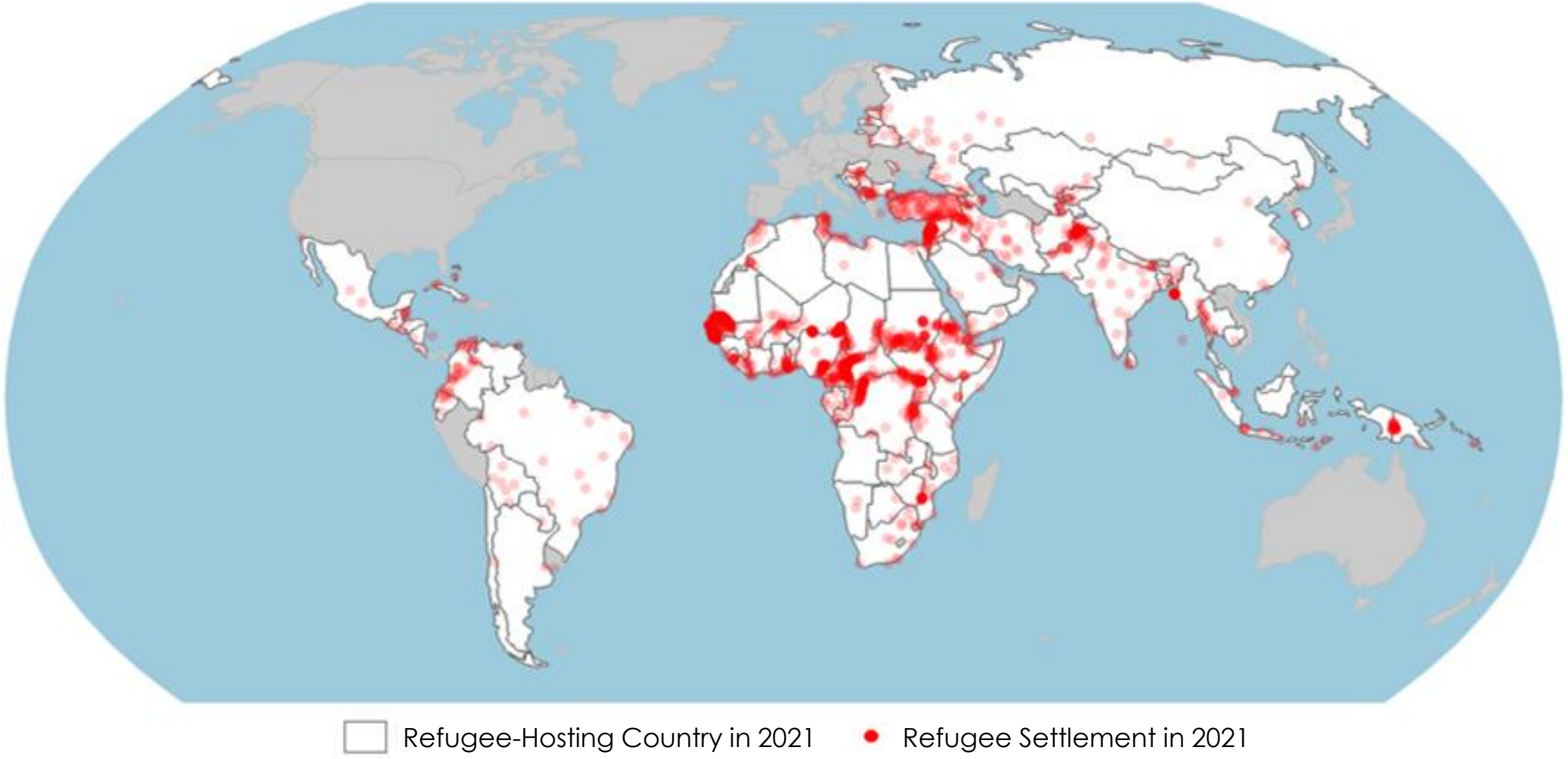
Prerequisites

- Fundamentals of Remote Sensing
- Using Google Earth Engine for Land Monitoring Applications
- Satellite Remote Sensing for Agricultural Applications
- Remote Sensing for Monitoring Land Degradation and Sustainable Cities SDGs
- Investigating Time Series of Satellite Imagery

Background:

Why is it important to monitor vegetation changes in and surrounding refugee settlements?

At the end of 2021, there were 26 million refugees across 170 of the world's 195 countries.



Map by Van Den Hoek

Refugees are international migrants who have been forcibly displaced from their home countries due to violence or persecution and have been granted protection under international law.

Source: UNWRA (2021)

Syria – 6.7 million refugees mainly in Turkey, Jordan, and Lebanon (UNHCR, 2022)

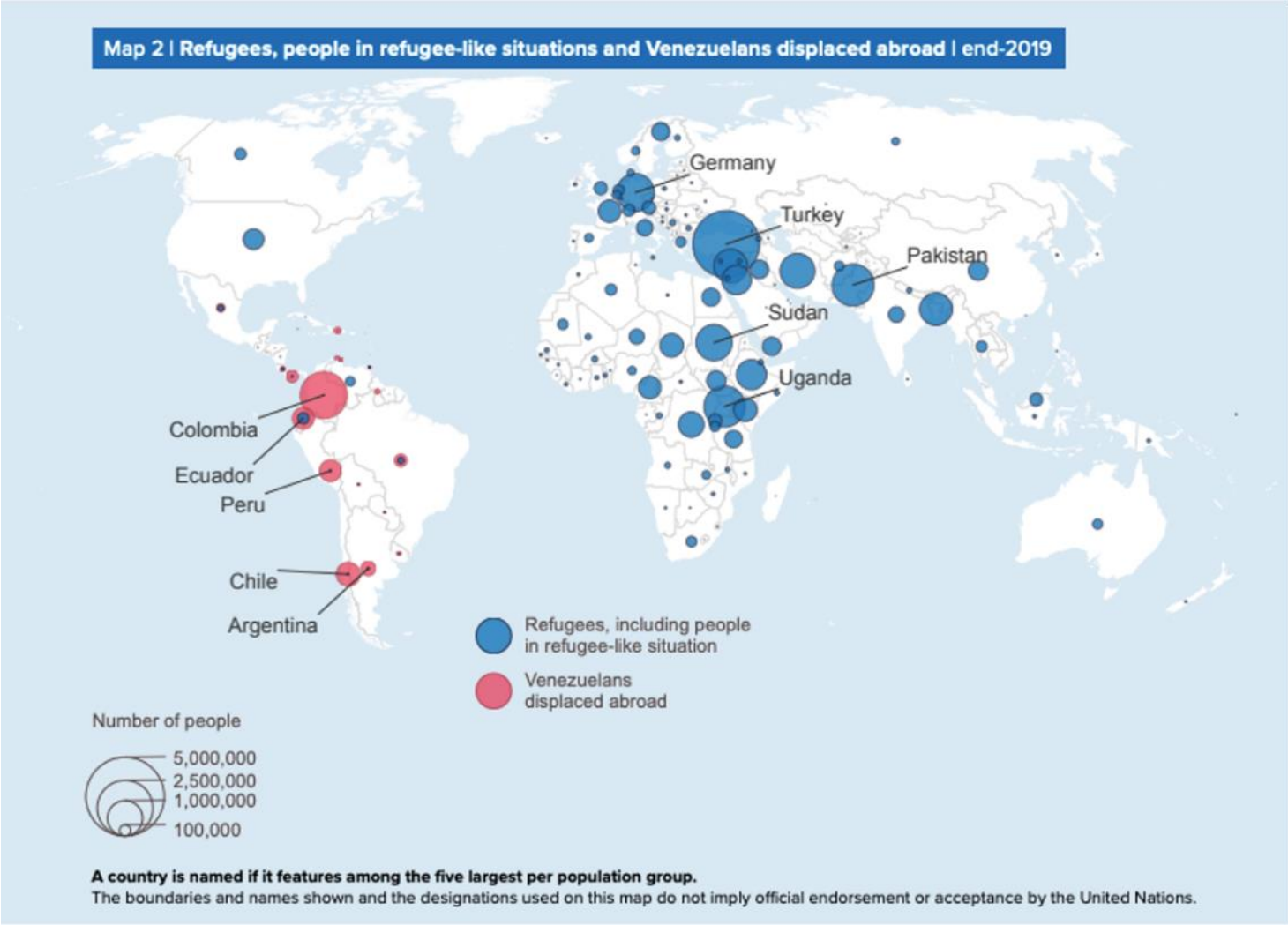
73% of refugees seek asylum in neighboring countries.

Source: UNHCR (2016)

Source: WorldVision (2017)

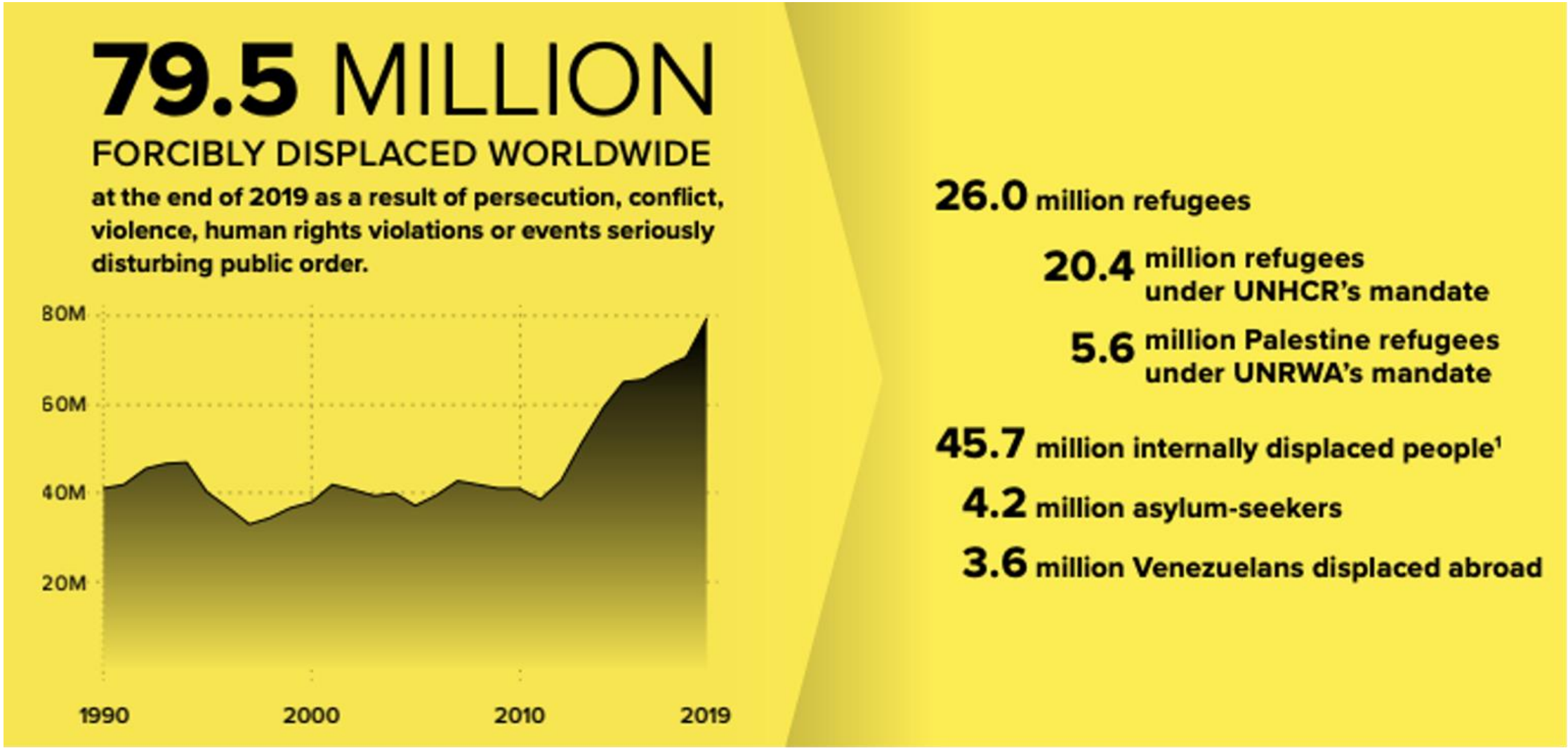
South Sudan - 2.2 million refugees mainly in Kenya and Uganda (UNHCR, 2022)

Developing countries host 86% of the world's refugees.



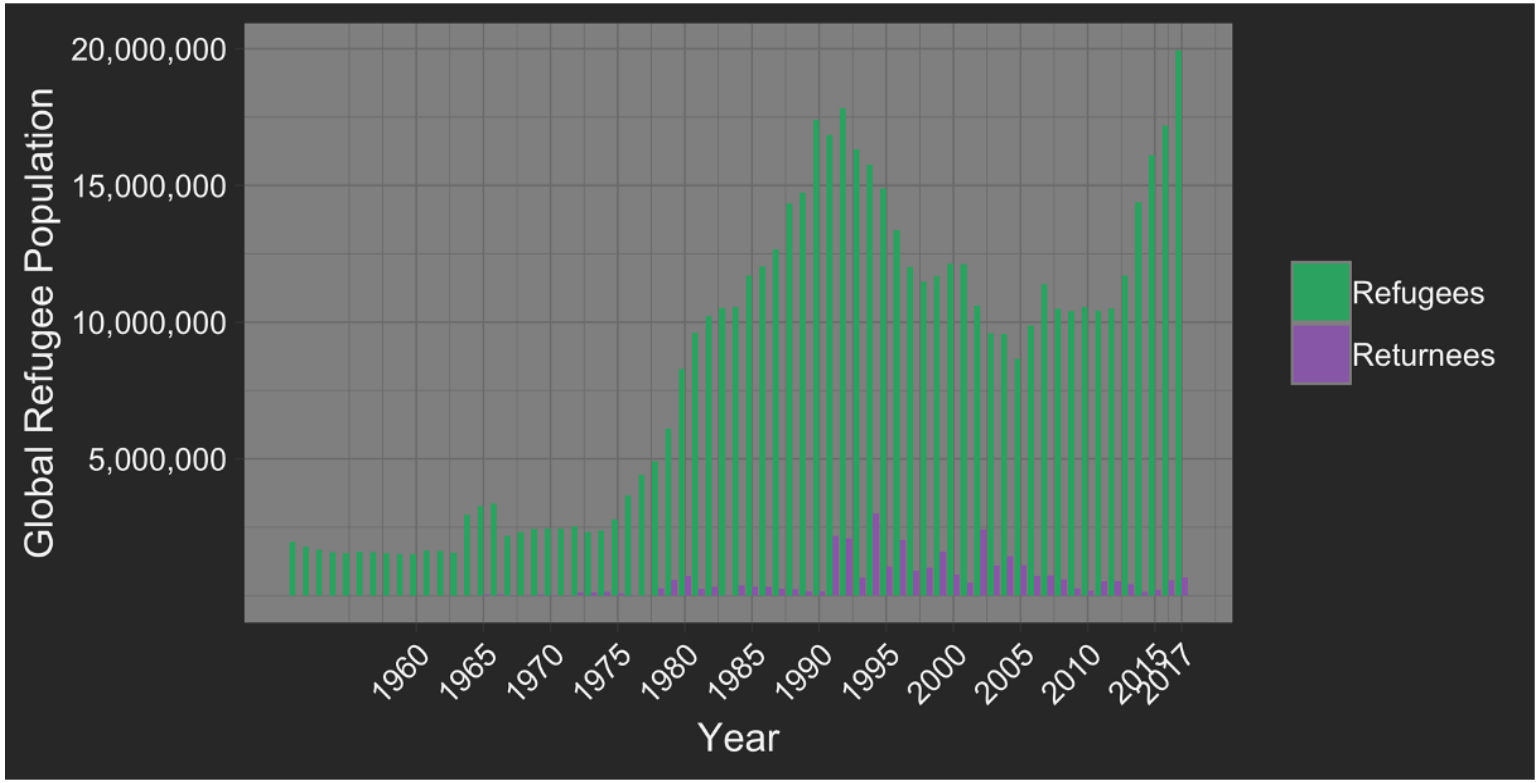
Source: UNHCR (2020)

Since 2010, the global forcibly displaced population has doubled.



Source: UNHCR (2020)

Two out of three refugees are in protracted refugee situations.

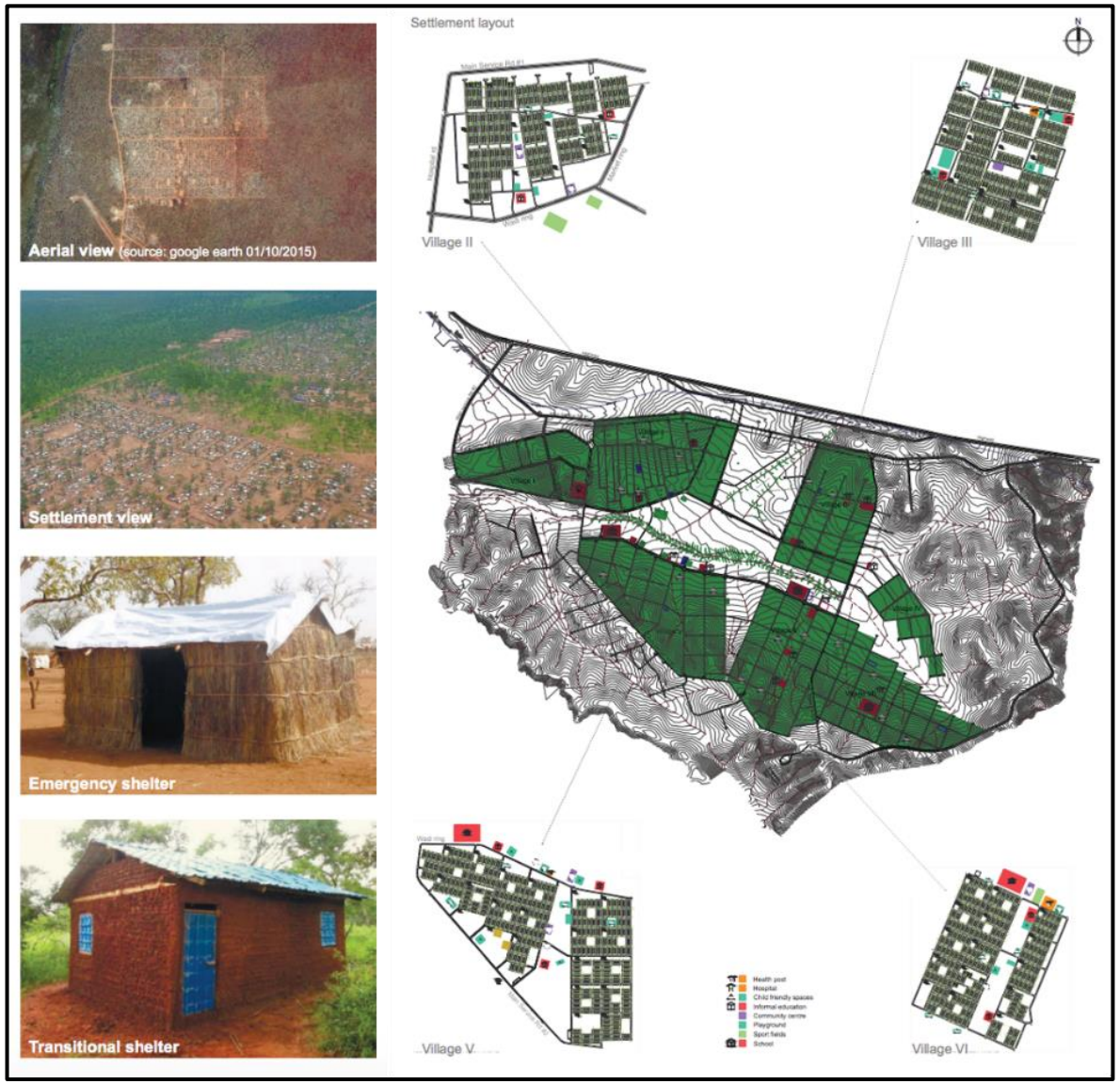


Source: UNHCR (2018)

- Protracted refugee situations are defined as '25,000 or more refugees from the same nationality have been in exile for five consecutive years or more in a given asylum country'.
- The growth of the global refugee population outpaces the number of returnees every year

United Nations High Commissioner for Refugees (UNHCR) shelters nearly a third of global refugees in settlements.

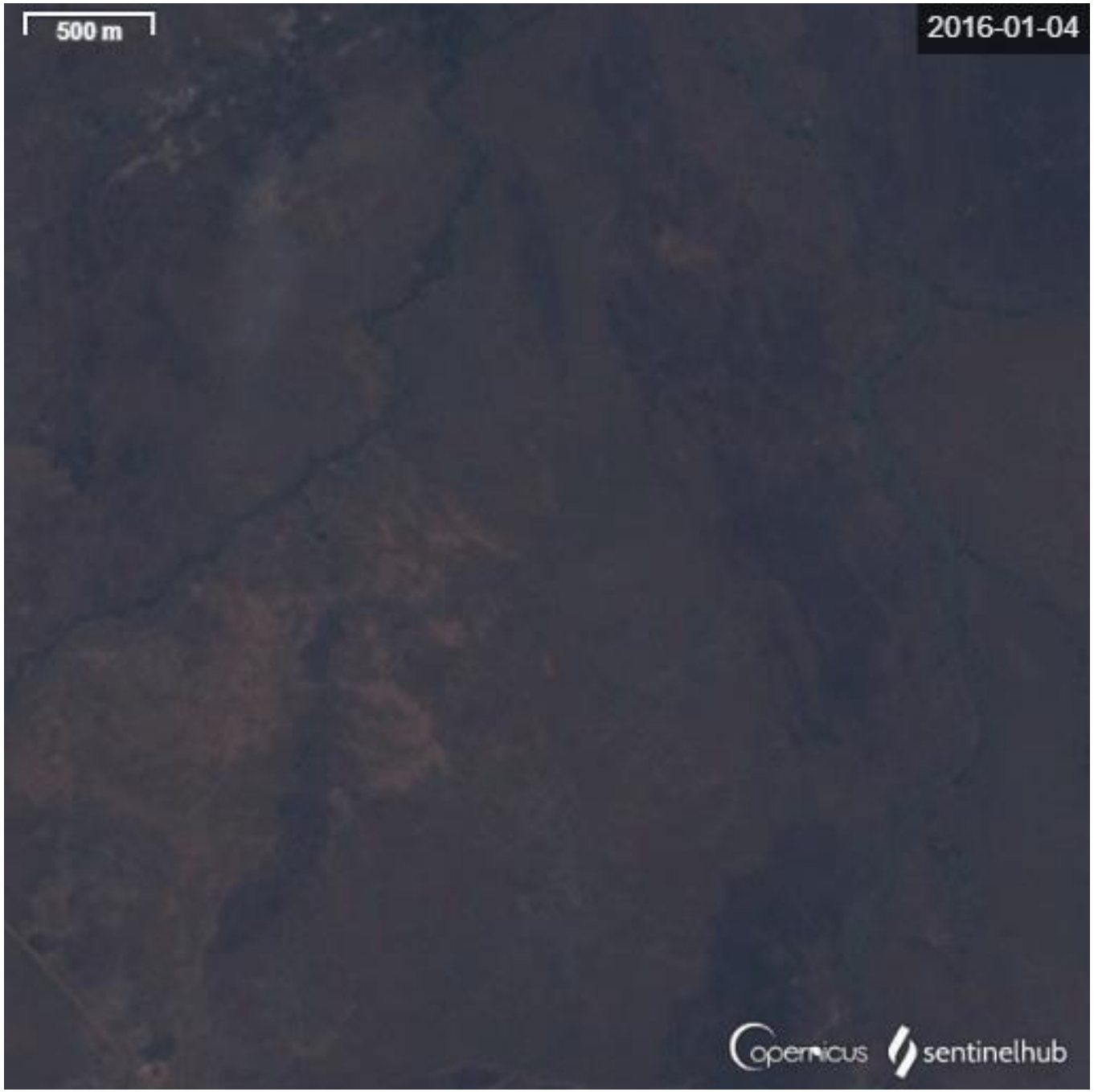
- There are many challenges with UNHCR site planning:
  - Ensuring sufficient space for shelter and agriculture
  - Efficiently distributing aid
  - Providing access to services within and nearby settlements
  - Mitigating environmental damage



Source: UNHCR (2018)

Due to the need for immediate relief, refugee settlements tend to be rapidly established and populated.

Much geospatial data on dwellings, land use, and infrastructure are collected during these initial months following refugee arrival.



UNHCR-managed refugee camps can be unplanned (left) or planned (right), resulting in a diverse pattern (i.e., spatial arrangement) of land covers and land uses between settlements.

Source: MAXAR/DigitalGlobe

Approximately one-third of refugees live in camps, including well-known camps of Za'atari, Jordan (left) and Kutupalong, Bangladesh (right).

Source: MAXAR/DigitalGlobe

Camp siting and conditions conform to the local context.

A Rohingya refugee camp in Bangladesh…

Source: Guardian (2017)

…looks very different from a Syrian refugee camp in Jordan.

Source: Getty Images (2013)

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- Satellite data are flexible and can be adapted to support different lines of inquiry at different stages of a settlement's lifespan.
- Satellite-derived information on environmental and climatic conditions in and around refugee settlements help to localize insights on refugee livelihoods, sustainable development, disaster risk reduction, and climate adaptation.

Why do we need to understand refugee settlement dynamics?

- Refugee settlements are dynamic landscapes.
  - Time series visualizations of satellite imagery can be especially helpful.
- Refugee settlements grow quickly to accommodate arriving and departing populations.
- It is common to see a variety of landscape changes across a settlement, such as grassland converted to built-up, or forest converted to agriculture.
- The complexity of refugee settlement establishment and growth means that a systematized method for tracking settlement growth can inform better site planning and aid distribution.
  - Assessing **bi-temporal change** allows for comparisons before and after settlement establishment.
  - Assessing **multi-temporal change** allows for finer temporal measurement of change for a variety of land cover transitions.

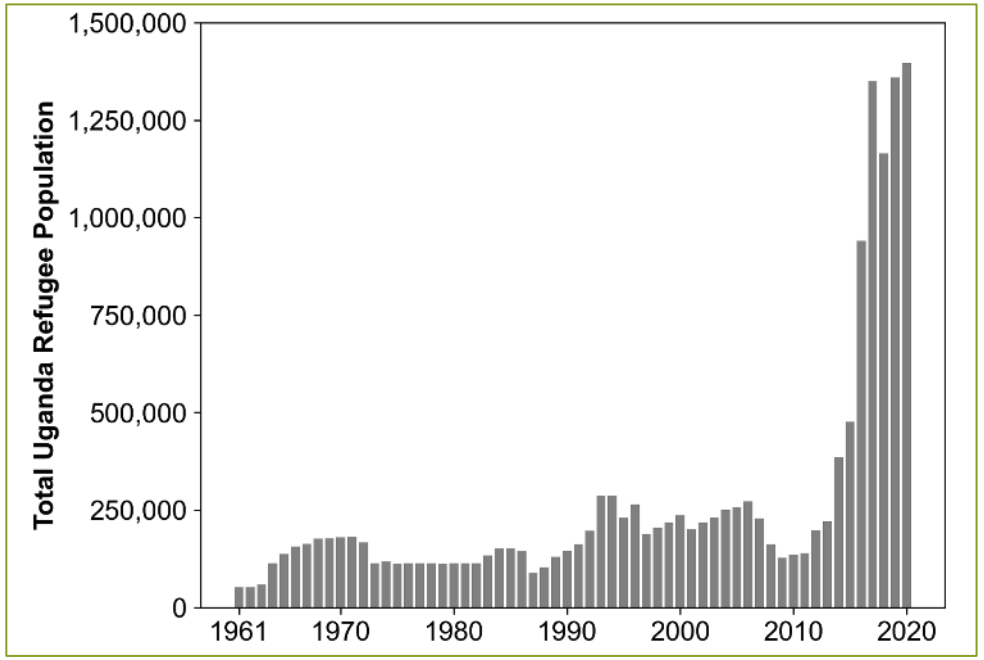
Case Study: Refugee Settlements in Uganda and Jordan

Our case study analysis focuses on refugee settlements in Uganda.

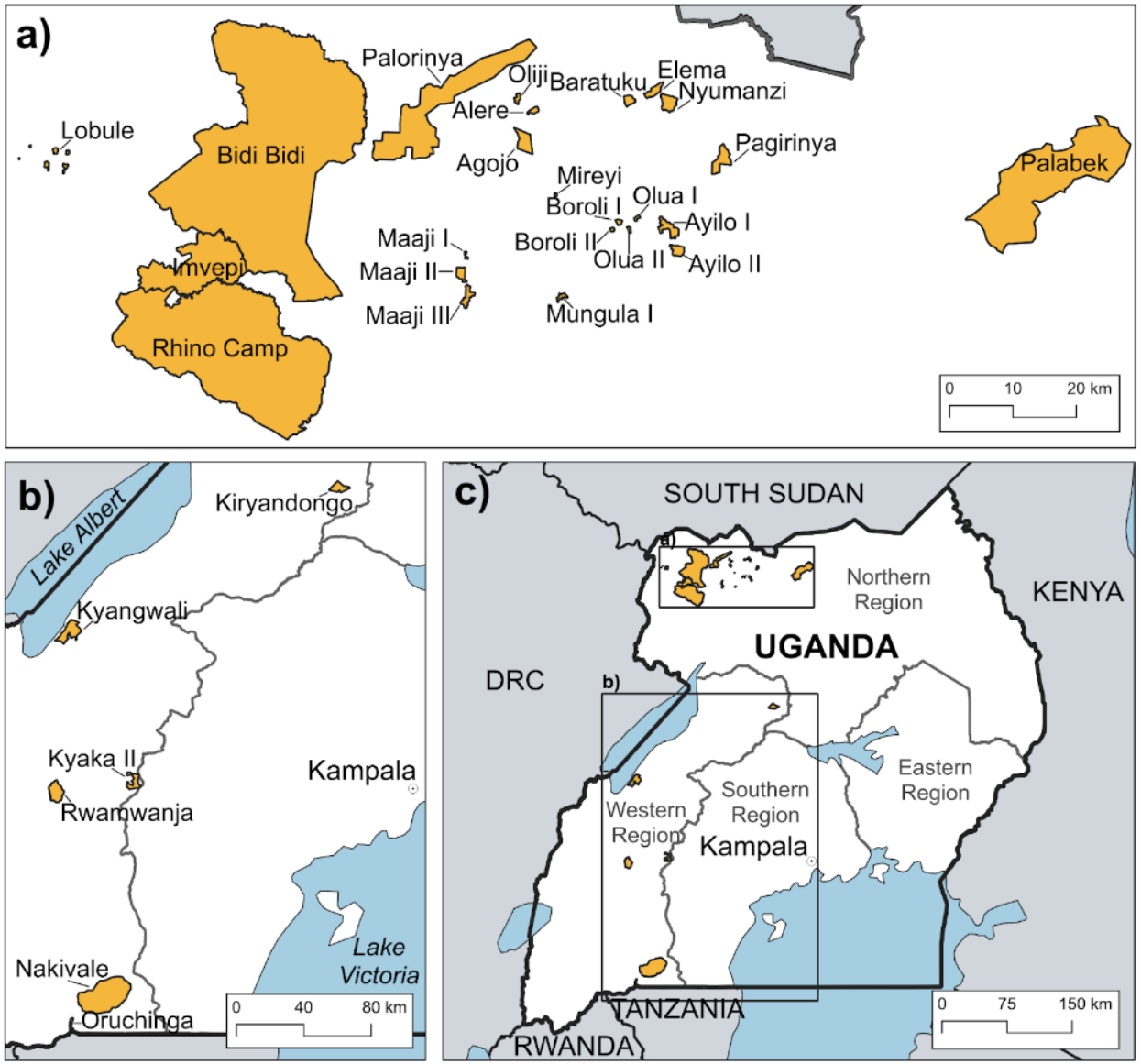
- The current total refugee population in Uganda is 1.4 million, primarily from South Sudan (950k) and Democratic Republic of the Congo (444k).
- Refugees in UNHCR-managed settlements are allocated a plot of land for their dwelling and agriculture, and granted access to services, such as health care, education, and freedom of movement.
- Uganda's refugee policy is framed around supporting refugee 'self-reliance' and has been widely praised.

Source: UNHCR (2017)

There are 32 UNHCR-Managed Refugee Settlements in Uganda.



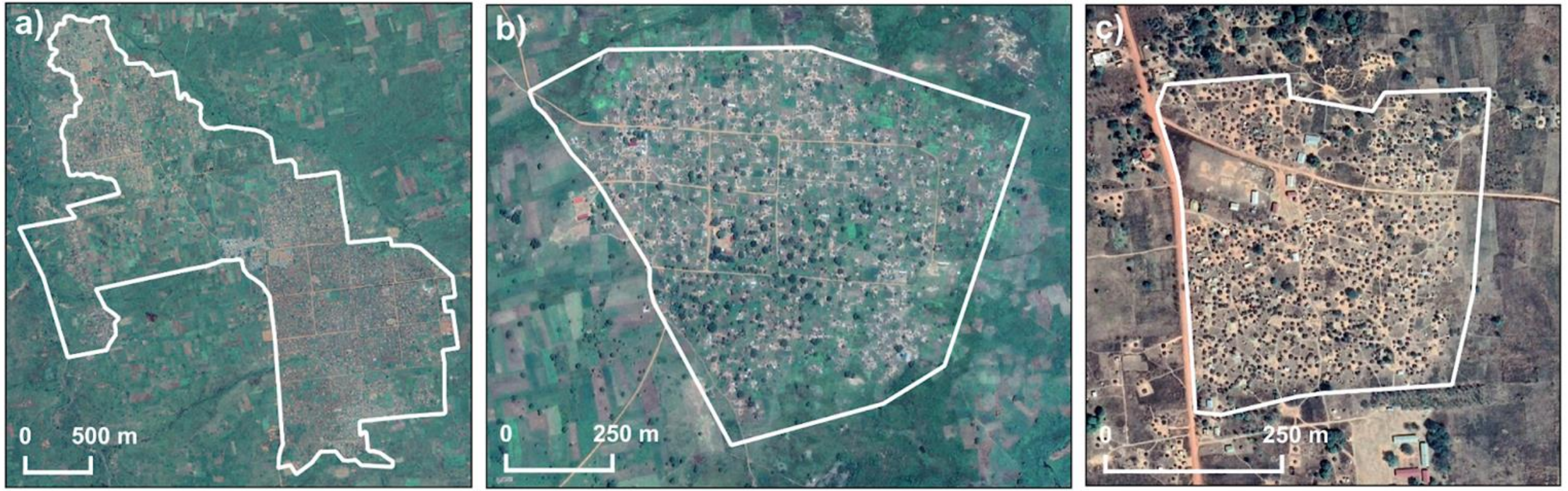
Source: Van Den Hoek & Friedrich (2021)



Ayilo I

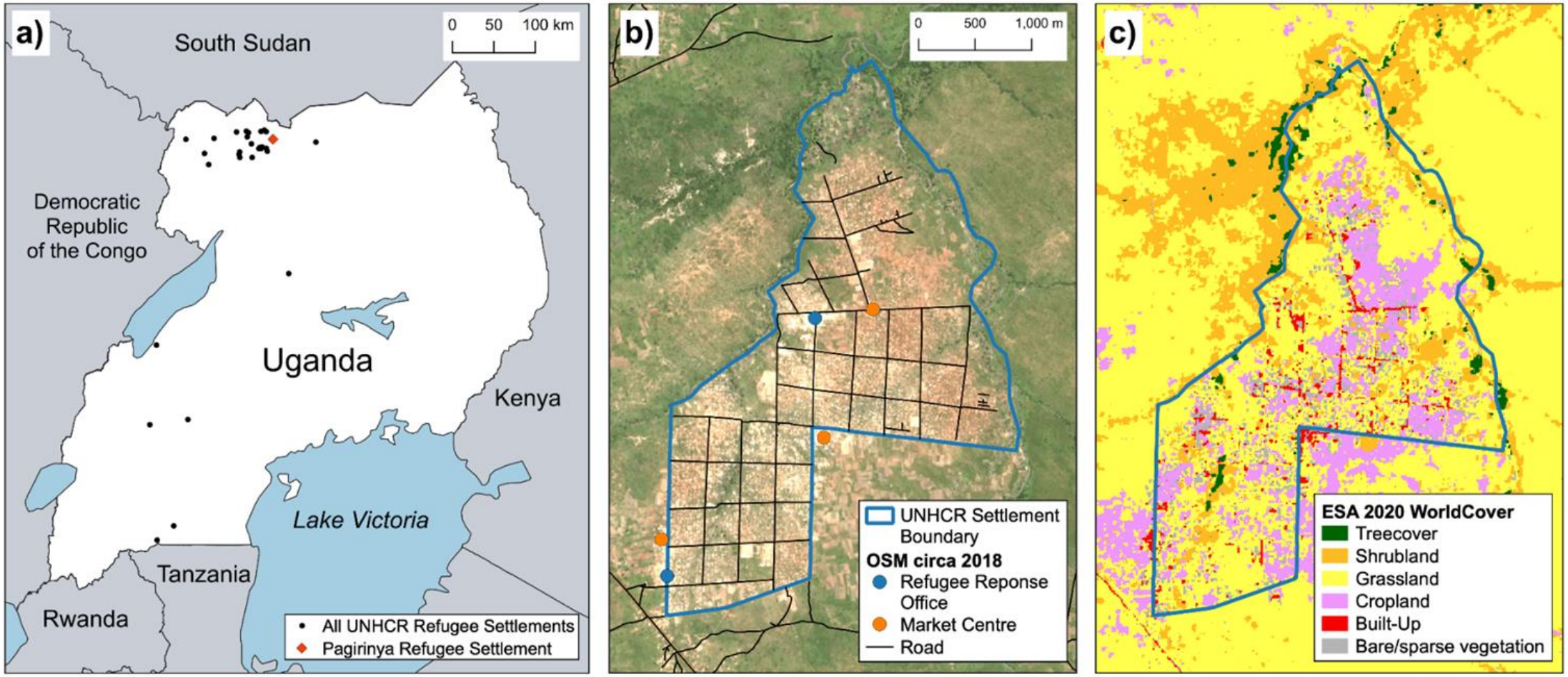
Boroli I

Mireyi



Source: Van Den Hoek & Friedrich (2021)

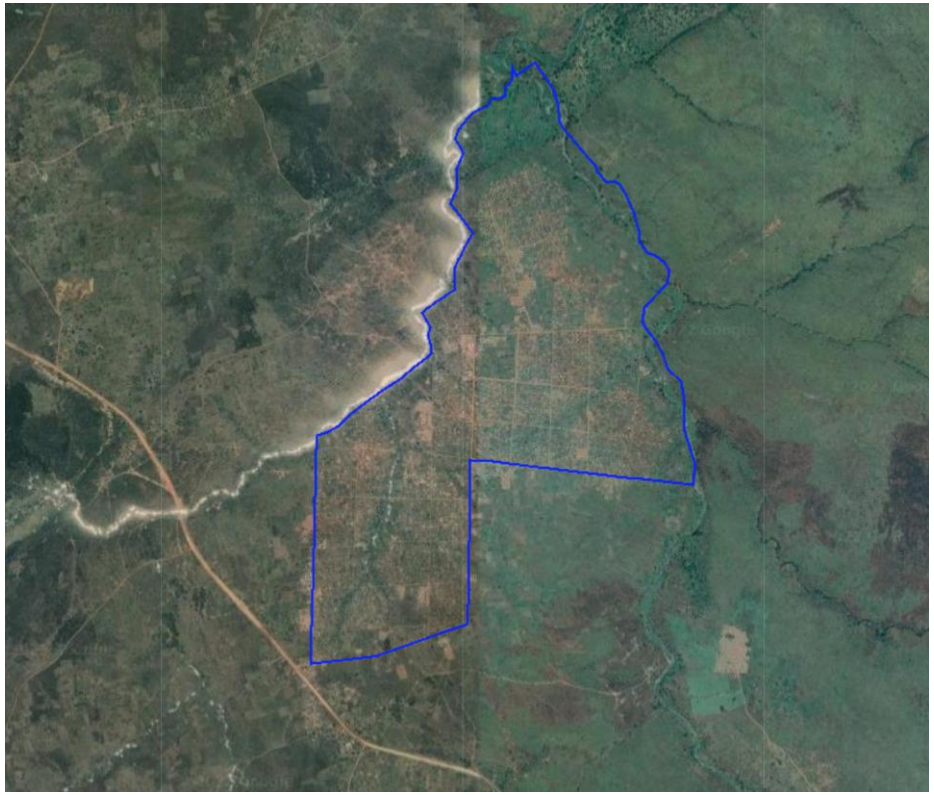
We'll focus on Pagirinya Refugee Settlement, established in 2016.



Source: Van Den Hoek & Friedrich *(forthcoming)*

Pagirinya Refugee Settlement

- Opened in 2016
- Located in northern Uganda
- Hosts ~36,000 refugees from South Sudan



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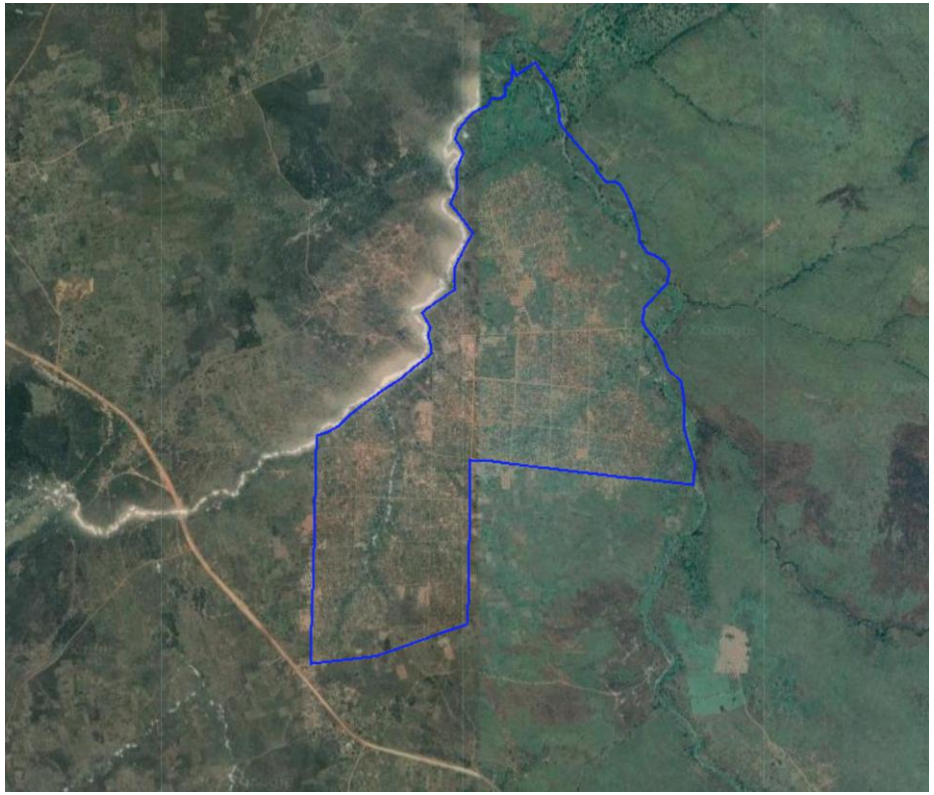


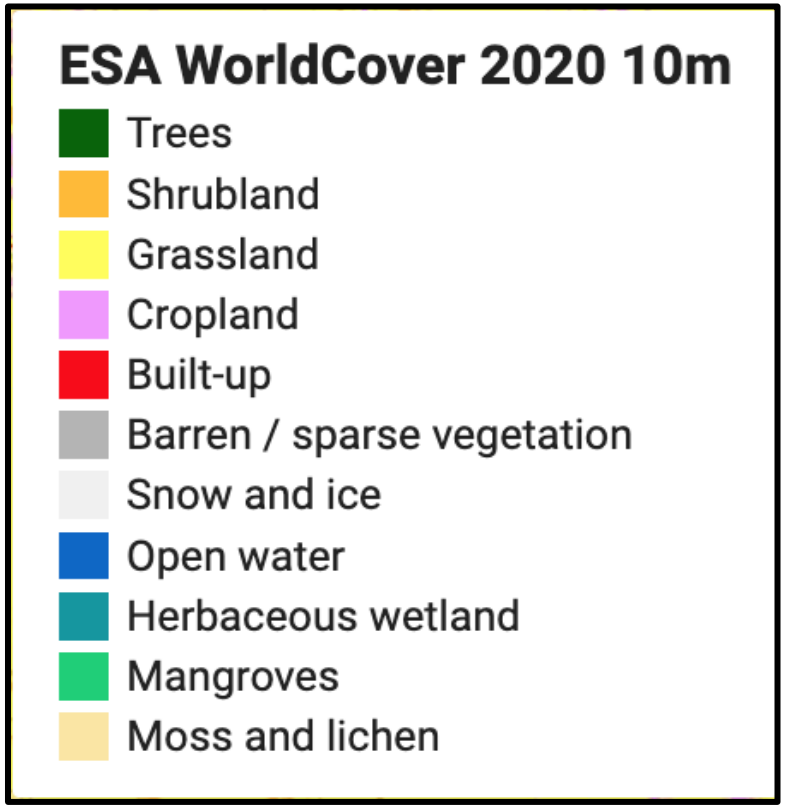
For comparison, let's also look at
Za'atari Refugee Settlement

- Opened in 2012
- Located in northern Jordan
- Hosts ~80,000 refugees from Syria

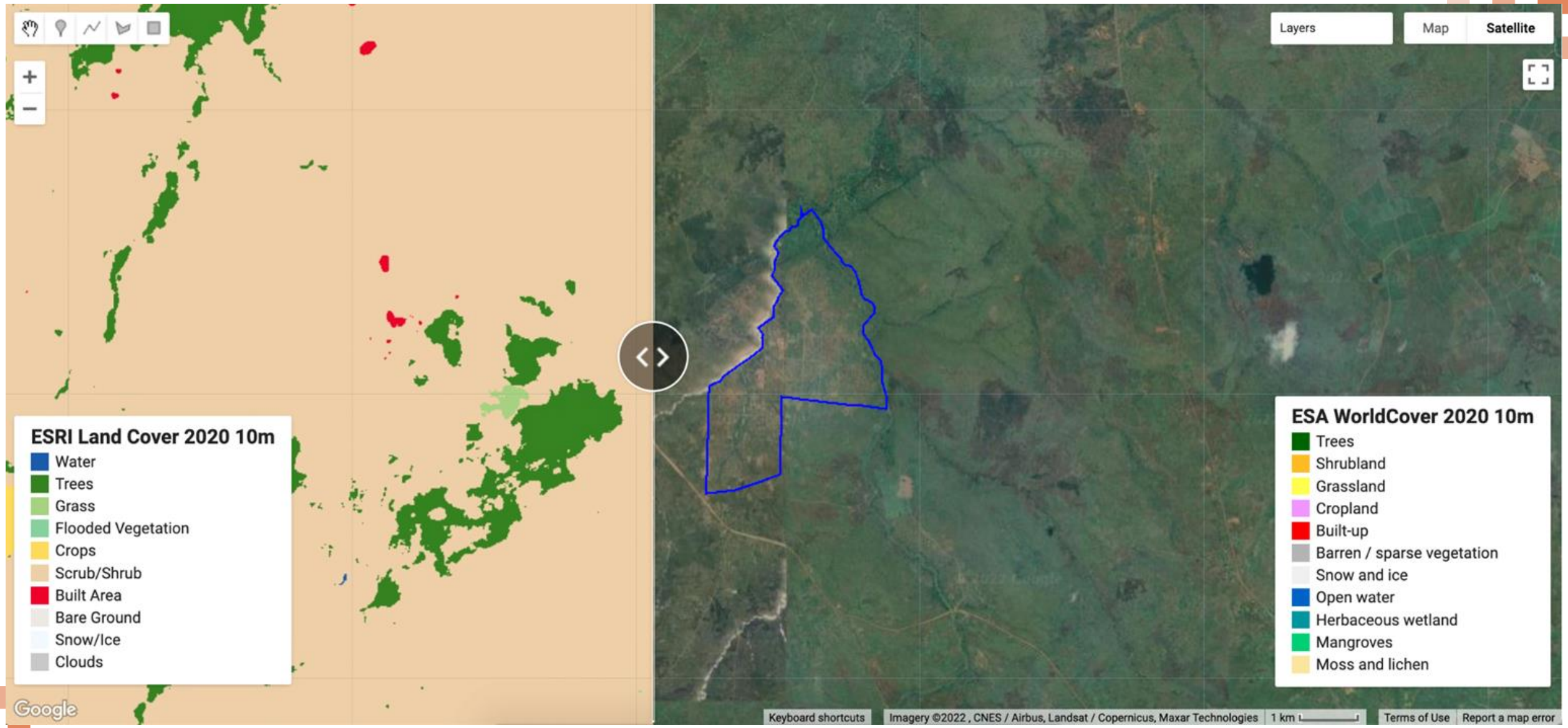
Task: Visualize and Compare Different Land Cover Products

EE Code Link

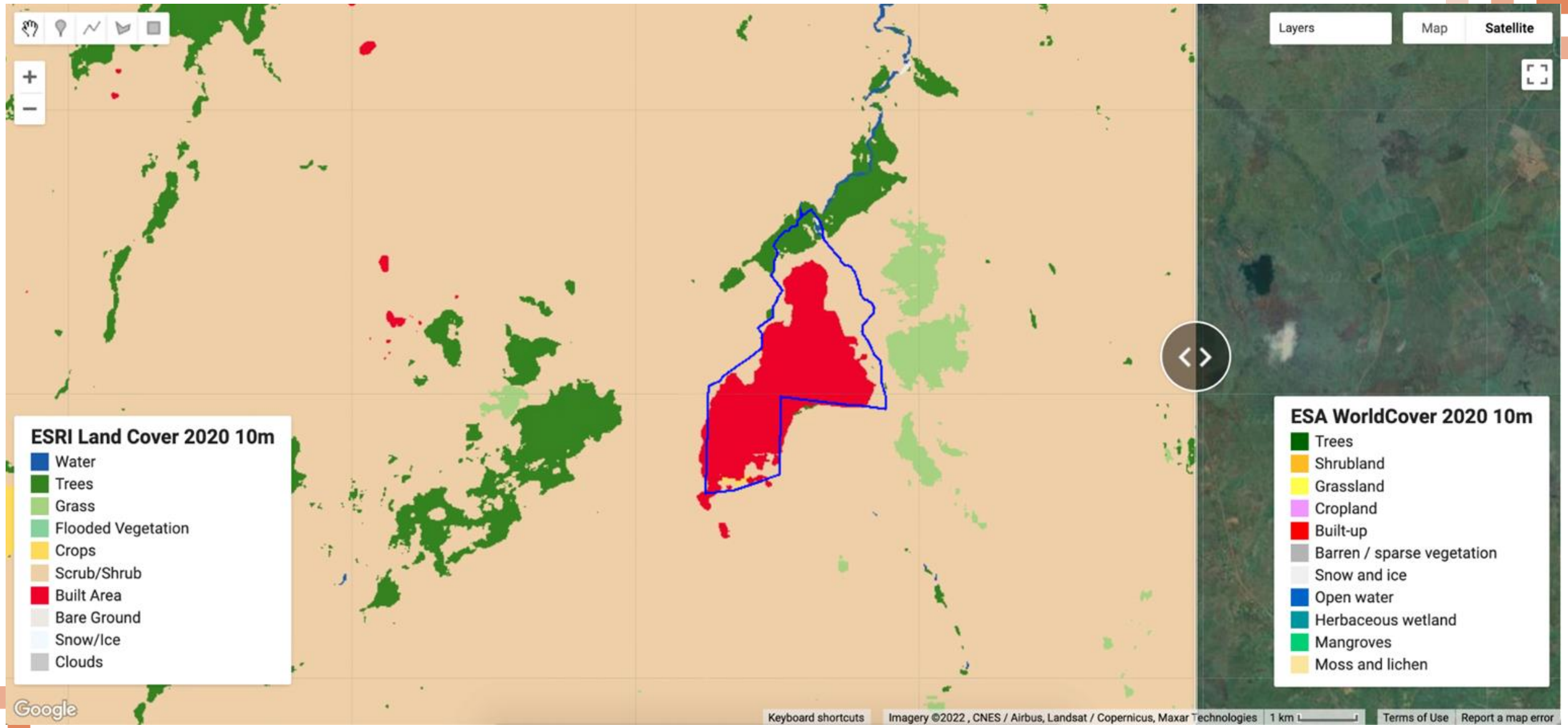
- **Let's first compare two different land cover products from 2020:**
  - ESRI Land Cover 2020
  - ESA WorldCover 2020



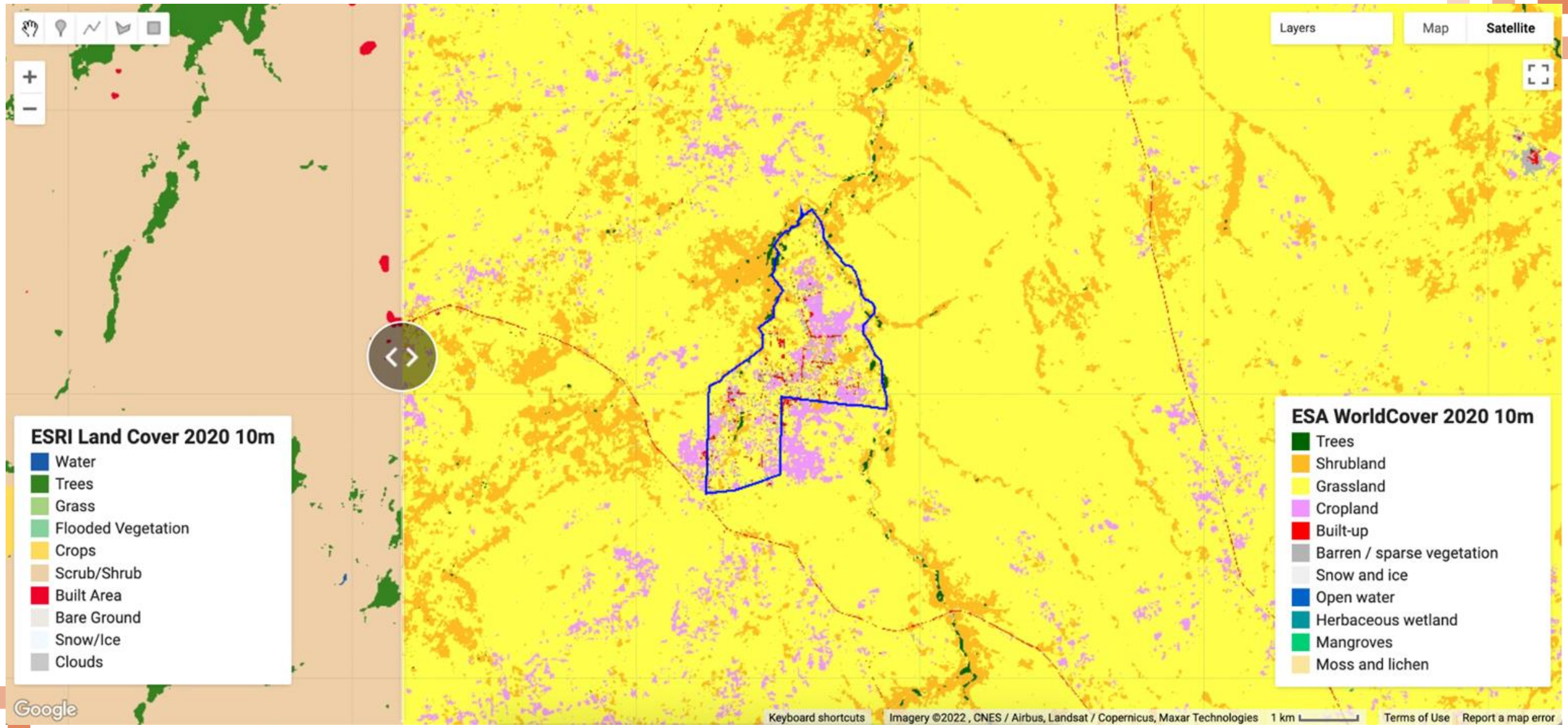
Pagirinya Refugee Settlement



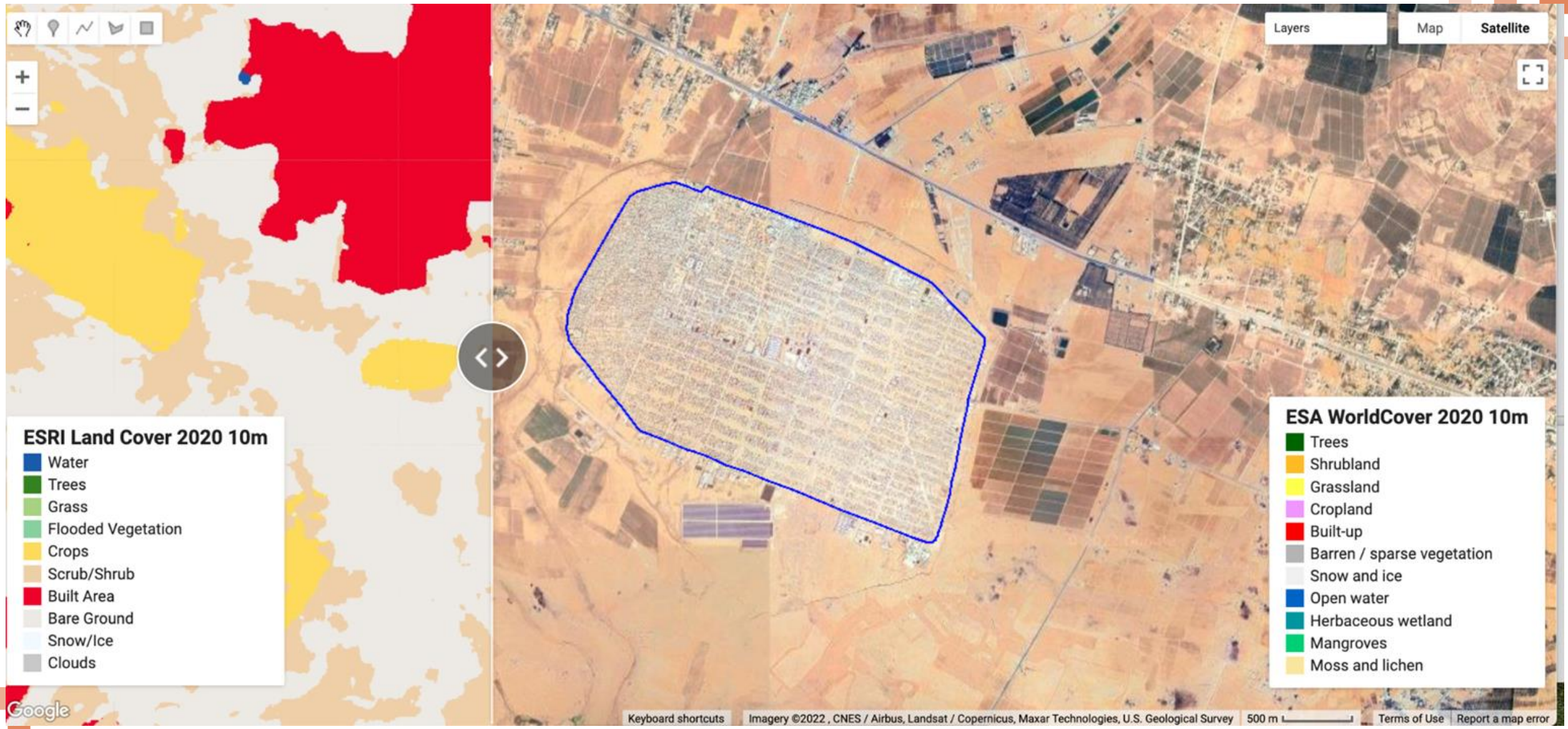
Pagirinya Refugee Settlement



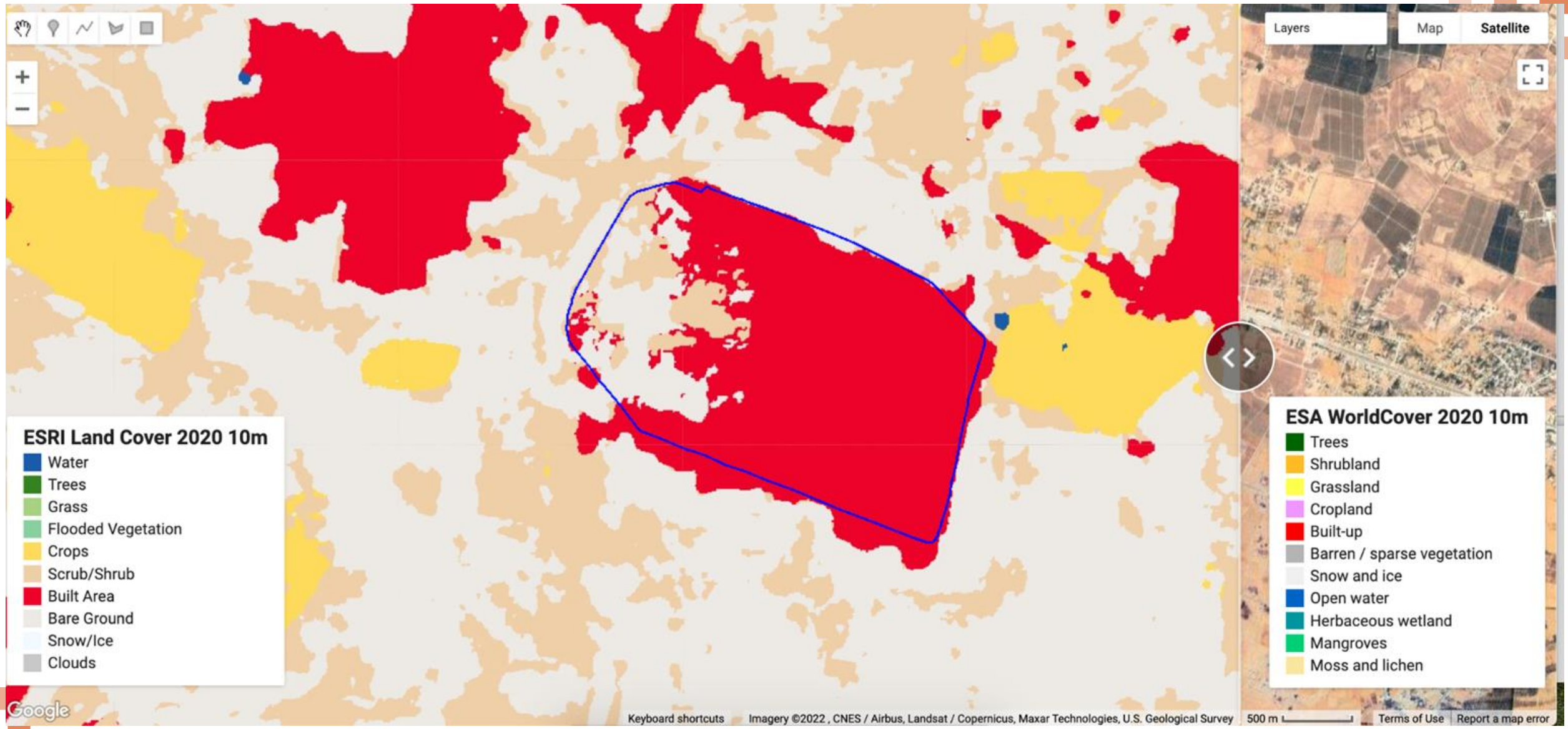
Pagirinya Refugee Settlement



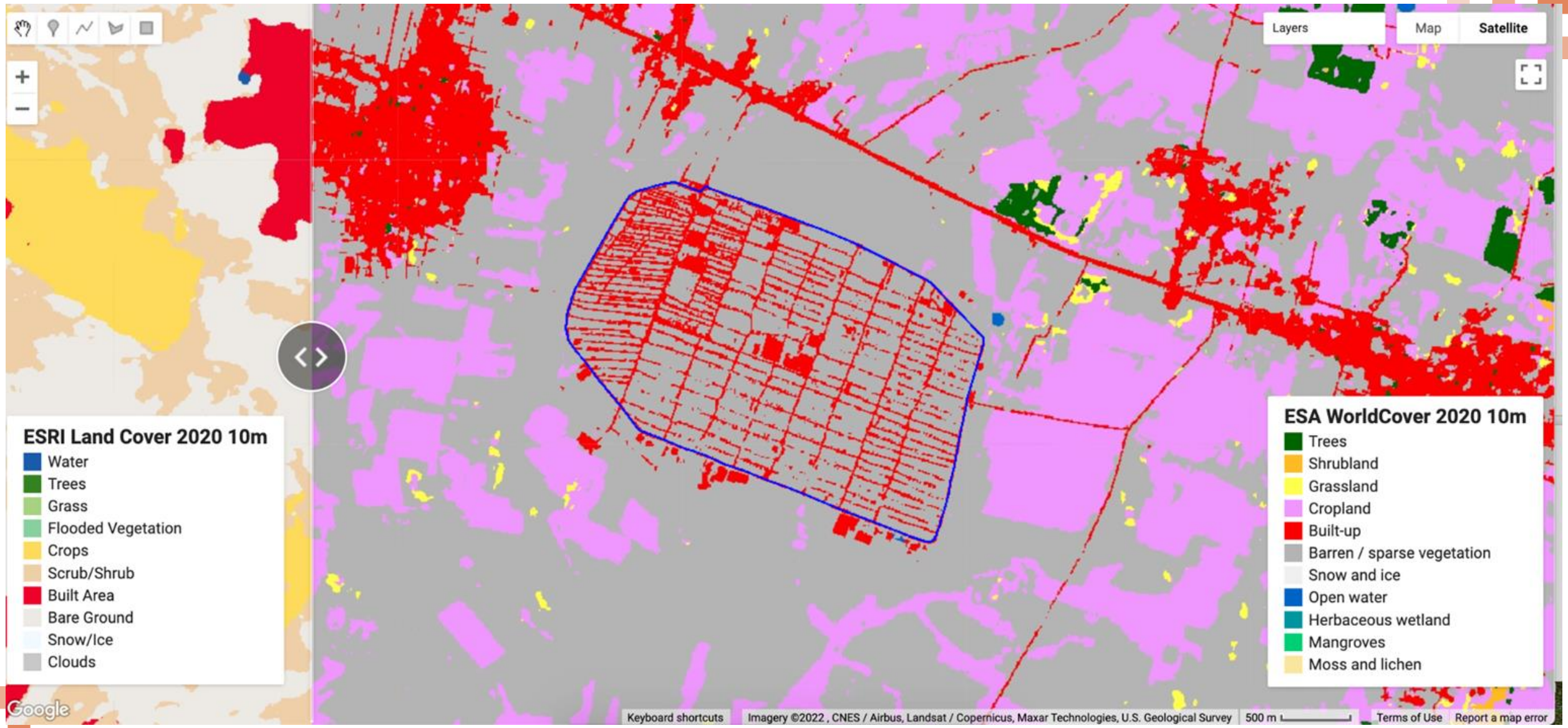
Za'atari Refugee Settlement



Za'atari Refugee Settlement



Za'atari Refugee Settlement



Where do you see similarities and differences between the products? Do the classes reflect the land cover that you see in the satellite base map?

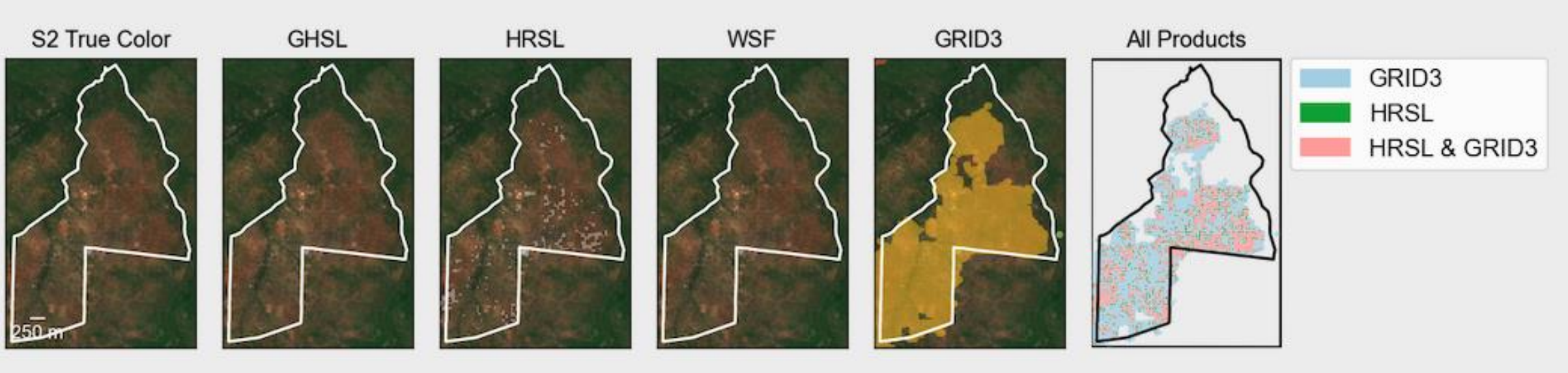
- There are several differences between the two land cover classifications:
  - The ESA WorldCover product appears to overlook built-up land at both settlements, but especially at Pagirinya
  - The ESRI Land Cover product seems to overlook agricultural land at Pagirinya
- It's important to remember that each product may have unique values as well as unique flaws – there is no such thing as an error-free dataset
- Cascading consequences of over- or under-represented classes for different satellite-informed estimates of population (see last training), Sustainable Development Goal (SDG) monitoring efforts (see this training), and analysis of climate hazards (see next training)

The land cover (or change) that is directly associated with the refugee settlement may not be self-evident.

- For Pagirinya and Za'atari, we can use the UNHCR refugee settlement boundary (shown in blue at the right) to directly link pixels to the refugee settlement.
- The UNHCR boundary is a *planning* boundary that delineates the land allocated for a refugee settlement.
- The boundary can help us distinguish between land directly accessed and used by refugees
- Since the planning boundary may include open vegetated land that has not (yet) been used by refugees for dwellings, roads, or farming, we may want to make a **functional** settlement boundary that better reflects the extent of refugee land use.

There are numerous satellite image-derived settlement datasets that may be helpful in delineating a functional refugee settlement boundary.

- Existing remote sensing-derived settlement datasets include:
  - Global Human Settlement Layer (GHSL)
  - High Resolution Settlement Layer (HRSL)
  - World Settlement Footprint (WSF)
  - Geo-Referenced Infrastructure and Demographic Data for Development (GRID3)



Adapted from Van Den Hoek & Friedrich (2021)

Task: Estimate the functional refugee settlement boundary using K-means

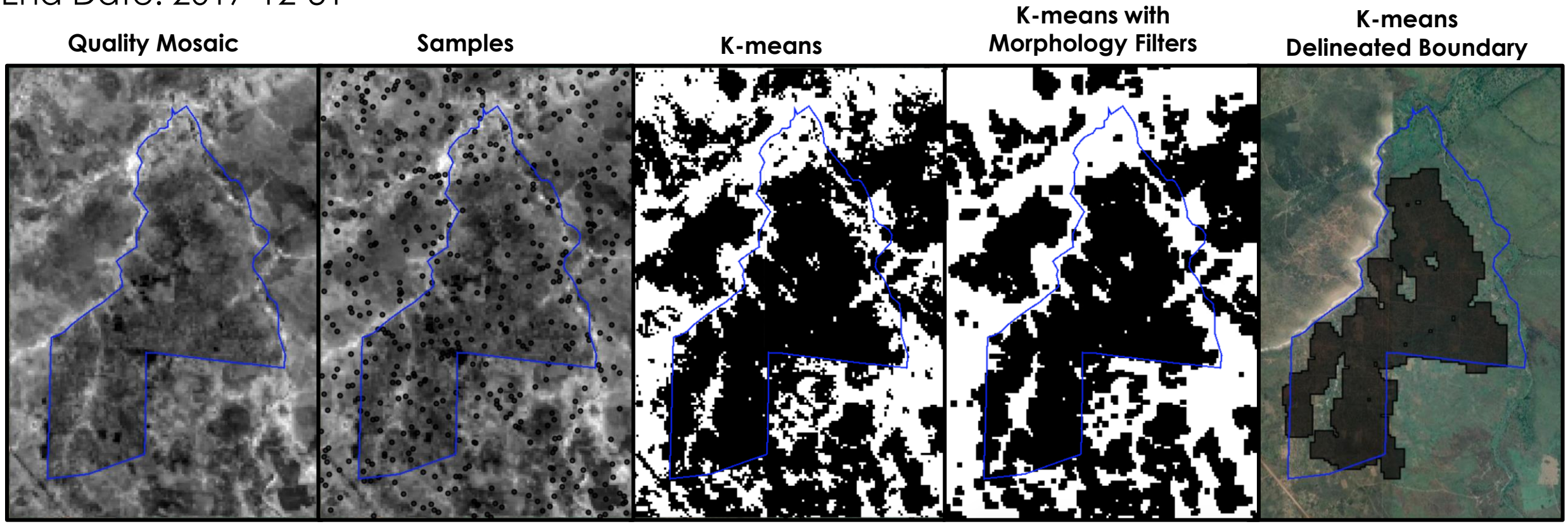
- K-means is an unsupervised classifier (i.e., it does not require training data) that randomly or evenly partitions spectral space into classes and then iteratively clusters image pixels into classes based on the minimum distance to the class centroid.

EE Code Link

- This script allows you to set the following variables:
  - Pagirinya or Za'atari Refugee Settlement
  - Satellite platform (Landsat 8 or Sentinel-2)
  - Spectral index (NDVI, NDBI, NBR)
  - Start and end dates for image compositing
- With this script, we will:
  - Compare the functional boundary to the UNHCR planning boundary
  - Compare Google Open Buildings Footprints and Microsoft Building Footprints with our functional refugee settlement boundary
  - Compare boundary estimation results between Pagirinya and Za'atari refugee settlements

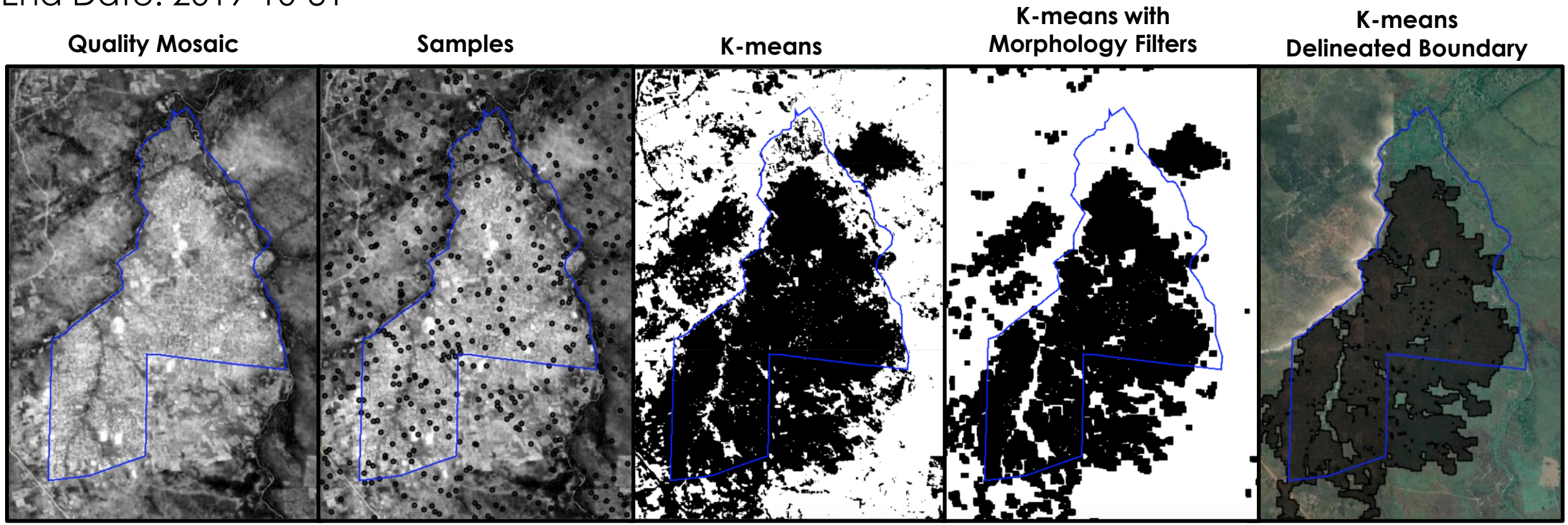
K-means at Pagirinya Refugee Settlement

Sensor: Landsat 8
Index: NDVI
Start Date: 2017-01-01
End Date: 2017-12-31



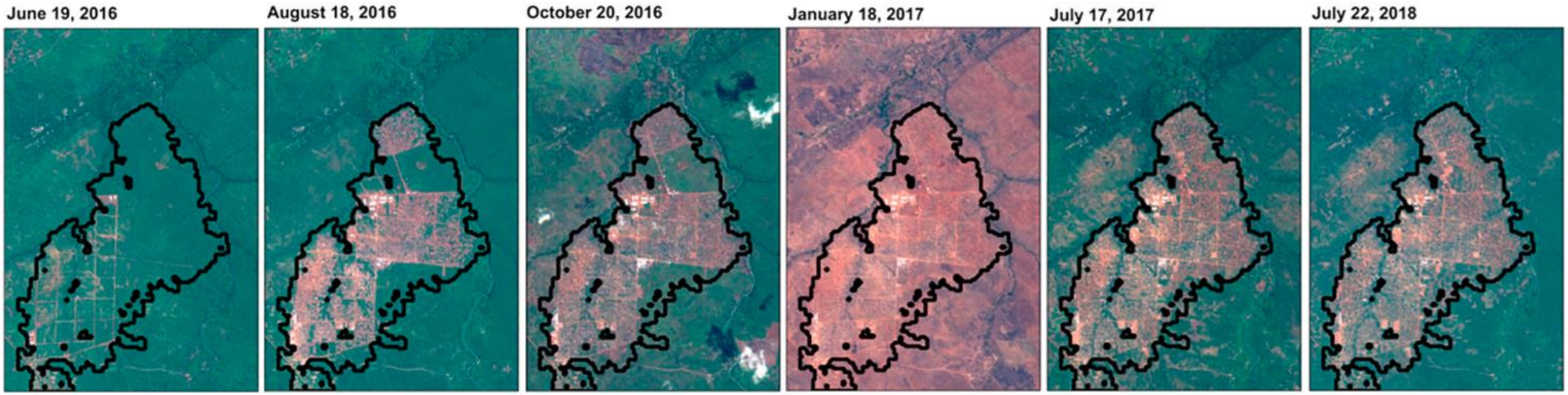
K-means at Pagirinya Refugee Settlement

Sensor: Sentinel-2
Index: NDBI
Start Date: 2019-04-01
End Date: 2019-10-31



Our estimation of the refugee settlement functional boundary depends on the sensor, spectral metric, and image date.

For example, the functional boundary below based on Landsat 8 NDVI imagery from July 2018 estimates the total extent of land use at that time but would need to be adjusted for earlier stages of the settlement's expansion.



Source: Friedrich & Van Den Hoek (2020)

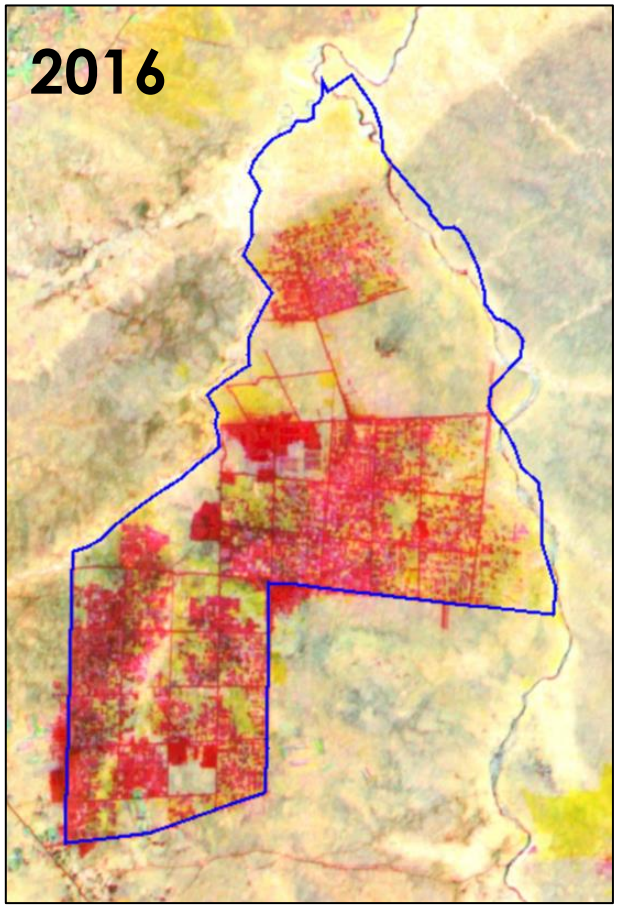
Task: Visualize differences in vegetation condition between years

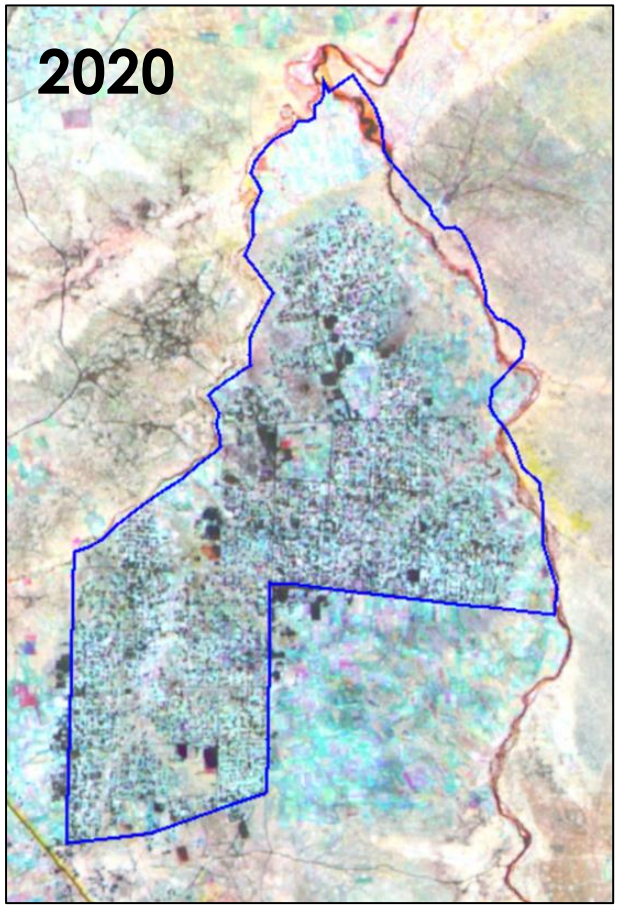
EE Code Link

- We'll compare seasonal differences at the refugee settlement using a three-season false-color RGB composite.

Red indicates higher NDVI in season 1 compared to seasons 2 and 3.

Red also outlines the earliest regions of change with refugee arrival.



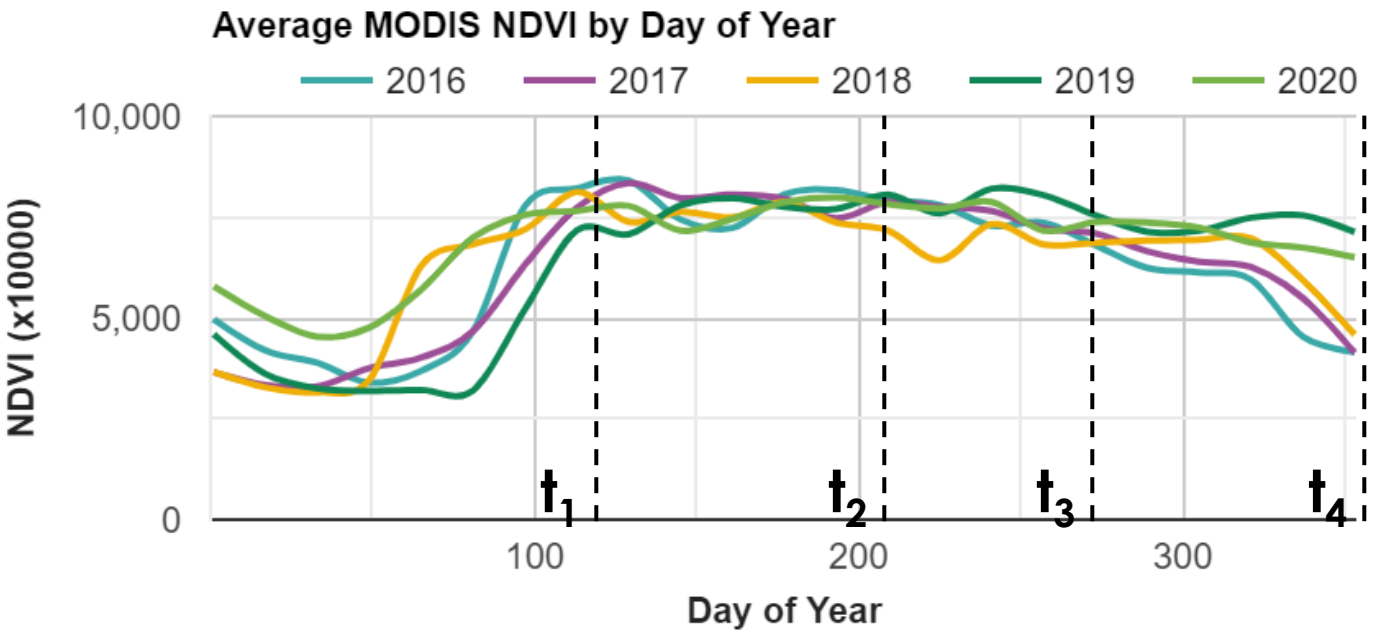


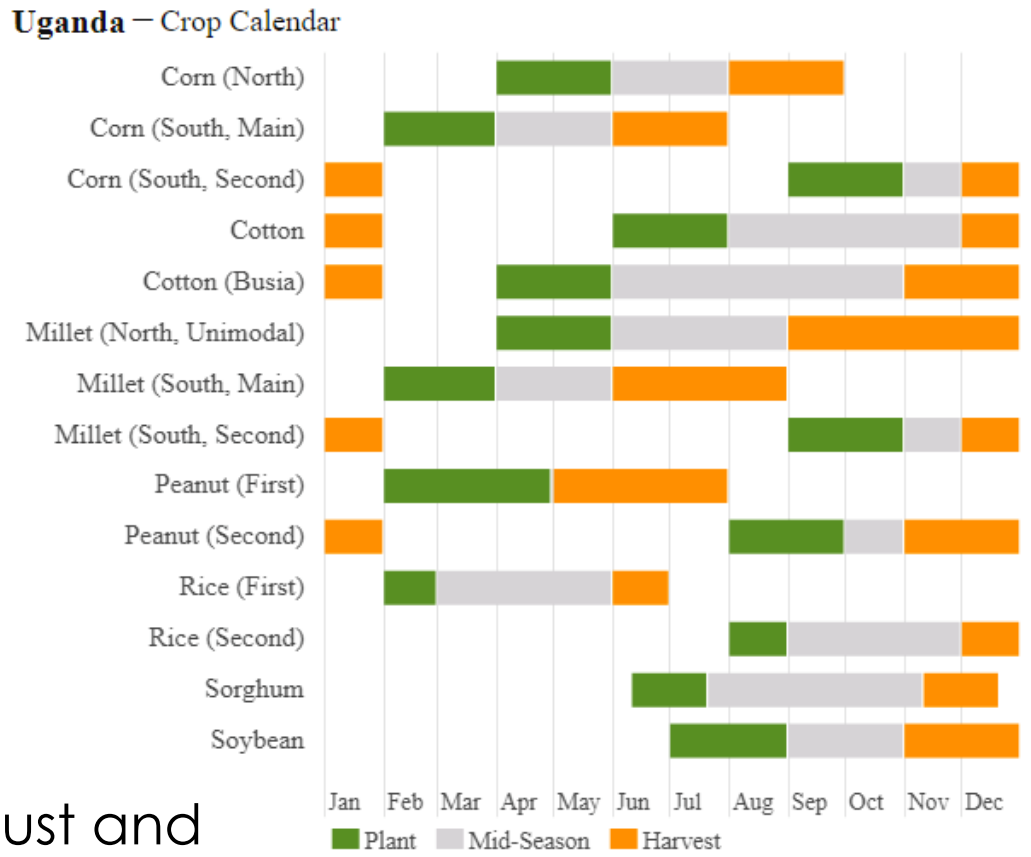
Teal indicates comparable NDVI in seasons 2 and 3, both of which have higher NDVI than season 1.

Teal also outlines the extent of cultivation in August through December.

We can use satellite time series and crop calendars to select dates that define different crop seasons.

At Pagirinya in Uganda…



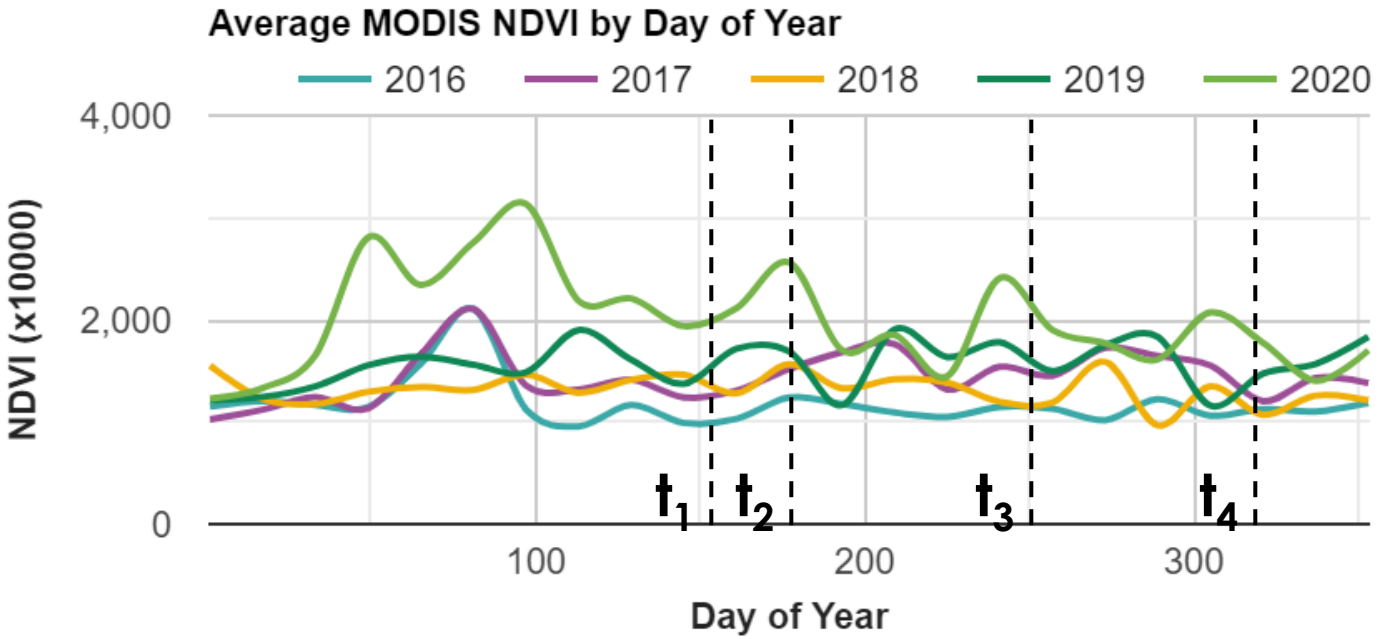


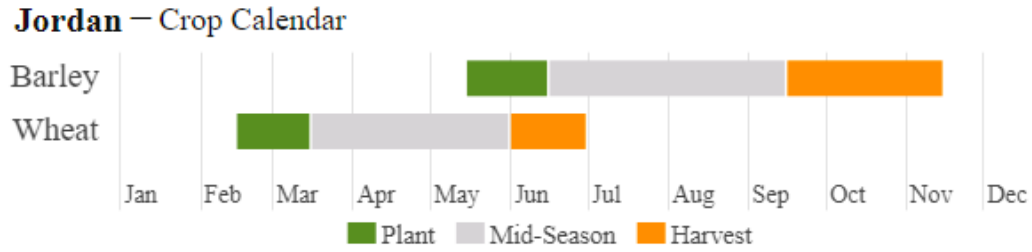
Source: USDA FAS

We'll target May through July (t_1-t_2) for peanut, August and September (t_2-t_3) for corn and millet), and October through December (t_3-t_4) for millet, sorghum, and soybean.

We can use satellite time series and crop calendars to select dates that define different crop seasons.

At Za'atari in Jordan…



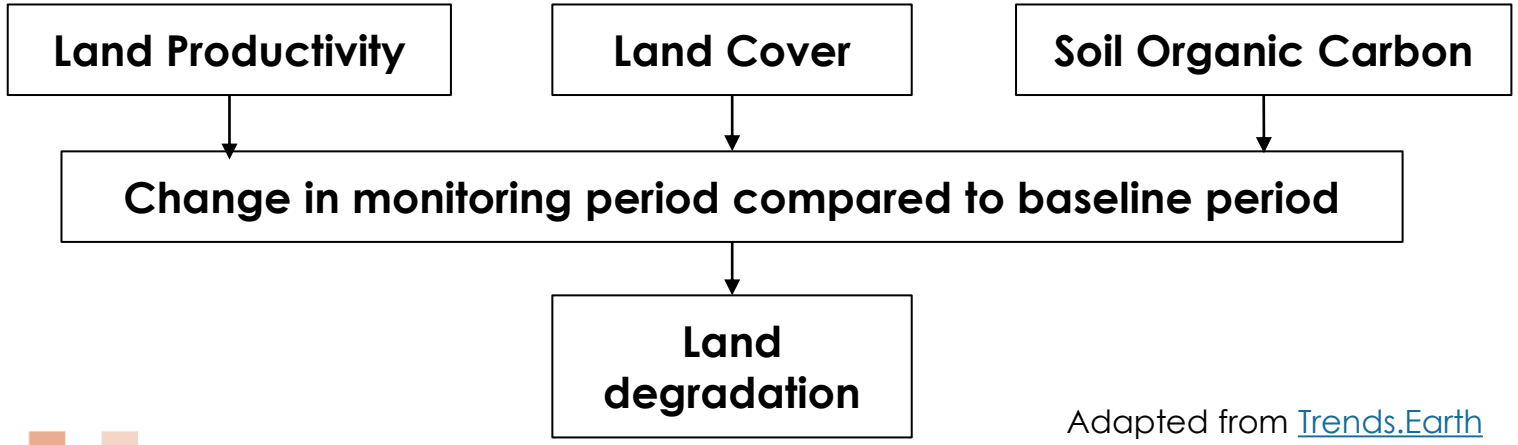


Source: USDA FAS

We'll target June (t_1-t_2) for wheat, and mid-September through mid-November (t_3-t_4) for barley.

Task: Assess land degradation at refugee settlements

- **Let's measure land degradation at our study refugee settlement using a Sustainable Development Goal (SDG) framework:**
  - SDG 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.
  - Target 15.3: By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world.
  - Indicator 15.3.1: Proportion of land that is degraded over total land area



Adapted from Trends.Earth

Using this framework, declined productivity and a conversion from high biomass land covers (i.e., forest) to low biomass land covers (i.e., urban) are indicative of land degradation.

Task: Assess land degradation at refugee settlements

EE Code Link

We'll measure the change in Net Primary Productivity (NPP) as one indicator of land degradation. NPP is a measure of the accumulation of vegetation over time.

- MODIS Net Primary Productivity (2001–present), 500-meter resolution

We'll also measure land cover changes.

- MODIS Land Cover (2000–present), 500-meter resolution

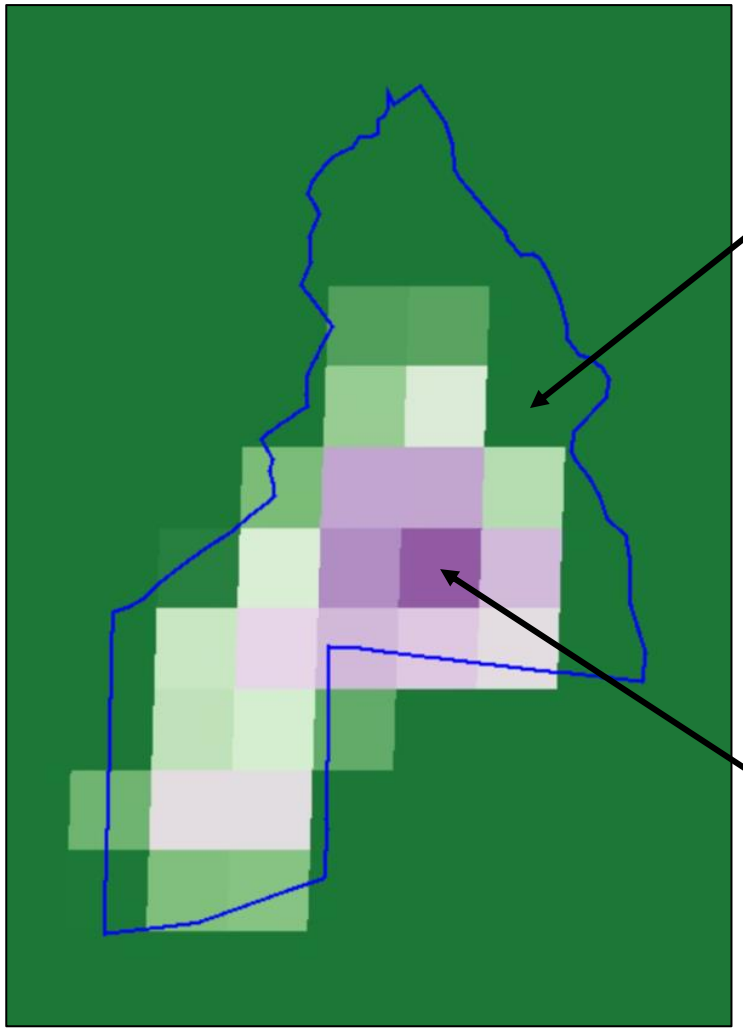
For both, we'll compare conditions during a baseline and monitoring period.

- We'll set our baseline as the period before refugee arrival (2000–2015) and our monitoring period begins following establishment (2017–present)

Note that Soil Organic Carbon (SOC) is commonly used in land degradation studies, but we lack reliable SOC data for our study area.

We see a marked effect on NPP with settlement establishment.

```
var NPP_baseline = MODIS_NPP.select("Npp").filterDate("2000-01-01","2015-12-31").mean()
var NPP_monitoring = MODIS_NPP.select("Npp").filterDate("2017-01-01","2020-12-31").mean()
```

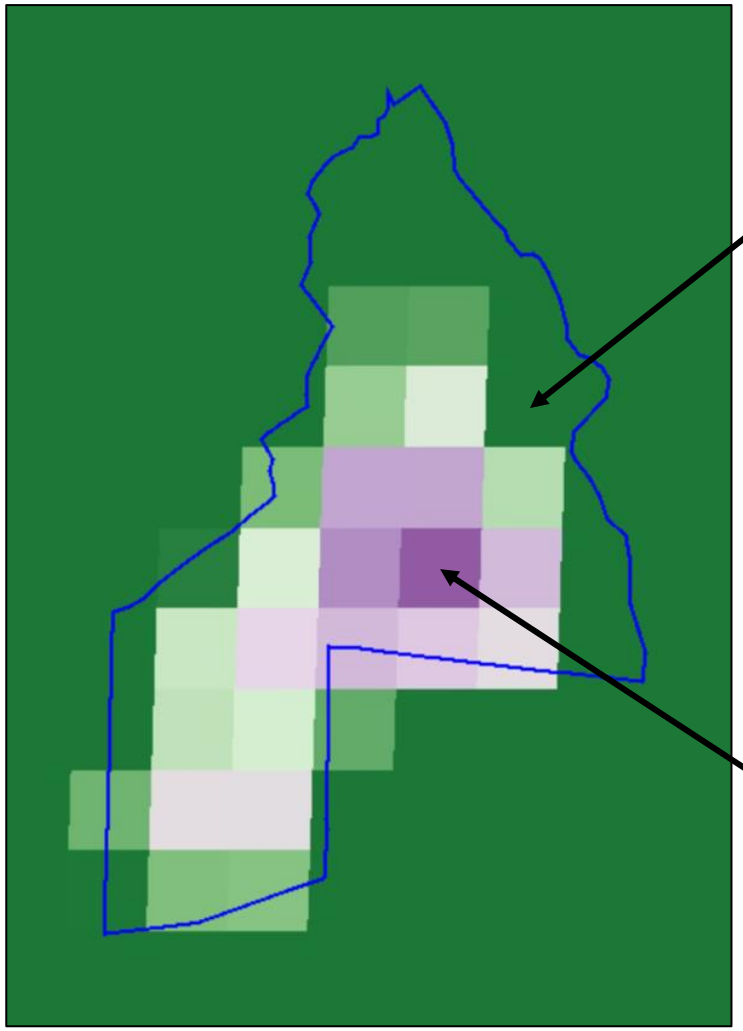


NPP_baseline: Image (1 band)
Npp: 7259.3125
NPP_monitoring: Image (1 band)
Npp: 7815.25
NPP_diff: Image (1 band)
Npp: 555.9375

NPP_baseline: Image (1 band)
Npp: 7283.625
NPP_monitoring: Image (1 band)
Npp: 6880.75
NPP_diff: Image (1 band)
Npp: -402.875

We see a marked effect on NPP with settlement establishment.

```
var NPP_baseline = MODIS_NPP.select("Npp").filterDate("2000-01-01","2015-12-31").mean()
var NPP_monitoring = MODIS_NPP.select("Npp").filterDate("2017-01-01","2020-12-31").mean()
```



NPP_baseline: Image (1 band)
Npp: 7259.3125
NPP_monitoring: Image (1 band)
Npp: 7815.25
NPP_diff: Image (1 band)
Npp: 555.9375

Increased NPP at the edge of the settlement!

NPP_baseline: Image (1 band)
Npp: 7283.625
NPP_monitoring: Image (1 band)
Npp: 6880.75
NPP_diff: Image (1 band)
Npp: -402.875

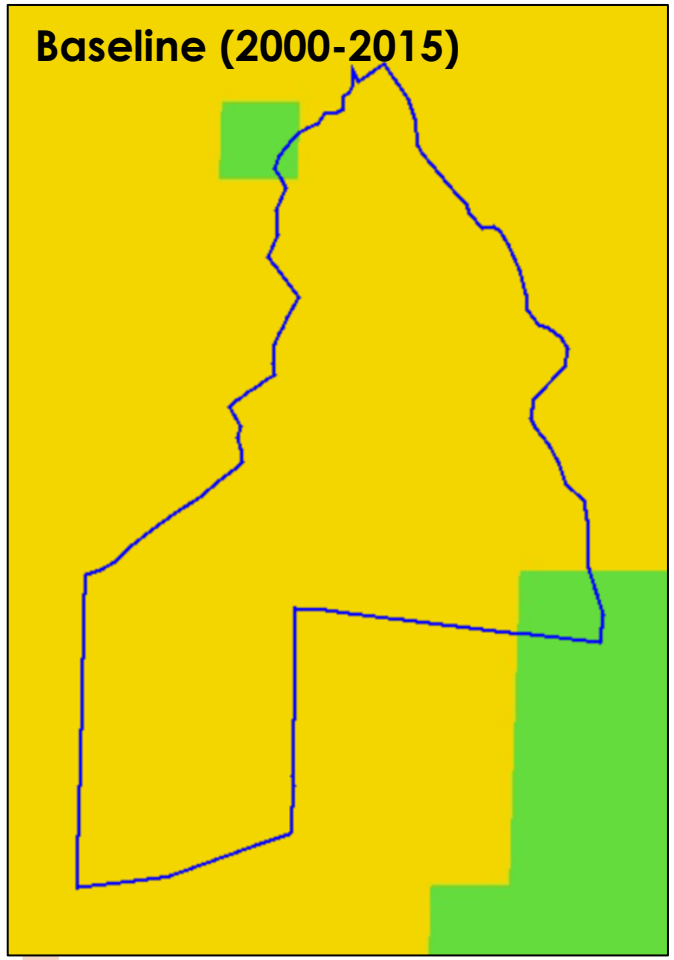
Decreased NPP at the settlement's core.

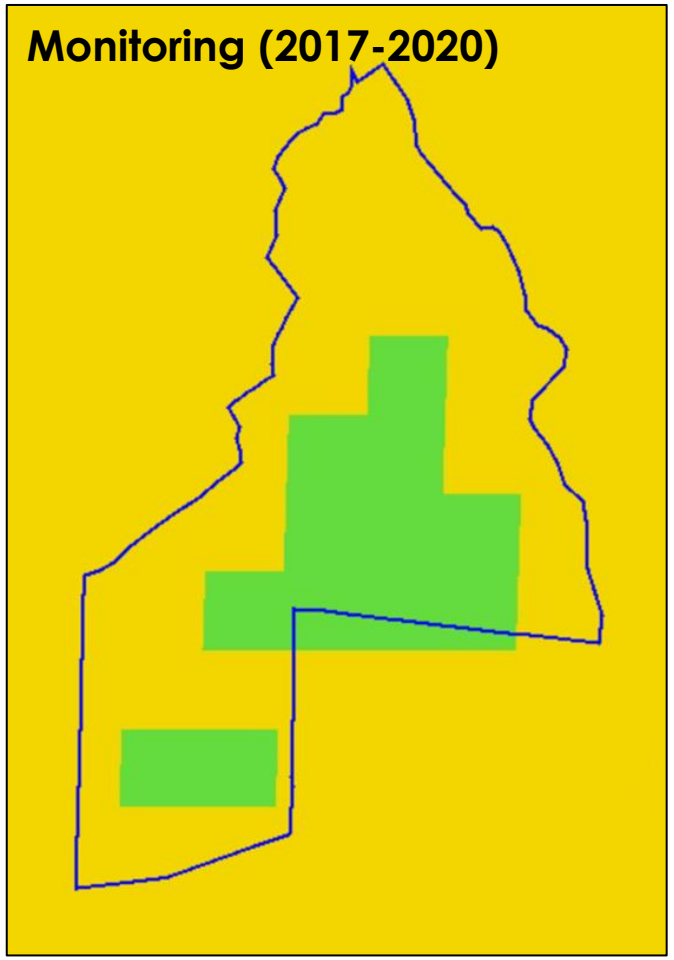
We see a similar story from a land cover change perspective.

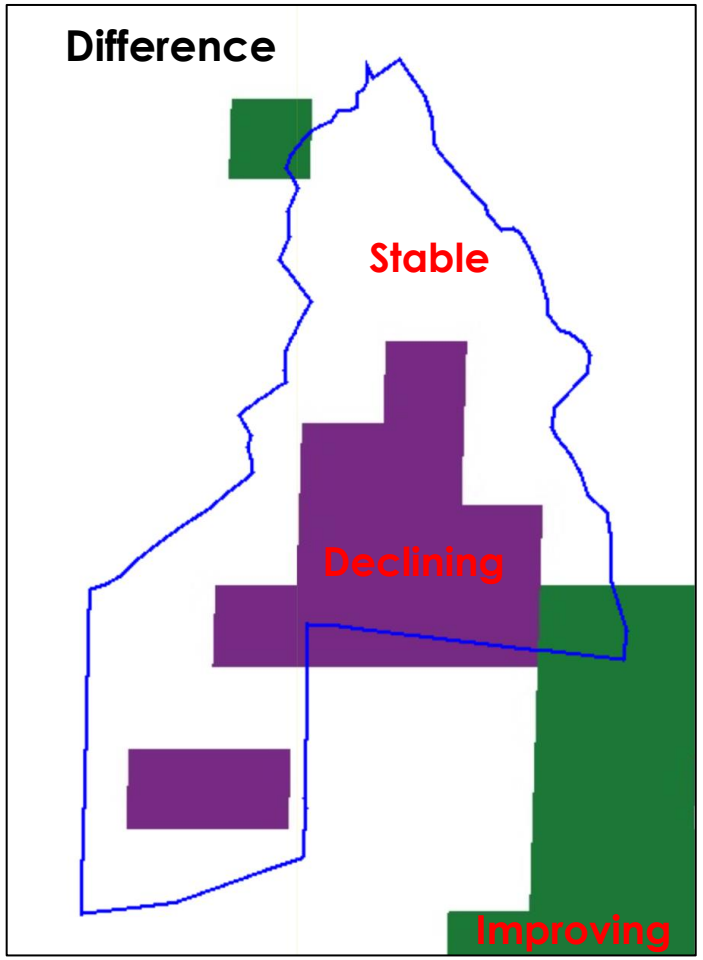
Pagirinya is mapped as being almost all **cropland** during the baseline period.

During the monitoring period, more **grassland** begins to appear within the boundary.

From a SDG 15.3.1 perspective, we mainly see *improving* land cover conditions within Pagirinya.

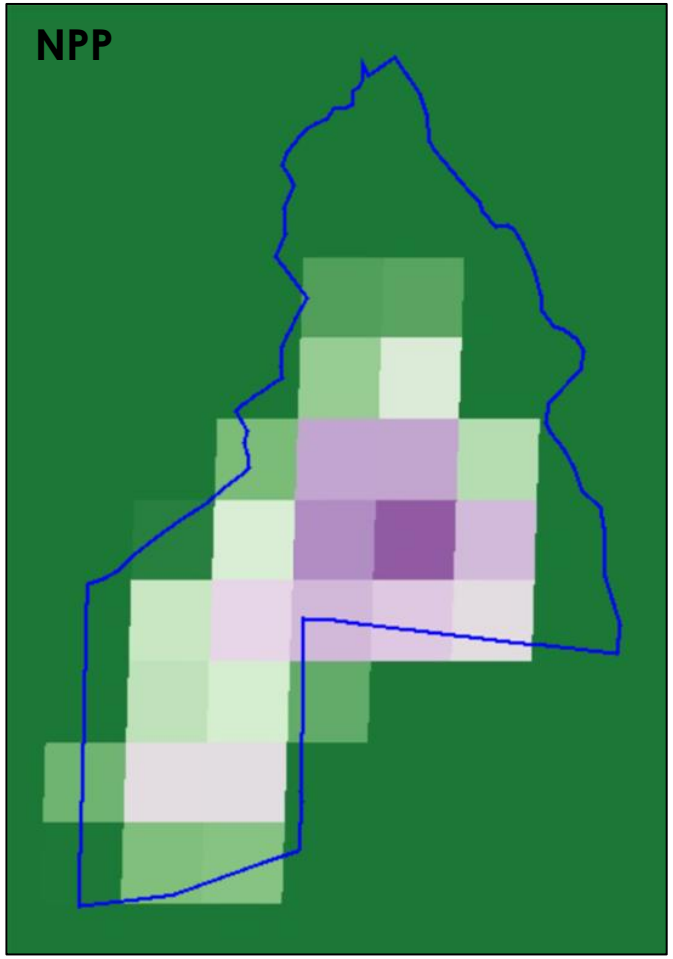




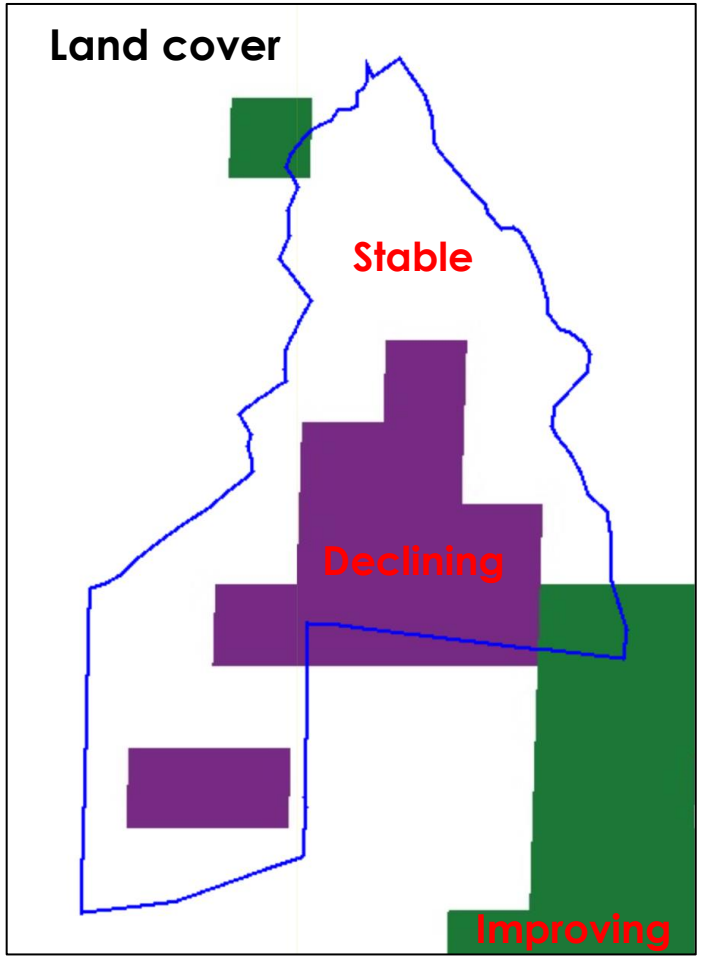


We see comparable stories between NPP and land cover change.

We mainly see *declining* NPP in Pagirinya.



We mainly see *degrading* land cover conditions in Pagirinya.



- Though we have agreement here, degradation assessments may point to conflicting trends between NPP and land cover.
- We need to understand the local context with regard to fuel needs and food production to properly weigh contrasting results and gauge the limitations of the approach.
- Publicly available inter-annual land cover datasets are likely to have insufficient spatial resolution for degradation assessments, and this means we may need to generate custom land cover maps for our settlements.

Citations

- *The impact of refugee settlements on land use changes and vegetation degradation in West Nile Sub-region, Uganda* by Bernard et al. (2020)
- *Assessing Cropland Abandonment From Violent Conflict In Central Mali With Sentinel-2 And Google Earth Engine* by Boudinaud & Orenstein (2021)
- *Combined use of SAR and optical data for environmental assessments around refugee camps in semiarid landscapes* by Braun et al. (2015)
- *Breaking ground: Automated disturbance detection with Landsat time series captures rapid refugee settlement establishment and growth in North Uganda* by Friedrich & Van Den Hoek (2020)
- *Vegetation changes attributable to refugees in Africa coincide with agricultural deforestation* by Maystadt et al. (2020)
- *Impacts of large-scale refugee resettlement on LCLUC: Bidi Bidi refugee settlement, Uganda case study* by Nakalembe et al. (2022)
- *Mapping land enclosures and vegetation cover changes in the surroundings of Kenya's Dadaab refugee camps with very high resolution satellite imagery* by Rossi et al. (2018)

Questions?

- Please enter your questions in the Q&A box. We will answer them in the order they were received.
- We will post the Q&A to the training website following the conclusion of the webinar.

Source: UNHCR/World Bank

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- Training Webpage:
  - https://appliedsciences.nasa.gov/join-mission/training/english/arset-humanitarian-applications-using-nasa-earth-observations

Thank you and please join us for Part 4 of the training:

Assessing Climate Hazards at Refugee Camps