Humanitarian Applications Using NASA Earth Observations

Part 2: Mapping Refugee Settlement Growth and Population Change

June 16, 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 2: Mapping Refugee Settlement Growth and Population Change

Motivation:

- Many refugee settlements rapidly grow following refugee arrival
- Refugee settlement expansion and population growth can strain available resources and existing infrastructure
- Satellite data can be used document the timing and rate of settlement change and support estimating the refugee population with the settlement

Goals:

- Examine land cover changes following refugee settlement establishment through visual and quantitative analysis
- Map rapid expansion of refugee settlements using time series data
- Analyze satellite data-informed demographic products and compare to official population estimates

Meet your presenters!

Hannah Friedrich

PhD student

University of Arizona

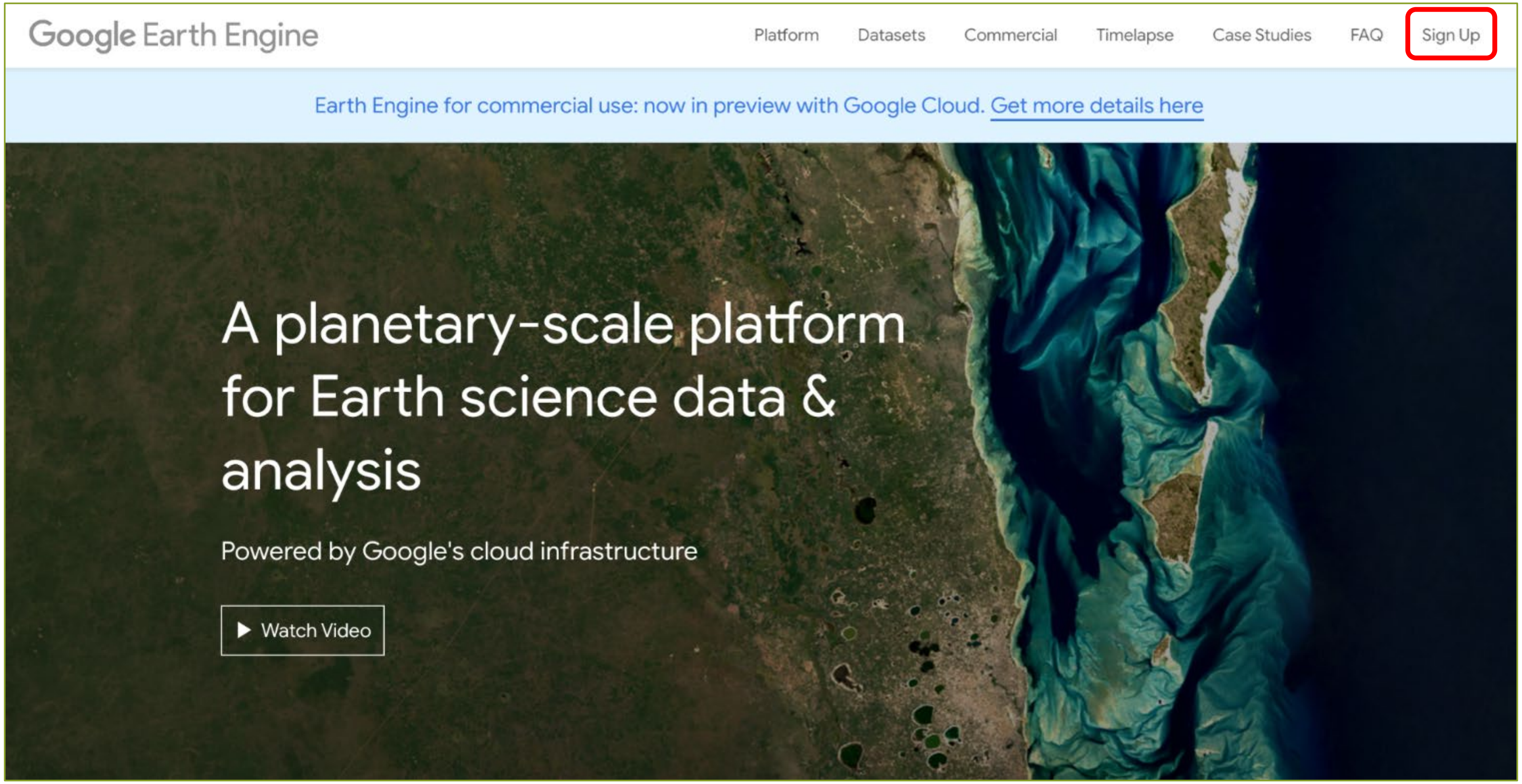
Jamon Van Den Hoek

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*.



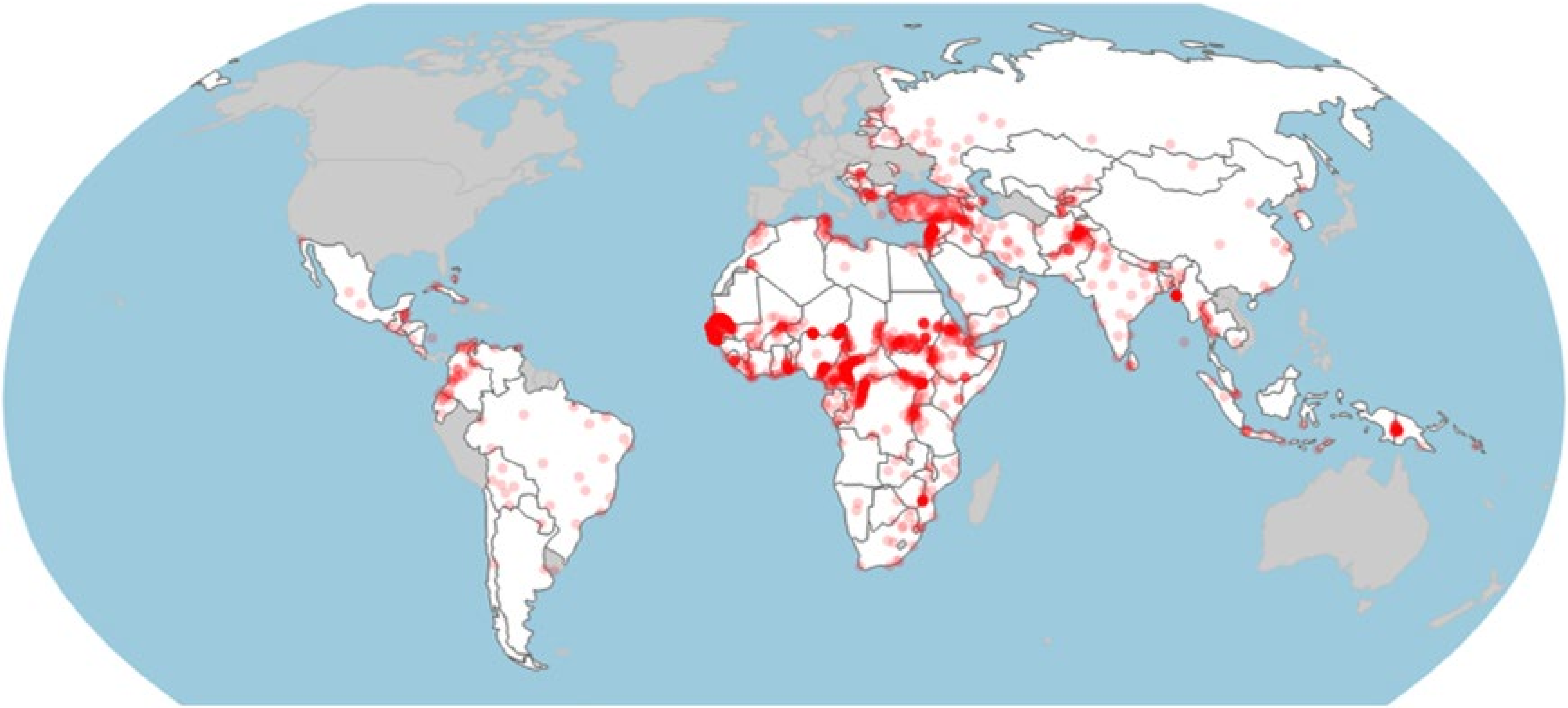
Prerequisites

- Fundamentals of Remote Sensing
- Using Google Earth Engine for Land Monitoring Applications
- Remote Sensing for Monitoring Land Degradation and Sustainable Cities SDGs
- Introduction to Population Grids and their Integration with Remote Sensing Data for Sustainable Development and Disaster Management
- Investigating Time Series of Satellite Imagery

Background:

Why do we need to understand refugee settlement dynamics?
How can NASA satellite data help?

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



Refugee-Hosting Country in 2021 · Refugee Settlement in 2021

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)

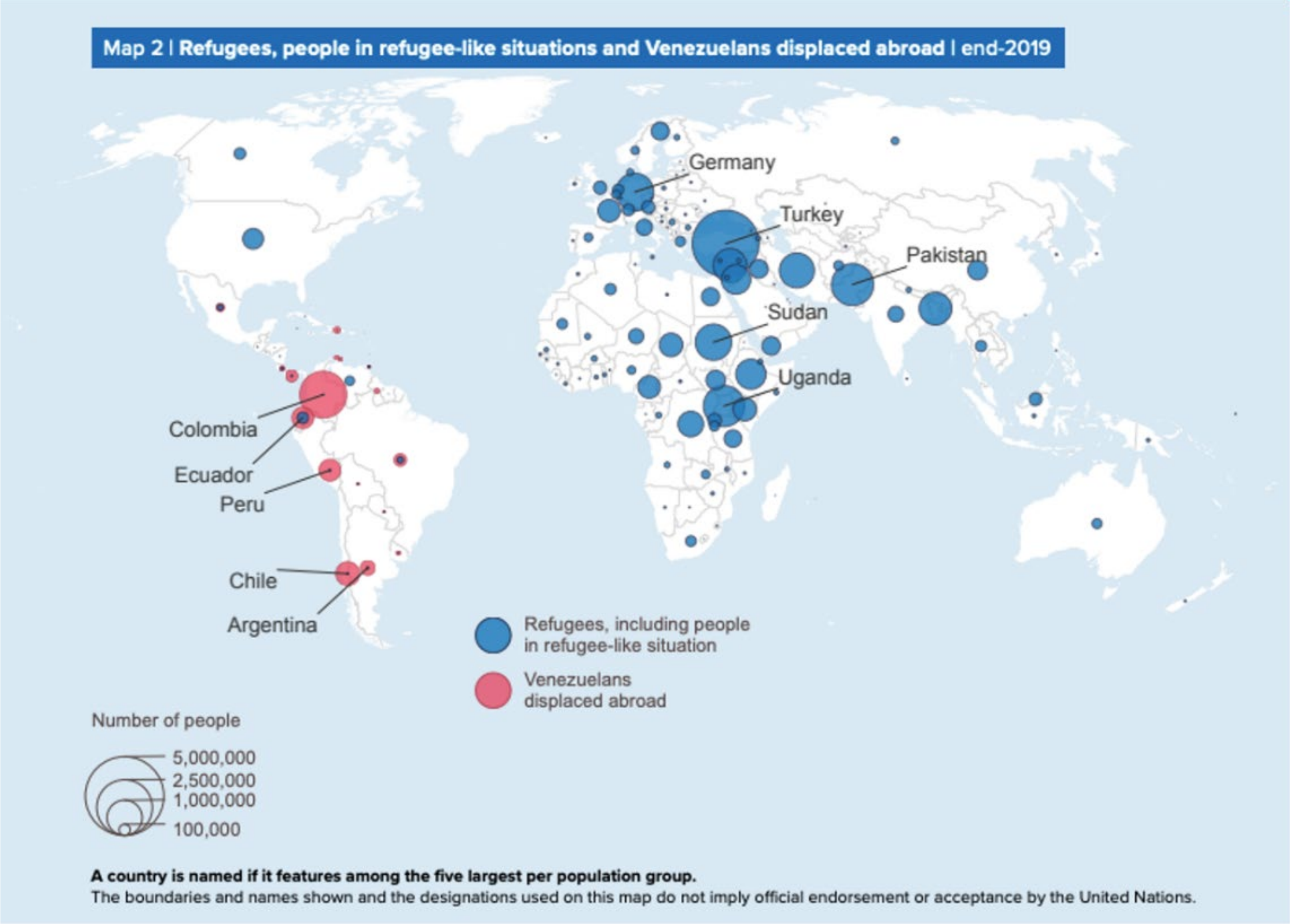
73% of refugees seek asylum in neighboring countries.

Source: [UNHCR (2016)]

Source: [WorldVision (2017)]

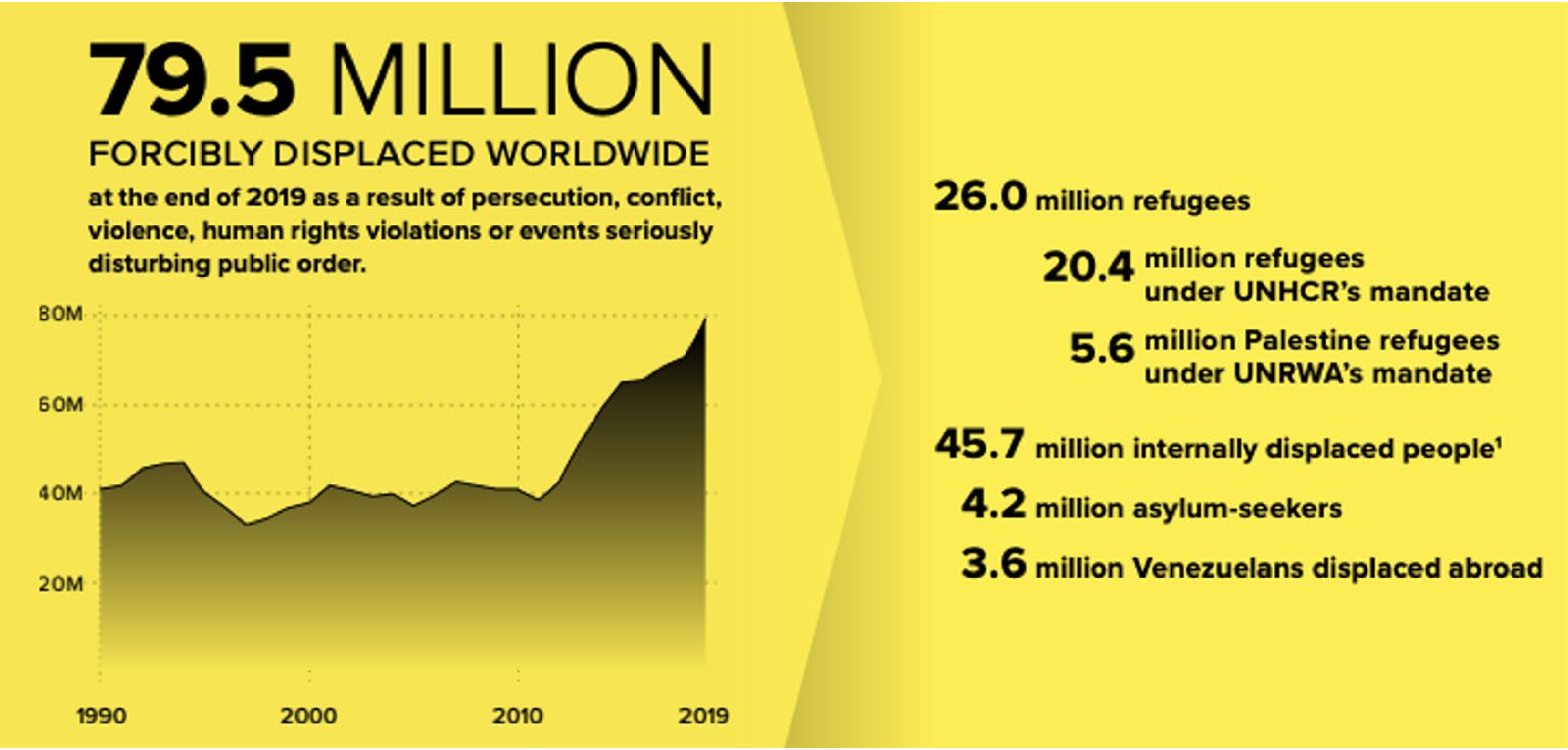
South Sudan - 2.2 million refugees mainly in Kenya and Uganda (UNHCR, 2022)

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



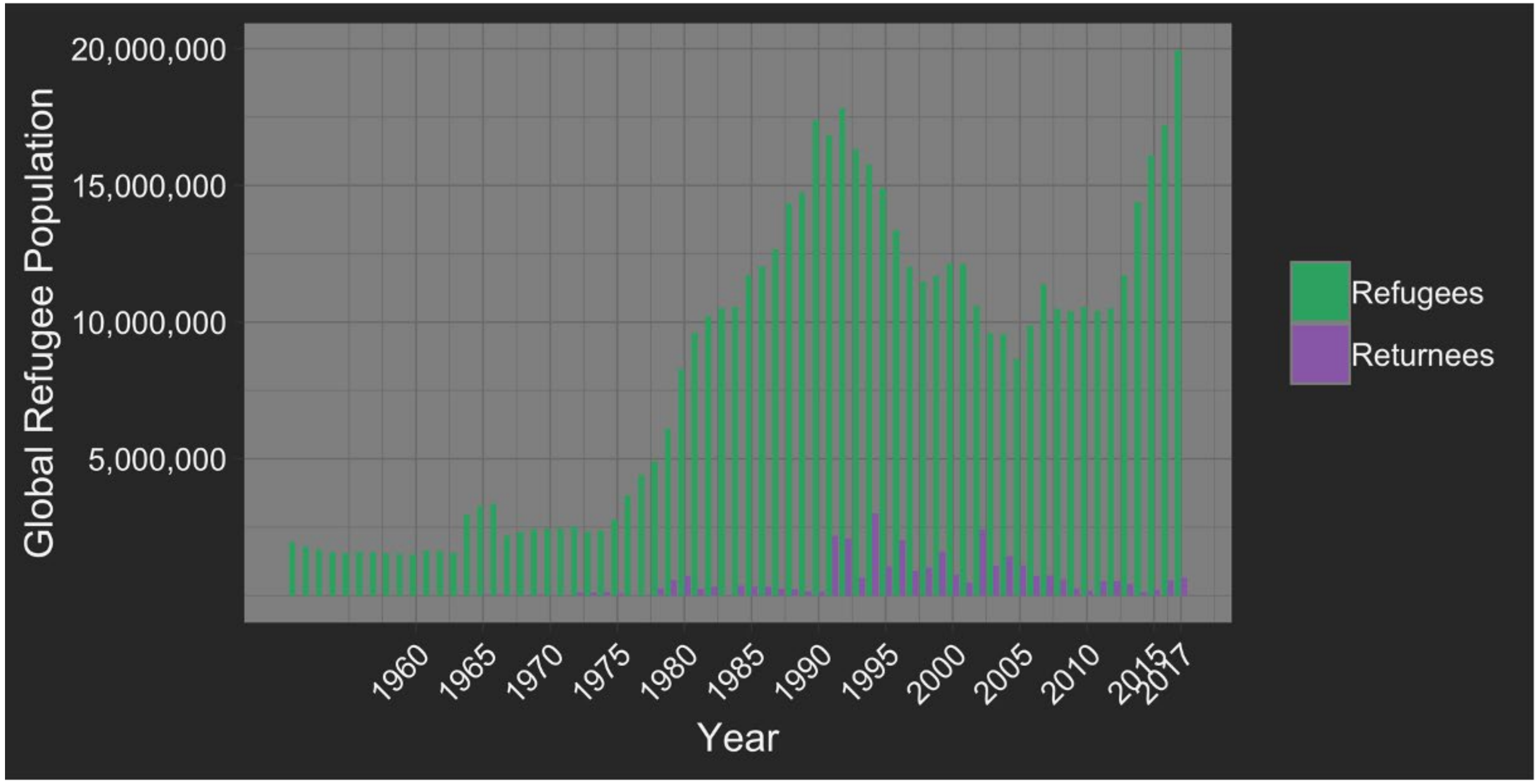
Source: [UNHCR (2020)]

Since 2010, the global forcibly displaced population has doubled.



Source: UNHCR (2020)

Two out of three refugees are in protracted refugee situations.

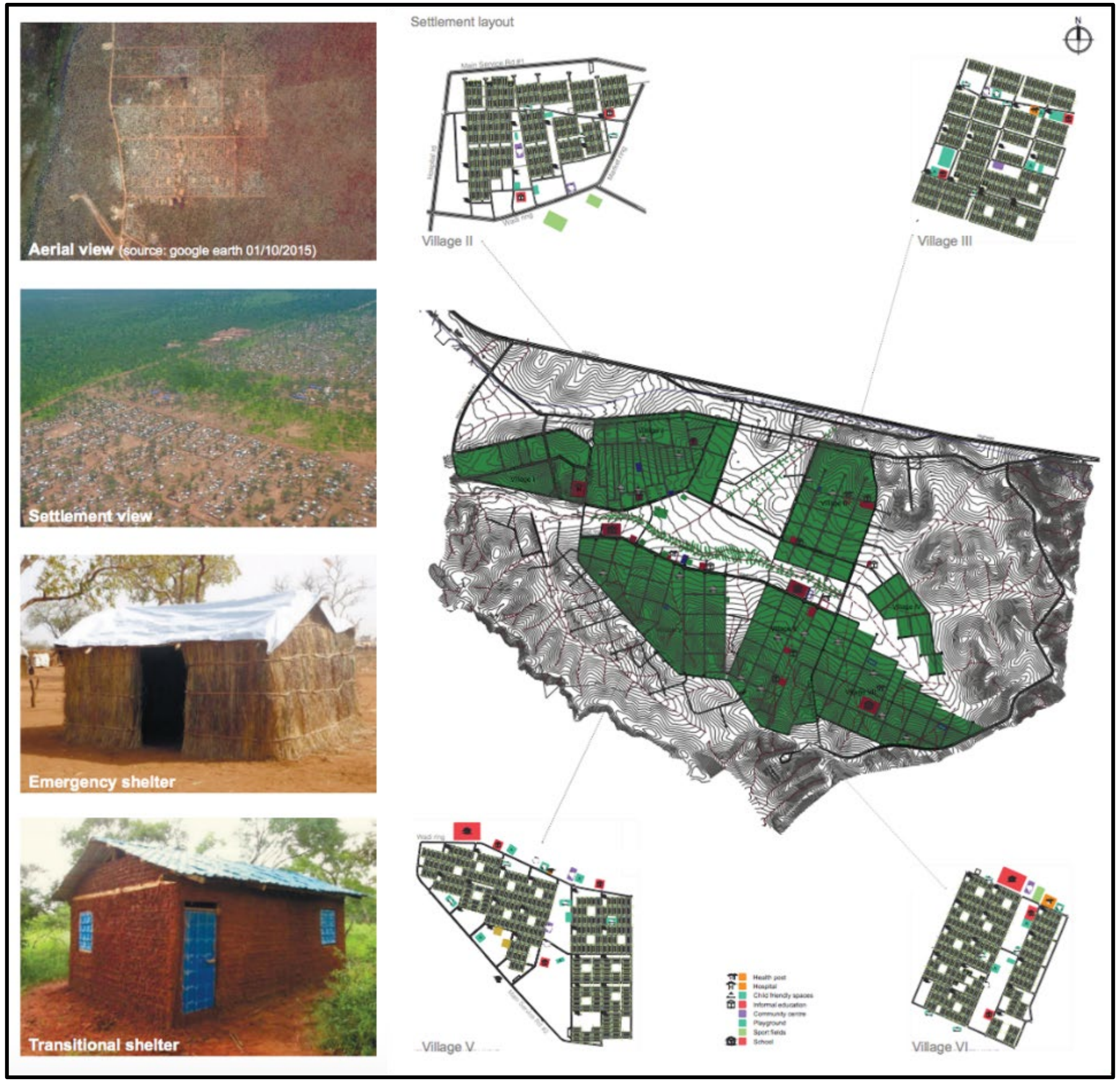


Source: [UNHCR (2018)]

- 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.

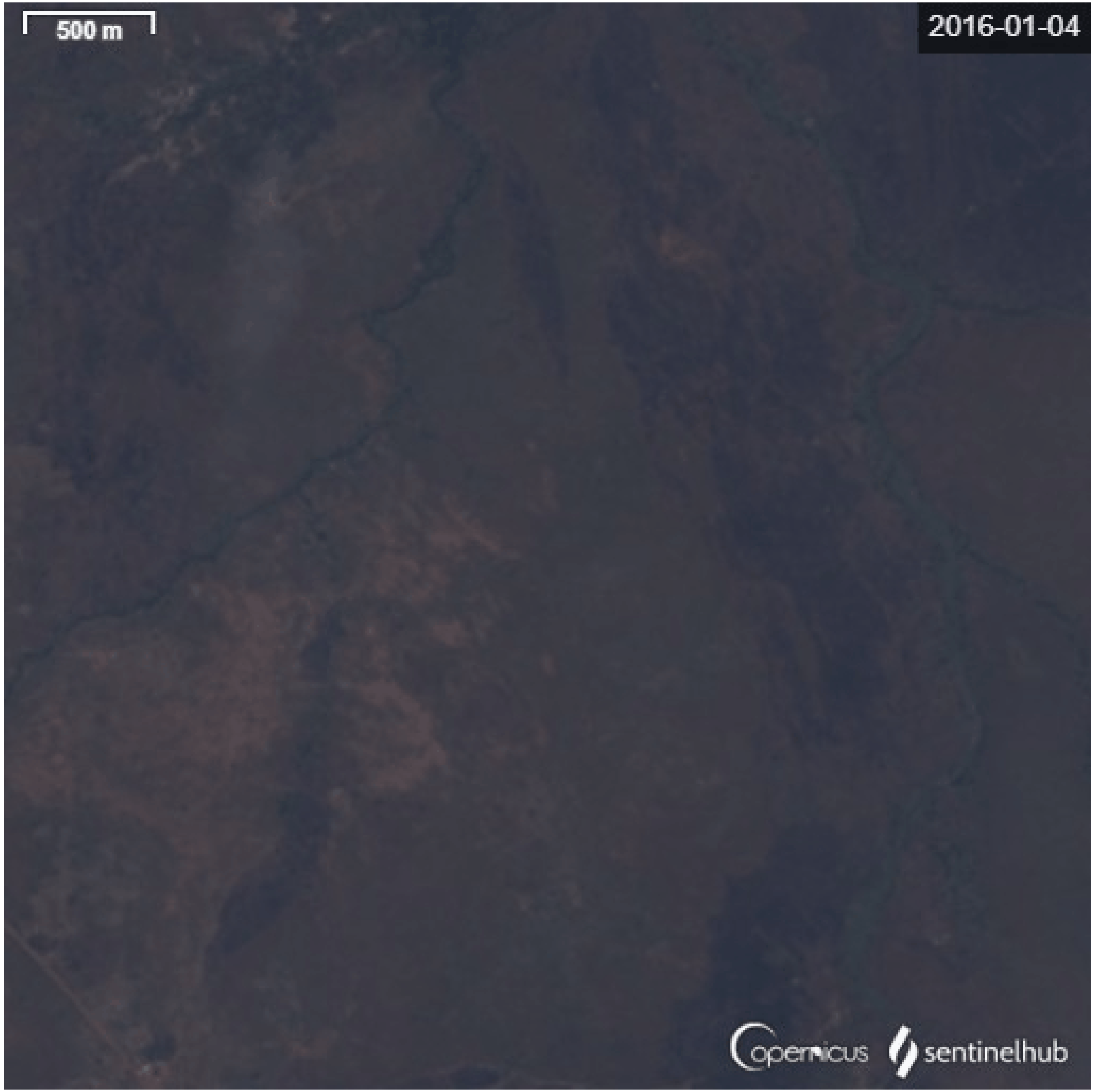
- There are many challenges with UNHCR site planning:
  - Ensuring sufficient space for shelter and agriculture
  - Efficiently distributing aid
  - Providing access to services within and nearby settlements
  - Mitigating environmental damage



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…

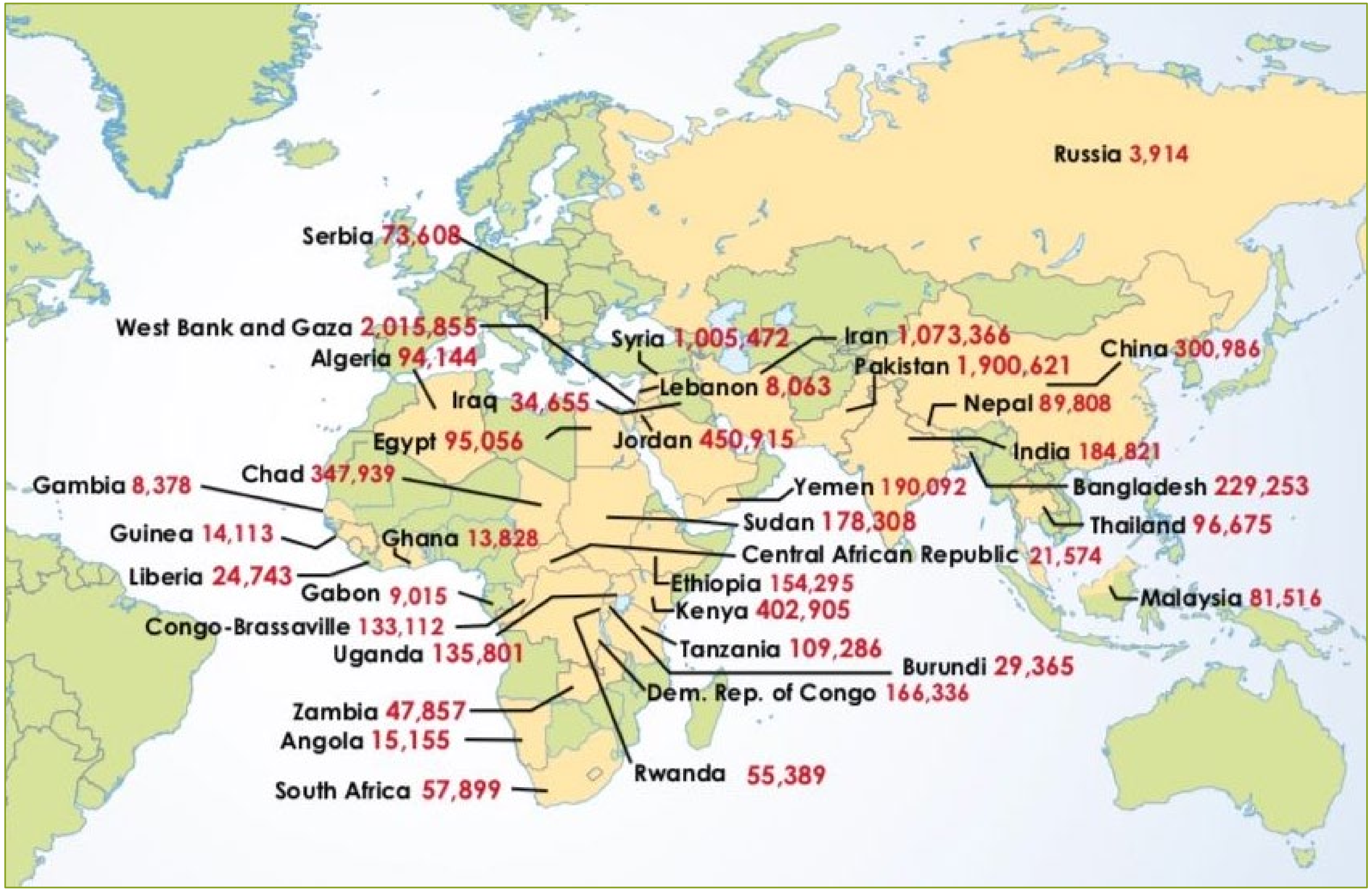
Source: [Guardian (2017)]

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

Source: [Getty Images (2013)]

Many refugee camps today will likely still be occupied for decades to come due to so-called ‘warehousing’ policies that restrict mobility.

- The average stay in a refugee camp is 10 years.
- Warehousing is a strong predictor of *protraction* as well as *dependence* on host governments.
- *Warehousing* isolates refugees geographically, marginalizes economically, and denies rights to migration and employment.



Source: [Smith (2004)]

Satellite remote sensing data are uniquely valuable for monitoring humanitarian conditions at refugee settlements.

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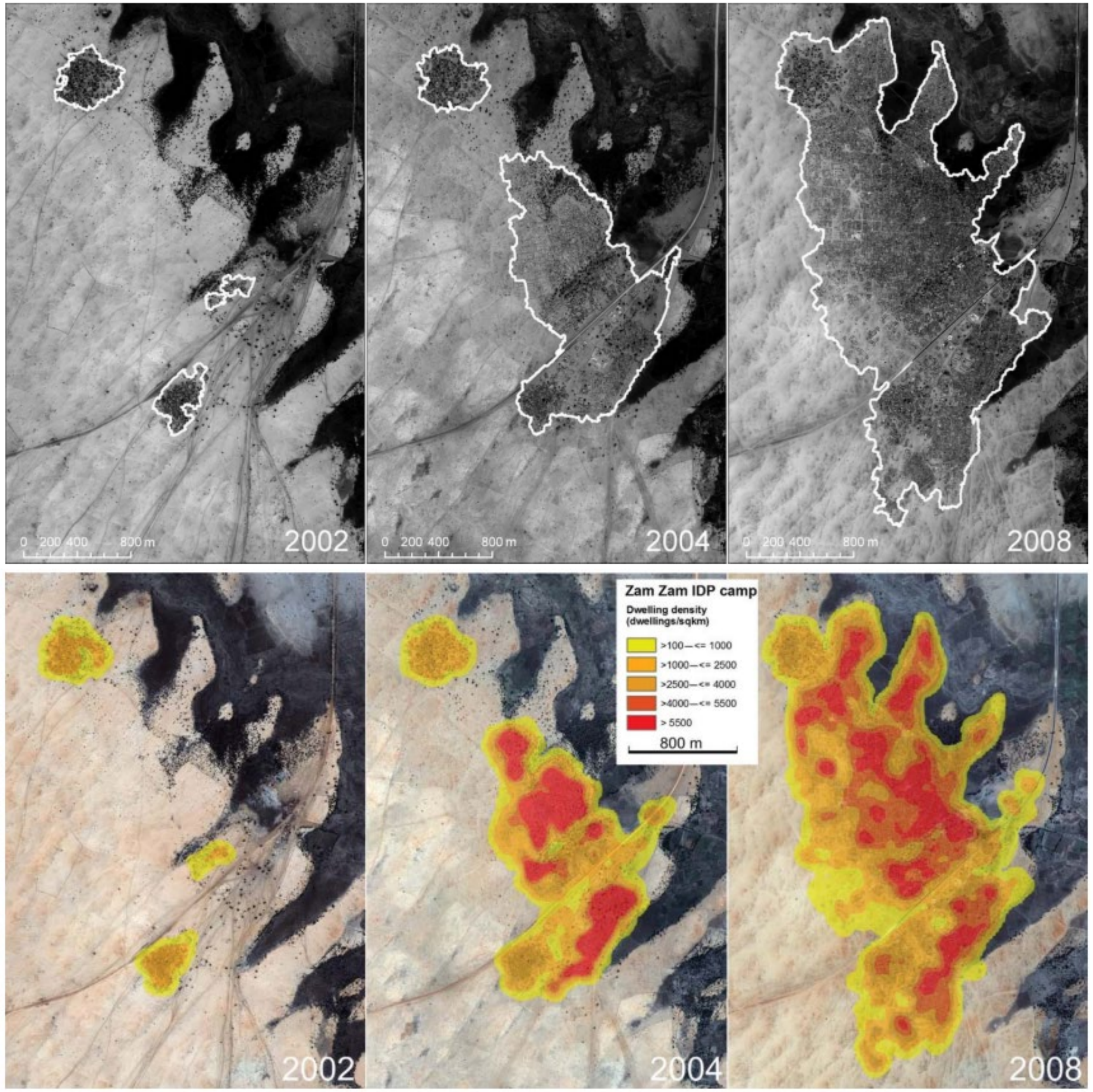
- Satellite data are flexible and can be adapted to support different lines of inquiry at different stages of a settlement's lifespan.
- Satellite-derived information on environmental and climatic conditions in and around refugee settlements help to localize insights on refugee livelihoods, sustainable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

Satellite data have been used for a variety of refugee settlement mapping applications.

- The earliest studies (e.g., Bjorgo, 2000) use satellite imagery to map or count refugee settlement dwellings, and this remains a common application (e.g., Raun et al., 2022; Quinn et al., 2018).

- Many other studies (e.g., Lang et al., 2010) use before and after “snapshots” to narrate settlement growth and estimate population.

- More recent studies leverage multitemporal or full time series of satellite data to map settlement expansion (i.e., Friedrich & Van Den Hoek, 2020) and land use/land cover changes (i.e., Nakalembe et al., 2022).



Source: Lang et al. (2010)

There are several challenges to monitoring refugee settlement dynamics using satellite data, including…

1. Refugee settlements and associated land use tend to be small-scale and are often difficult to detect or accurately characterize using publicly available satellite data from NASA and ESA platforms.

2. Dwellings and other structures and infrastructure within refugee settlements may be diffusely distributed and intermixed with vegetation and bare earth.

3. Refugee settlements are often rapidly built and settled, and settlements are established and closed each year around the world.

4. There is a general scarcity of up-to-date data on land cover/land use changes, and sometimes settlement-level population dynamics, at refugee settlements that would be needed for validating satellite-based maps.

We'll be dealing with some of these challenges in this and the next training.

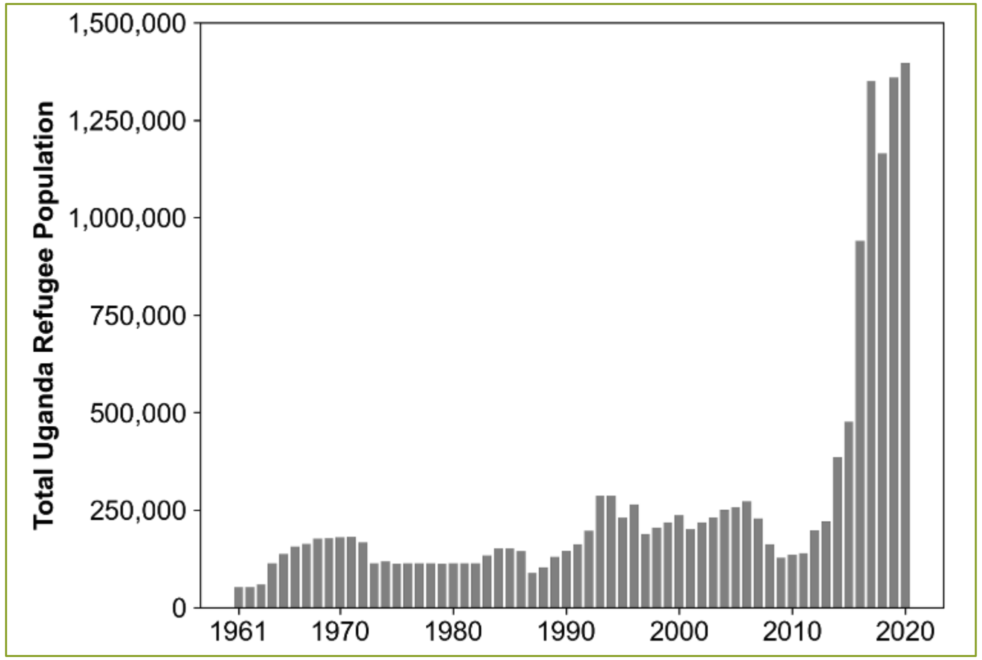
Case Study: Refugee Settlements in Uganda

Our case study analysis focuses on refugee settlements in Uganda.

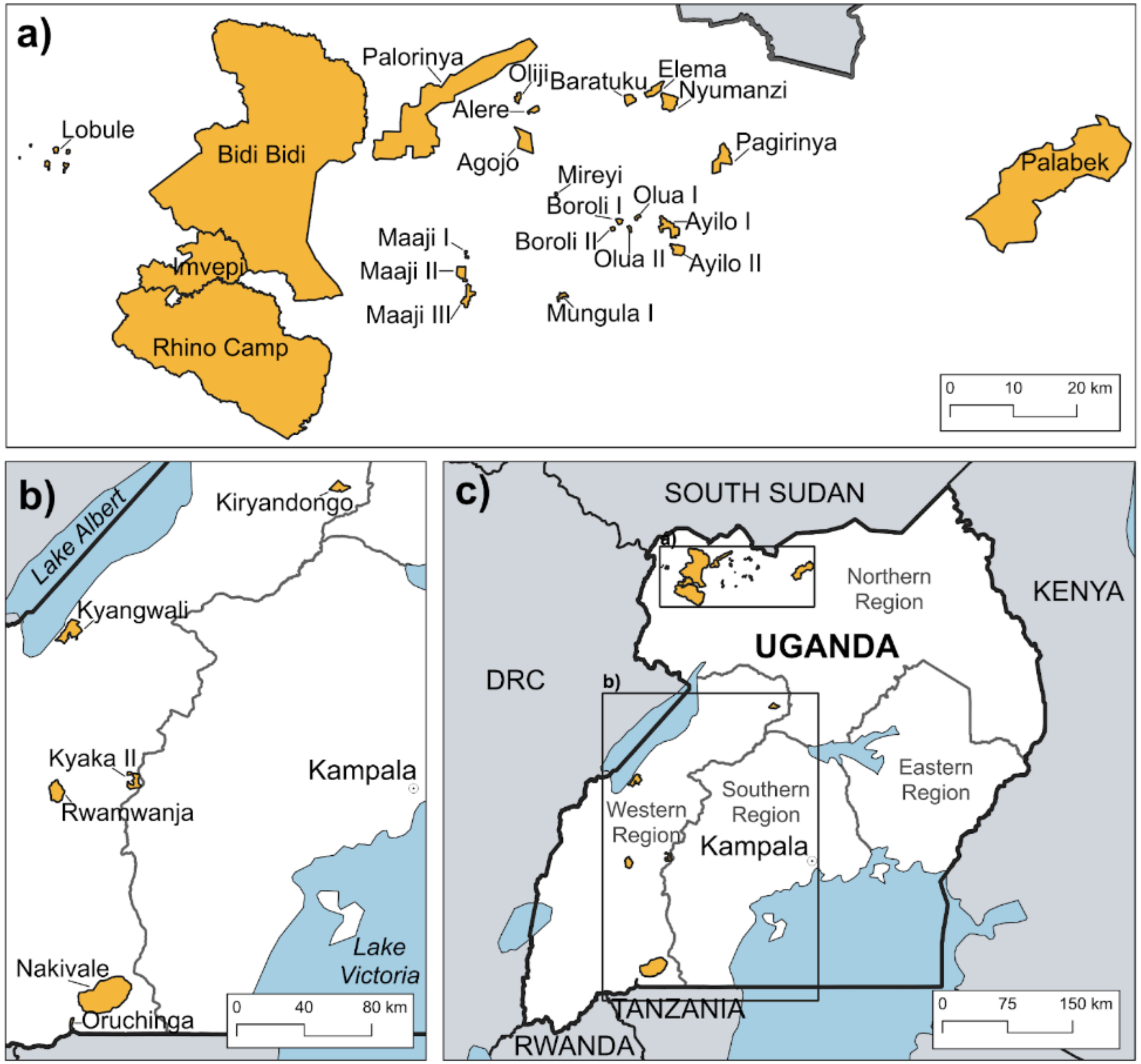
- The current total refugee population in Uganda is 1.4 million, primarily from South Sudan (950k) and Democratic Republic of the Congo (444k).
- Refugees in UNHCR-managed settlements are allocated a plot of land for their dwelling and agriculture, and granted access to services, such as health care, 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)]



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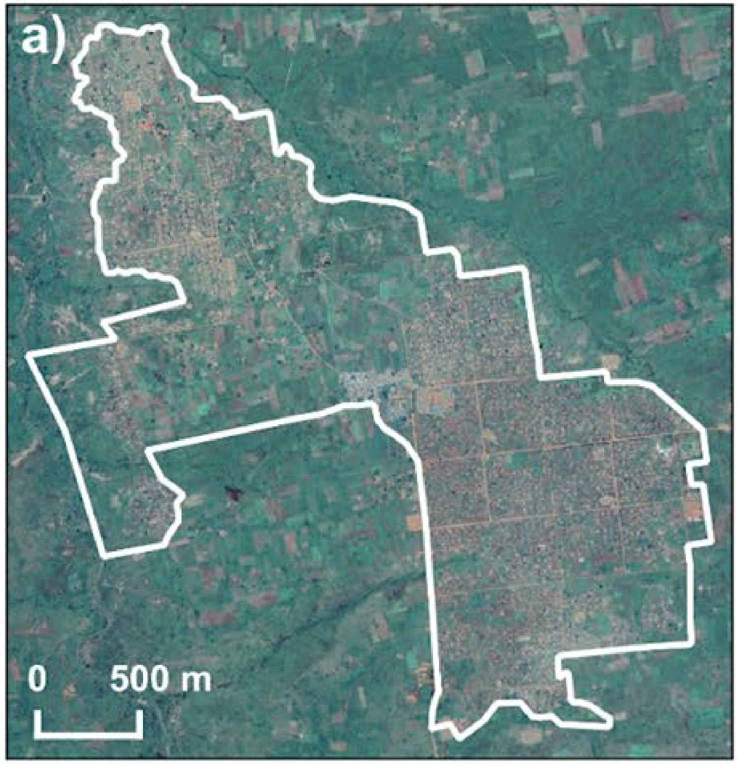

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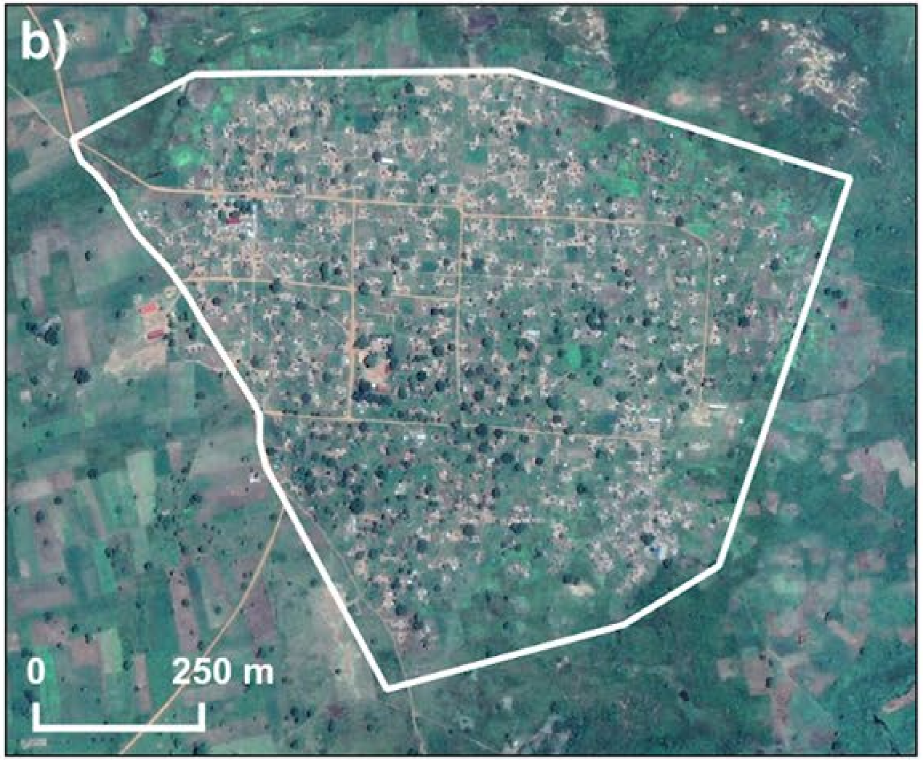
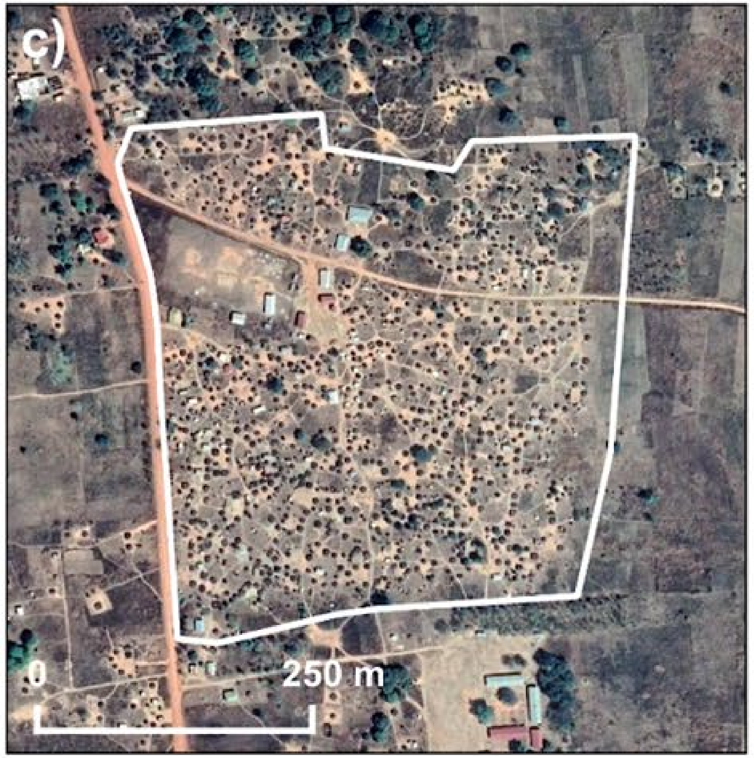
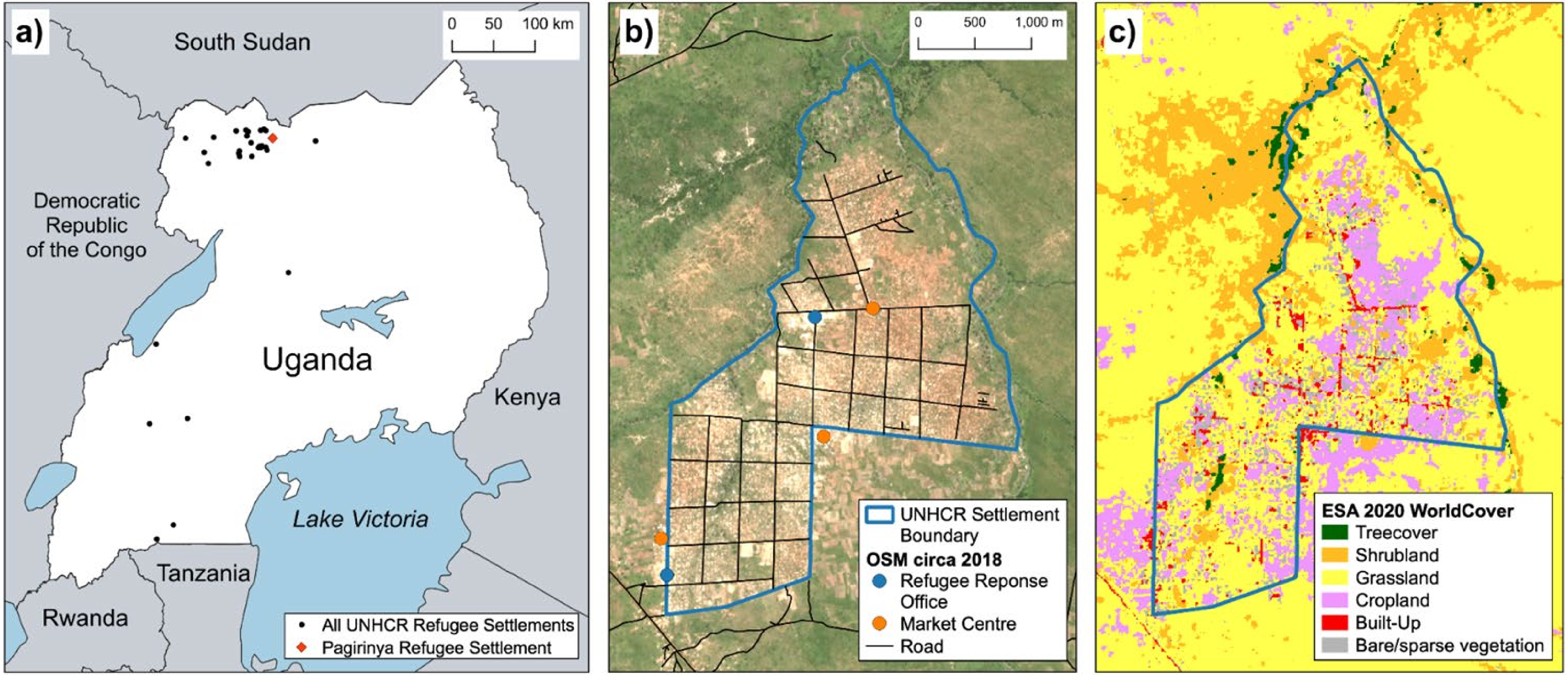


Mireyi



Source: [Van Den Hoek & Friedrich (2021)]

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

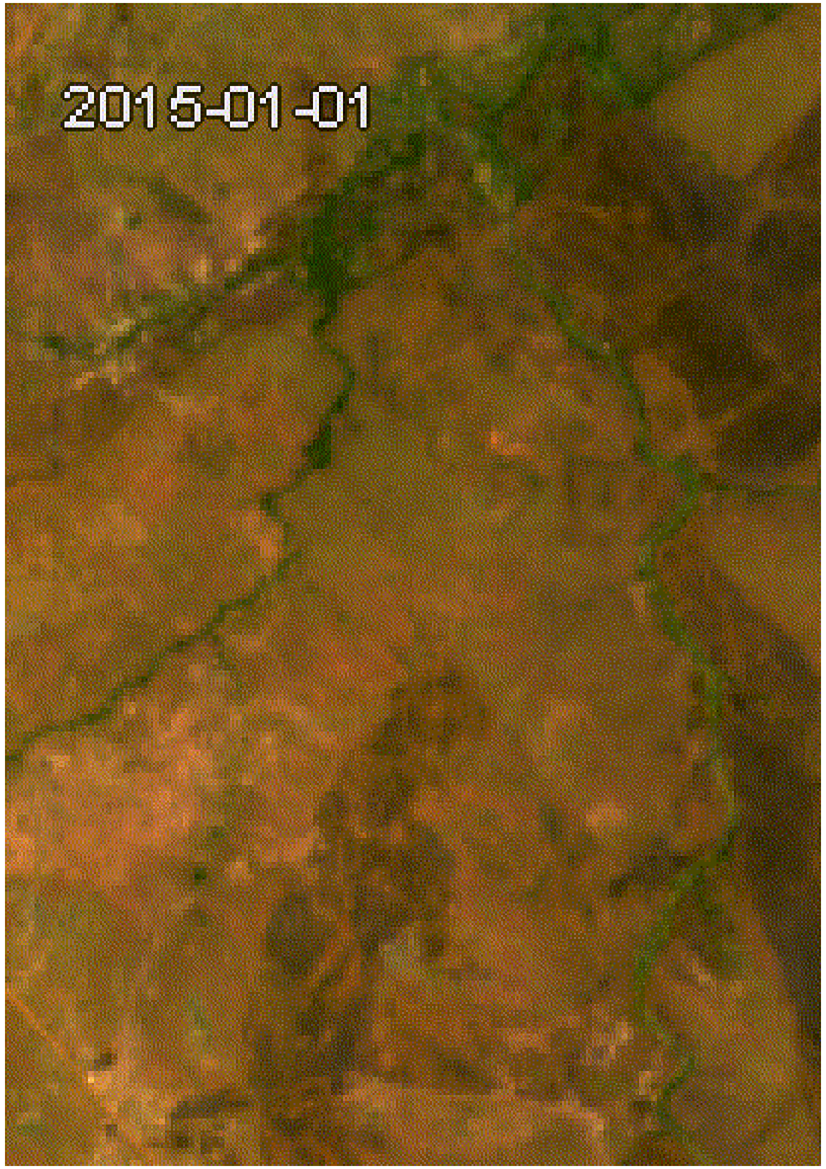


Source: Van Den Hoek & Friedrich (*forthcoming*)

Let's begin with our first task of visualizing the settlement and expansion of Pagirinya Refugee Settlement.

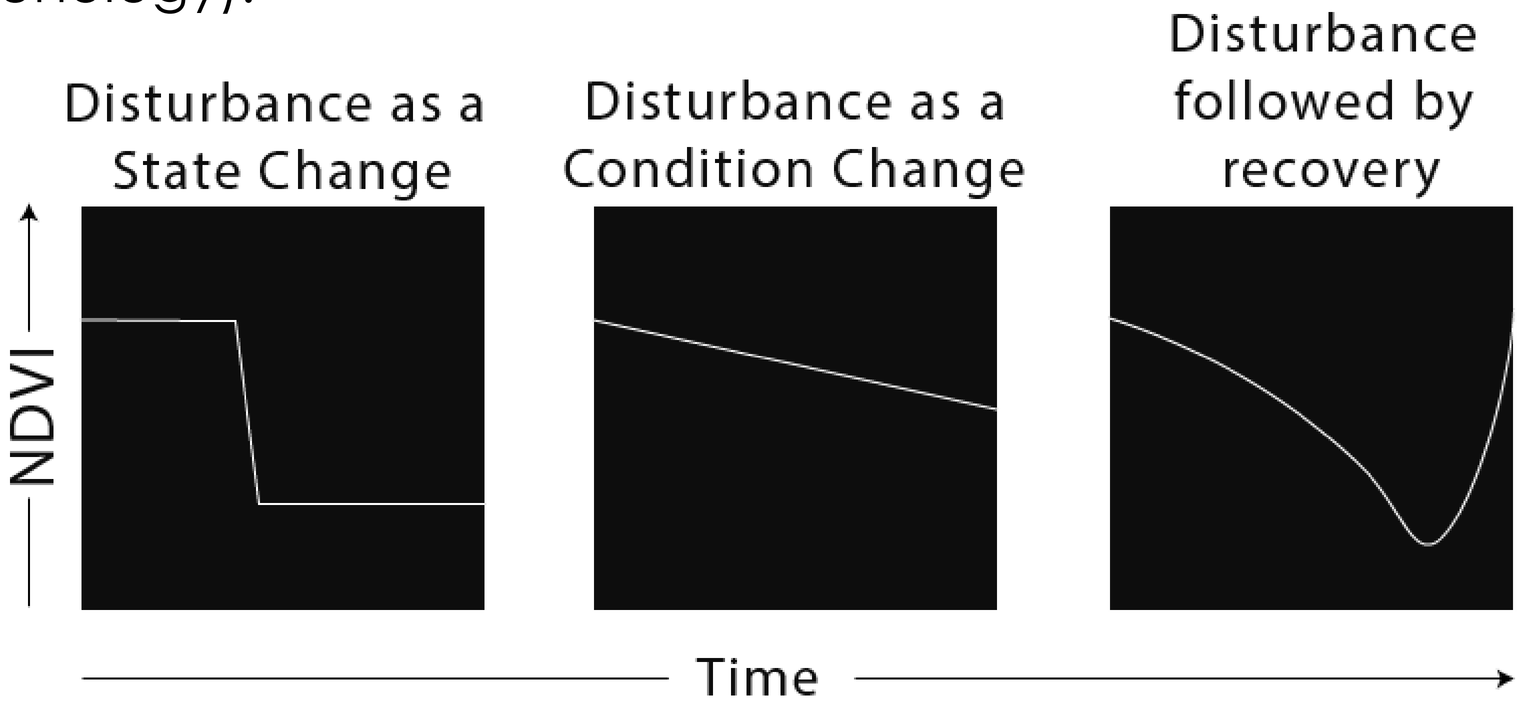
Task: Generate a time series video of Landsat 8 imagery from 2015 – 2020

EE Code Link



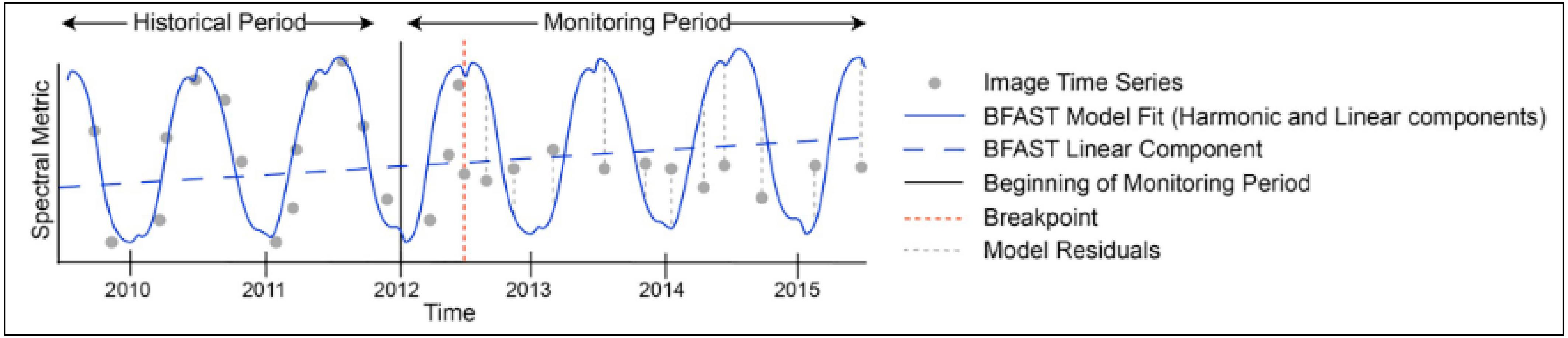
We can also use *time series disturbance* detection approaches to document land cover changes within and around refugee settlements.

- A land cover change (i.e., disturbance) event can be an abrupt change in state, gradual change in state or condition, or a change followed by a recovery.
- We can analyze Landsat time series data with the Breaks for Additive Seasonal and Trend (BFAST) disturbance detection algorithm, which accounts for long term trend (browning due to protracted drought, for example) as well as seasonal trends (phenology).



Breaks for Additive Seasonal and Trend (BFAST)

- BFAST is a remote sensing time series detection algorithm built for identifying disturbances by accounting for long term trend (browning due to protracted drought, for example) as well as seasonal trends (phenology).
- Inputs: Image time series, user-defined parameters
- Outputs: Pixel-level date of disturbance (i.e., breakpoint timing) and magnitude of change (i.e., the medial residual between expected and observed values during the monitoring period)



BFAST can be parameterized in recognition of landscape (phenology) and disturbance dynamics.

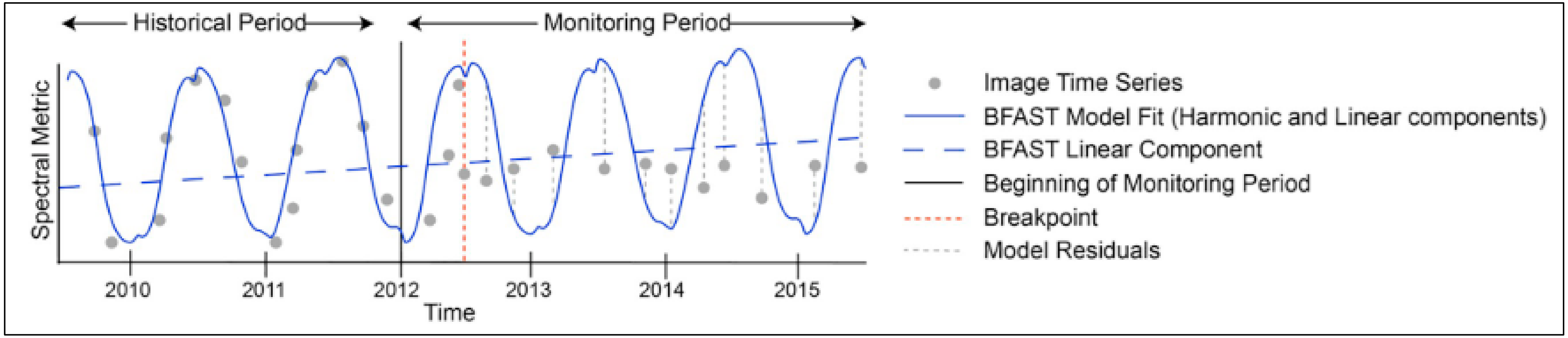
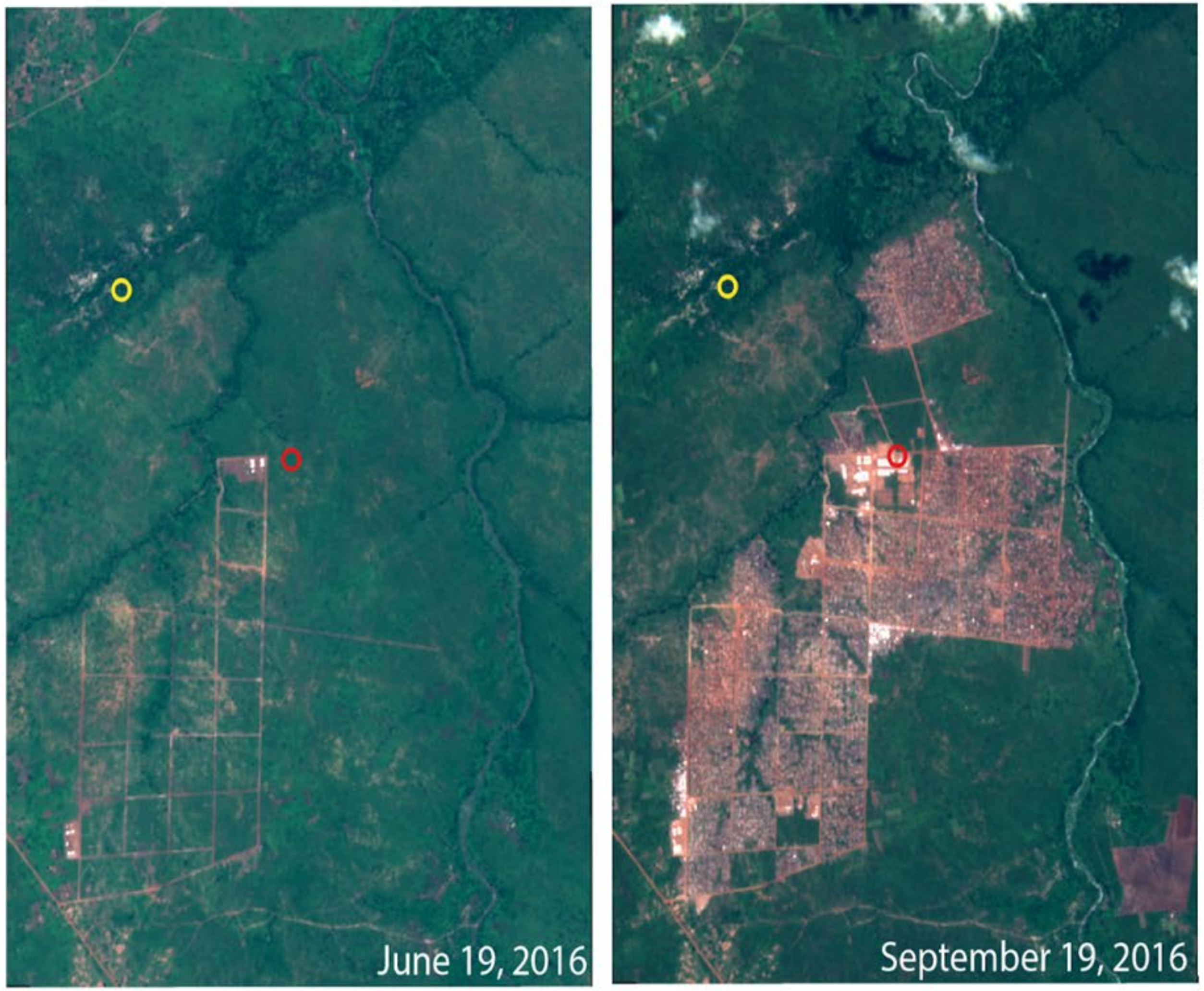


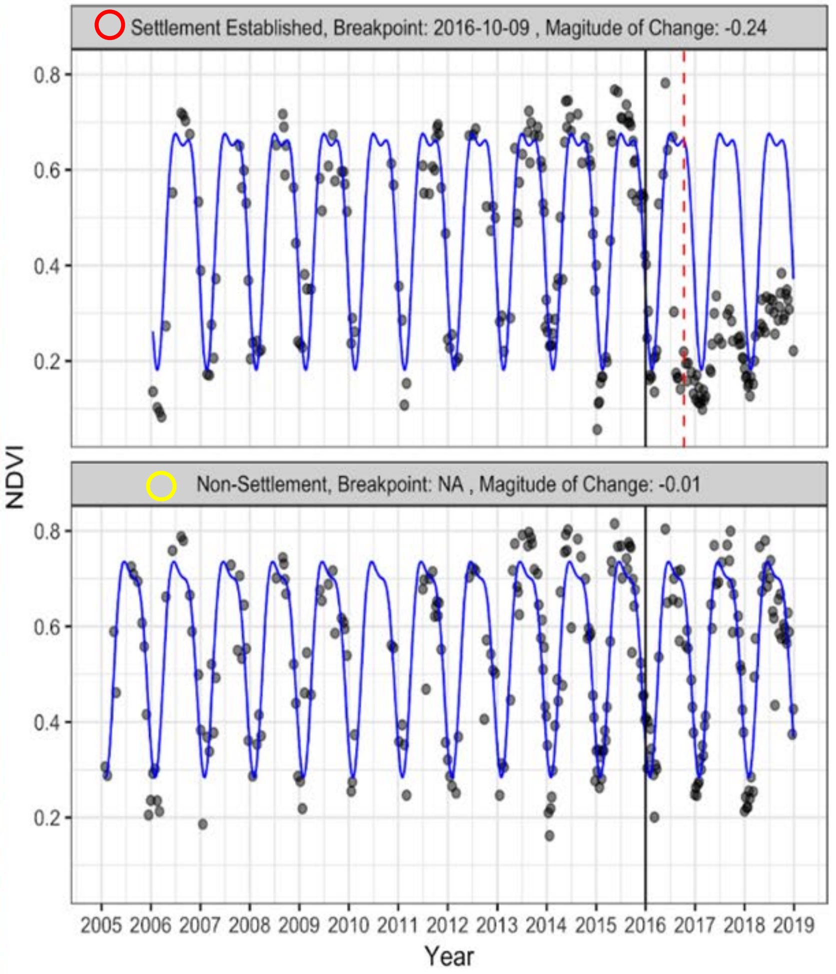
Table 1
BFAST parameters, potential values and description of parameter.

Parameter	Value	Description
Formula (model fit)	trend	Fit model on linear trend
	harmonic	Fit model on seasonal harmonic
	trend and harmonic	Fit model on both linear trend and seasonal harmonic
h	0, 0.25, 0.5, 1	Fraction of the total length of time series equal to the number of observations used to fit the linear model for each segment if there are multiple breakpoints
Order	1, 2, 3, etc.	Order of seasonal harmonic
History (specify how stable history period is estimated)	ROC (default)	Reverse ordered cumulative sum
	BP	Bai and Perron breakpoint estimation
	all	all (entirety of historical time series before start date)
Start	date	Start of monitoring period
End	date	End of monitoring period (if not defined, the rest of time series after start date is included)

Source: Friedrich & Van Den Hoek (2020)

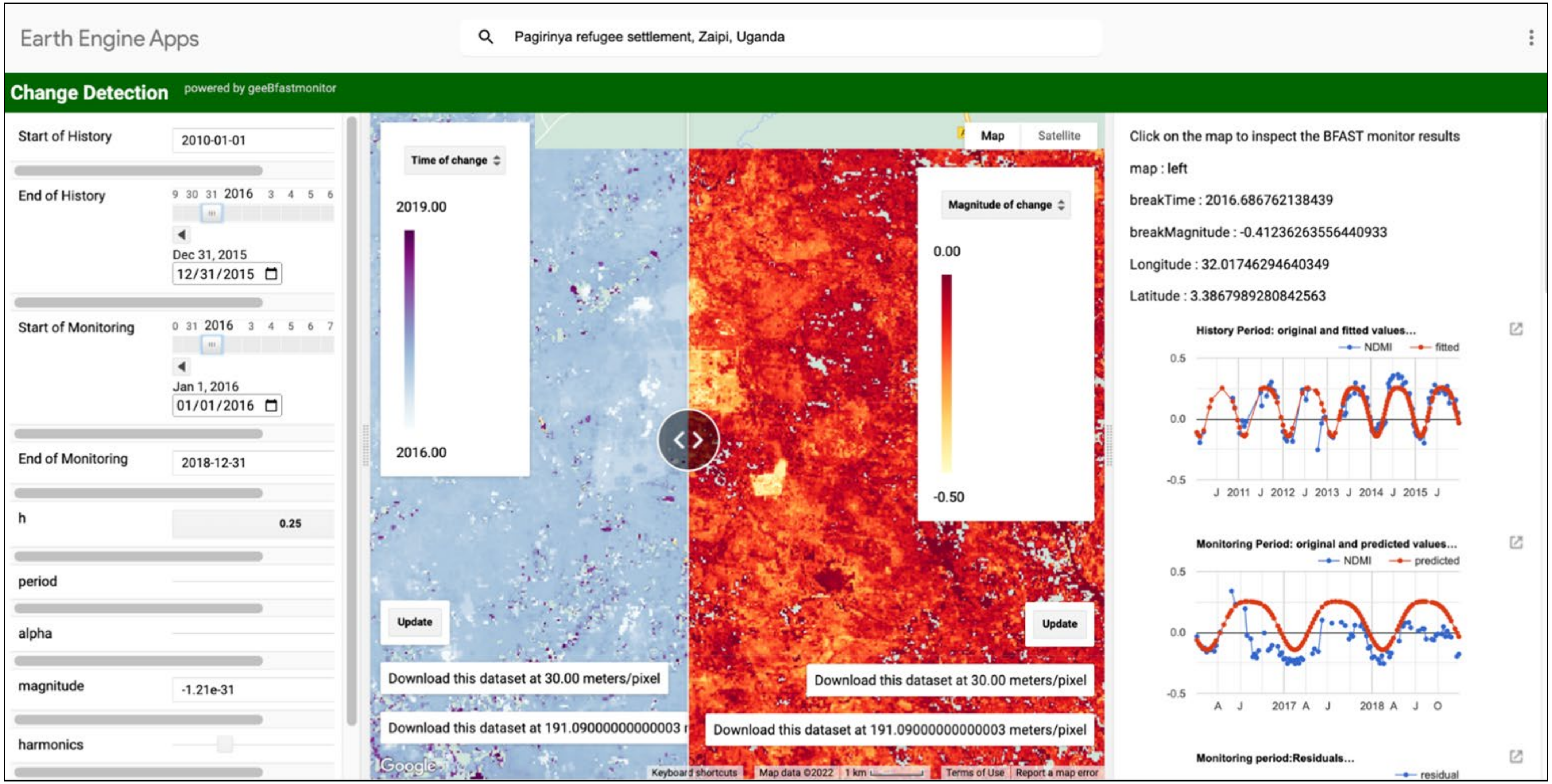
BFAST Results at Pagirinya Refugee Settlement, Opened in 2016



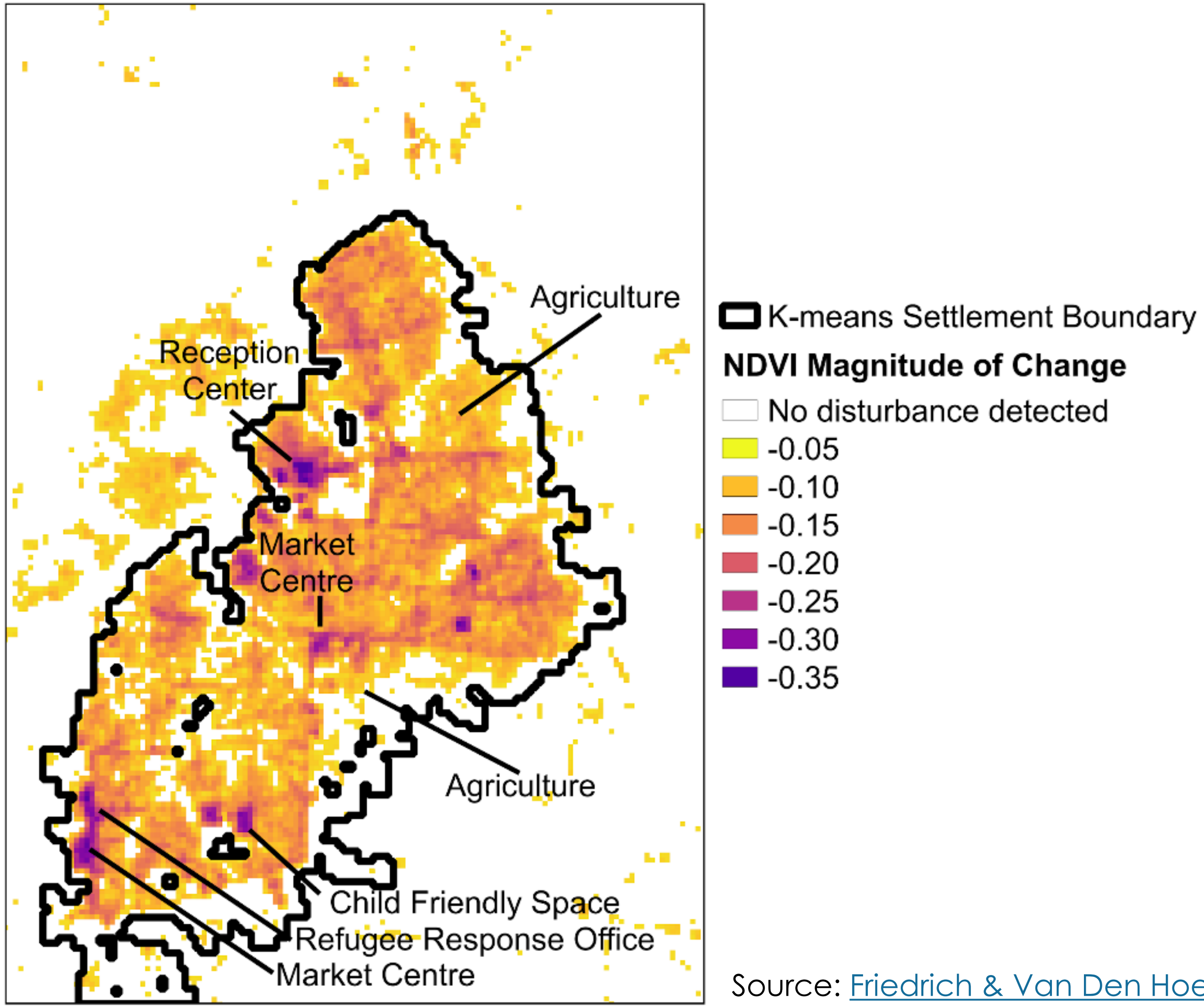


Source: [Friedrich & Van Den Hoek (2020)]

BFAST Monitor Google Earth Engine App at "Pagirinya Refugee Settlement"



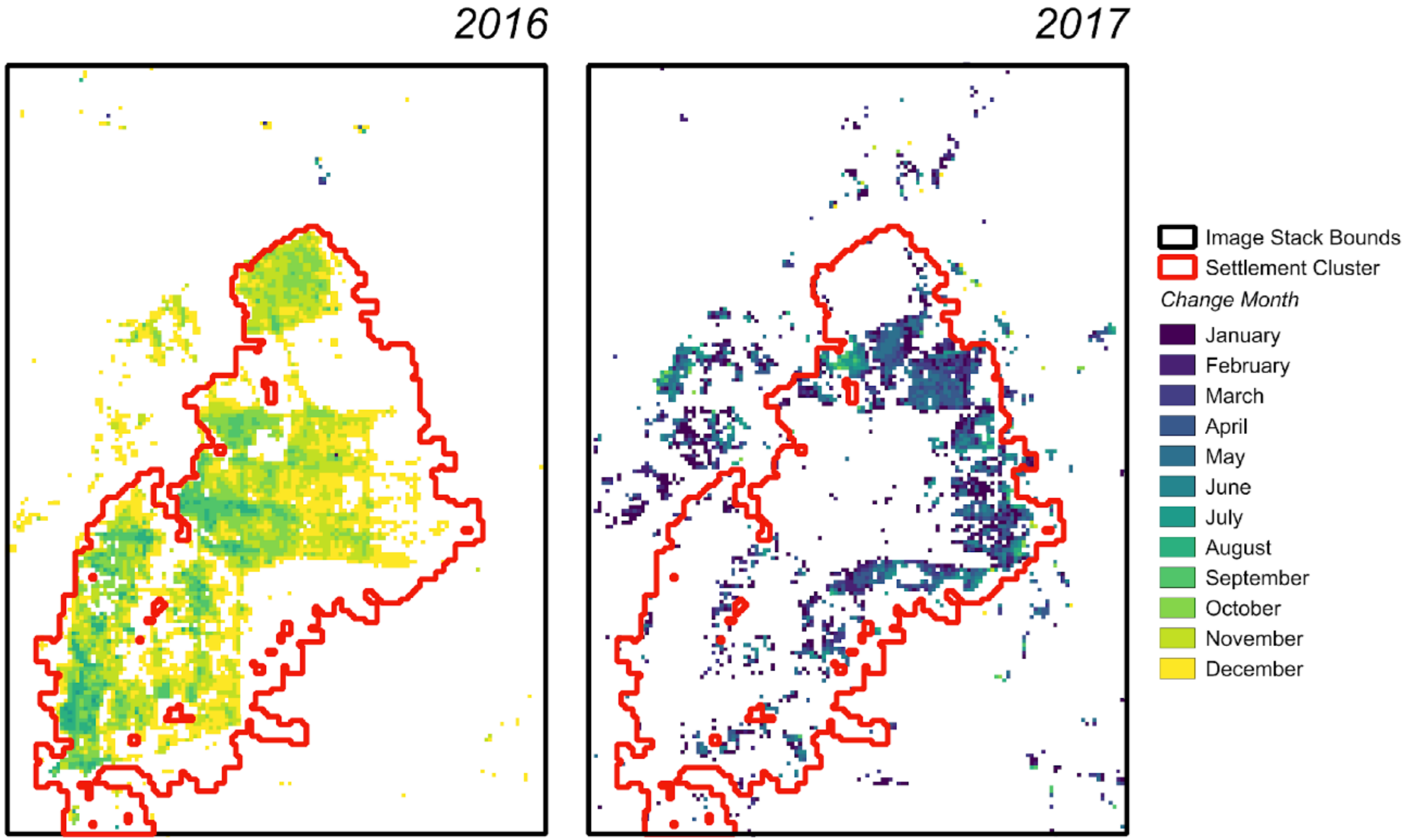
BFAST captures the geographic pattern of conversion of natural vegetation to infrastructure, dwellings, and agriculture.



Source: [Friedrich & Van Den Hoek (2020)]

Looking at the dates of disturbance, we see a step-by-step account of the establishment and expansion of Pagirinya Refugee Settlement.

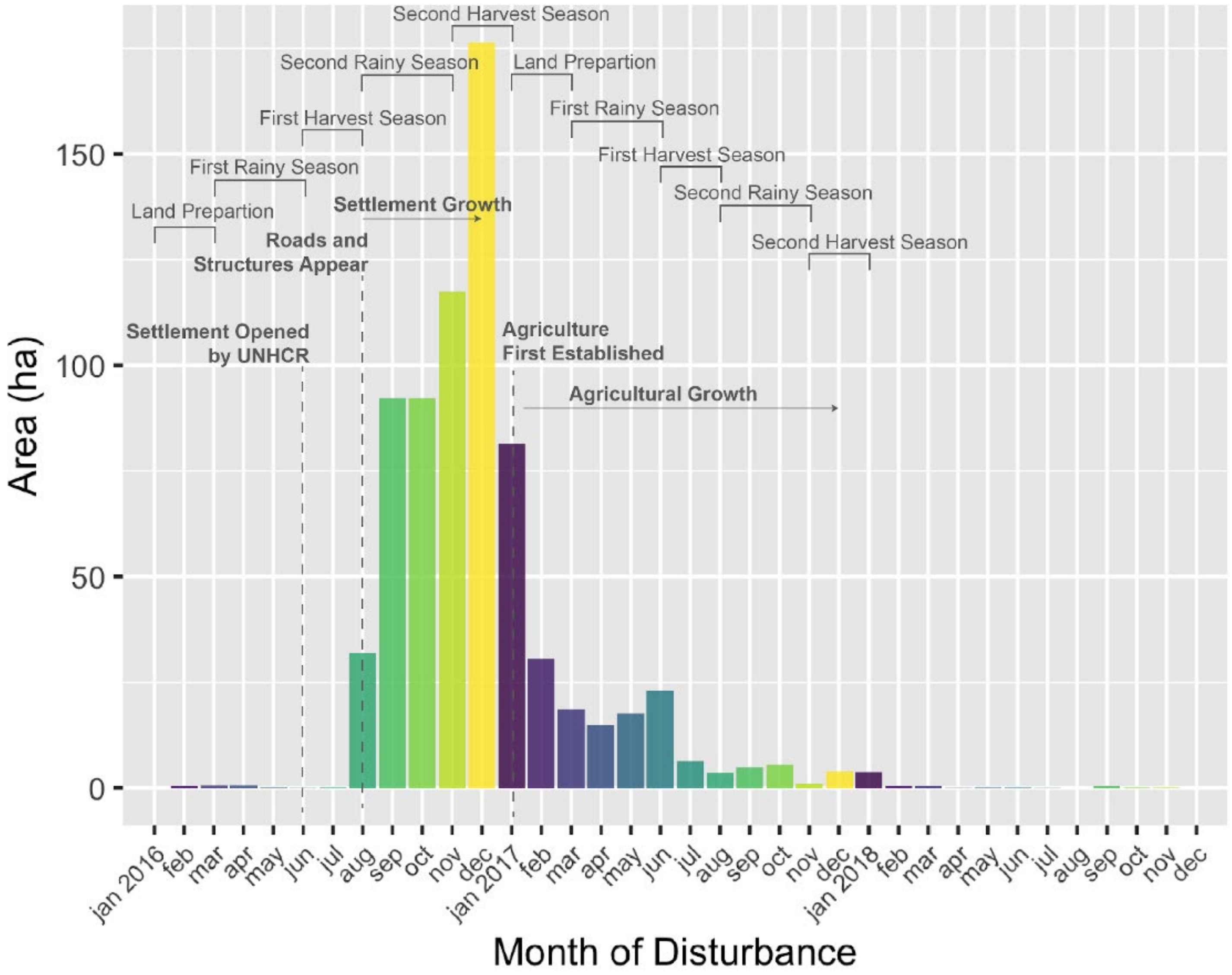
- BFAST shows that the majority of settlement was established in mid to late 2016.
- Comparing to UNHCR reports, the cumulative disturbed area in 2016 matches the settlement's surface area.



Source: [Friedrich & Van Den Hoek (2020)]

Looking at the dates of disturbance, we see a step-by-step account of the establishment and expansion of Pagirinya Refugee Settlement.

- The additional disturbance that BFAST mapped from early 2017 took place at the periphery of the settlement, mainly for agricultural cultivation.
- Looking at the timeline of disturbance, the agricultural cycle presents itself in BFAST outputs where we see large areas of land cleared in Jan 2017 in preparation for cultivation.



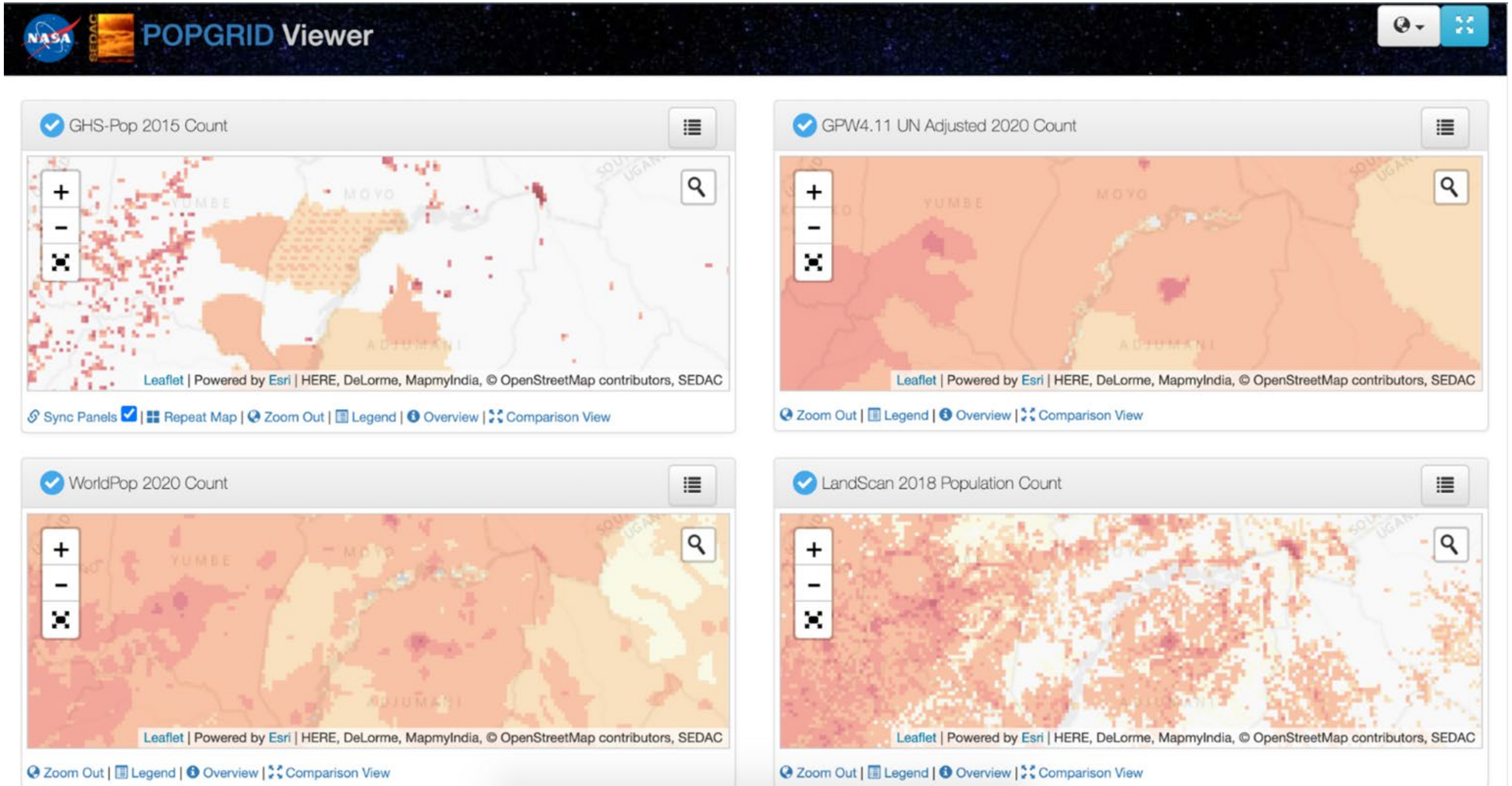
Source: [Friedrich & Van Den Hoek (2020)]

The timing, magnitude, and spatial extent of changes that BFAST mapped are a result of refugee arrivals to Pagirinya.

- These land cover dynamics data hint at population dynamics.
- UNHCR reports refugee populations at the settlement-level with monthly or quarterly population-specific or more general fact sheets and reports national and global refugee populations annually and mid-year.
- The different scales and priorities of population data collection result in some irregularities in the population datasets in terms of the date of data collection and the scale of the analysis (i.e., sub-settlement, settlement-level, administrations, national, regional).
- These issues inhibit long-term monitoring and cross-settlement and cross-national comparisons of population counts.
- However, satellite data can help shed light on settlement-level population dynamics!

There are a variety of population datasets available of varying spatial and temporal resolutions.

POPGRID Viewer



For our case study, we'll compare three commonly used satellite-derived population datasets that disaggregate national population data to pixels.

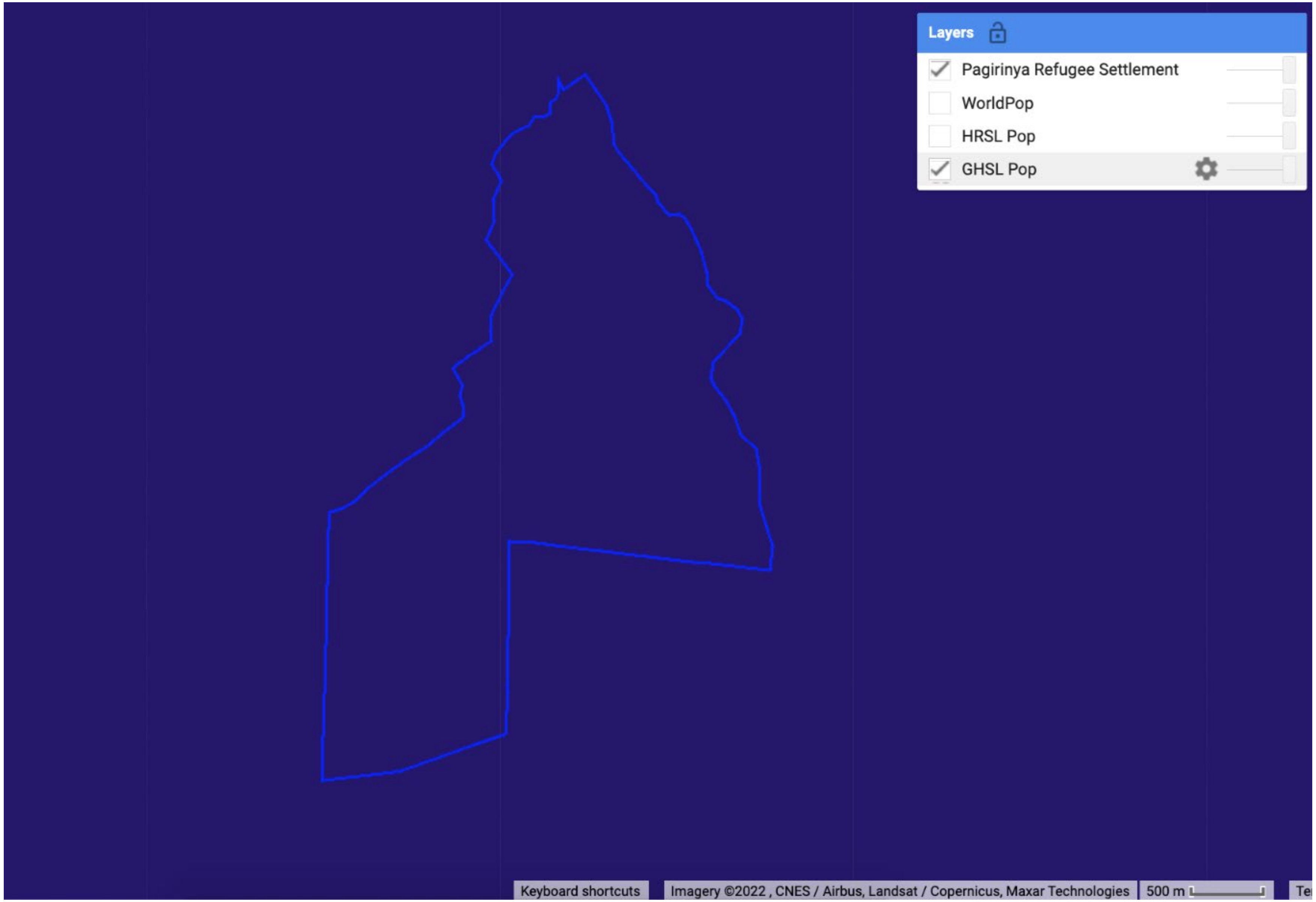
Dataset	Methodology	Sensor	Spatial Resolution	Temporal Resolution	Source
Global Human Settlement Layer Population (GHSL)	Dasymetric with built-up dataset	Landsat	250 meter	1975, 1990, 2000, 2015	Hosted as a public EE asset.
High Resolution Settlement Layer (HRSL)	Binary dasymetric	Landsat	30 meter	Single timestamp (imagery sourced 2011–2015)	Shared as a public asset.
WorldPop Constrained	Statistical/ dasymetric (top-down constrained)	Multiple geospatial covariates & building footprints	100 meter	2020	Shared as a public asset. Publicly available from WorldPop.

Let's see how well we can monitor population in Pagirinya.

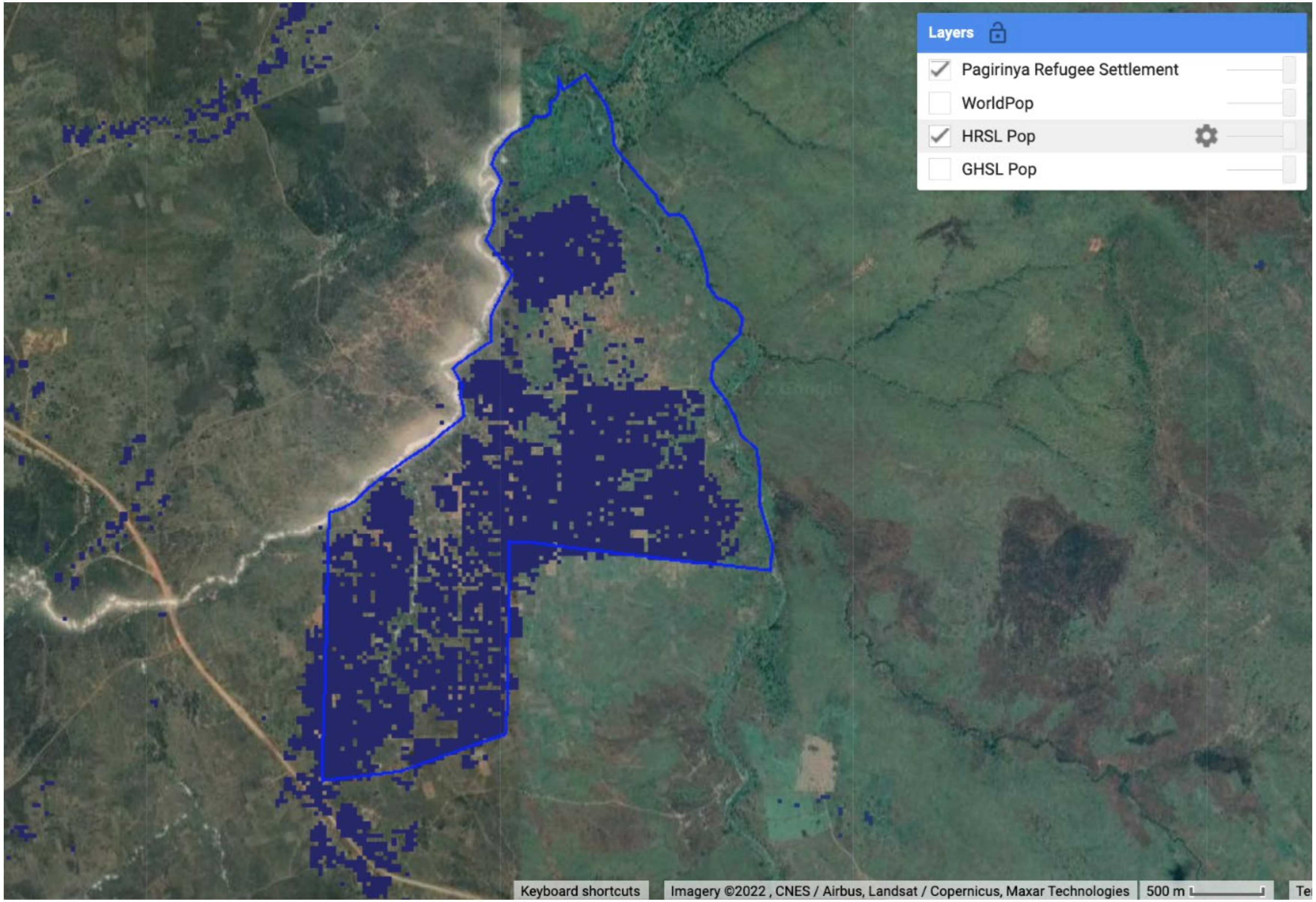
Task: Compare estimates of population counts from three satellite-derived population products and compare with UNHCR population data

[EE Code Link]

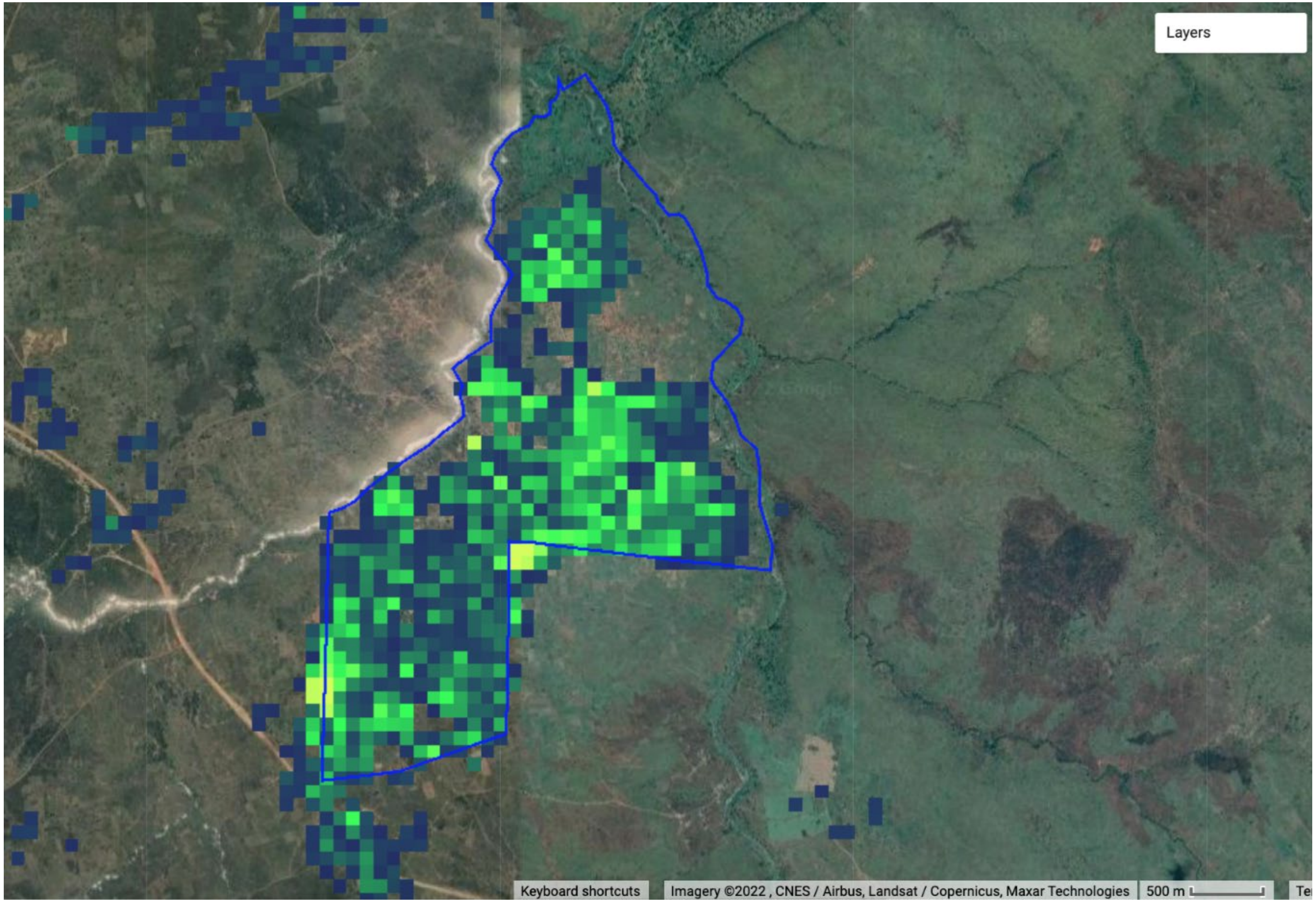
GHSL from 2015 (250 meter)



HRSL from ~2019 (30 meter)



WorldPop Constrained from 2020 (~100 meter)



Across all three population datasets, we find a consistent, large underestimation of refugee population.

```
GHSL: 0
GHSL_diff: -36784
HRSL: 42.696342280750514
HRSL_diff: -36741.30365771925
Name: Pagirinya Refugee Settlement
UNHCR_Pop: 36784
WorldPop: 7183.477453875074
WorldPop_diff: -29600.522546124925
YearEst: 2016
```

```
GHSL: 2678.1927795410156
GHSL_diff: -65025.807220458984
HRSL: 6279.097919603079
HRSL_diff: -61424.90208039692
Name: Kiryandongo Refugee Settlement
UNHCR_Pop: 67704
WorldPop: 18039.148836934324
WorldPop_diff: -49664.85116306567
YearEst: 2014
```

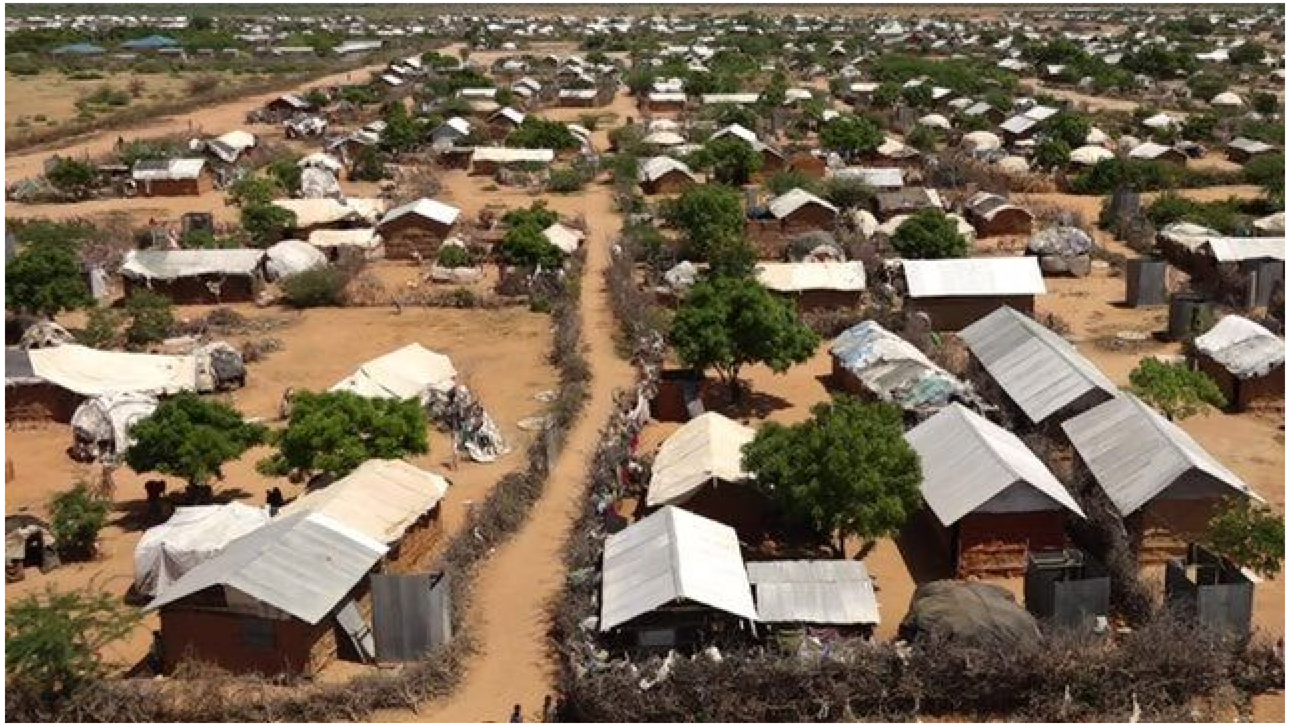
- Why is this the case when population datasets are being developed at higher spatial resolutions?
  - National census data do not include refugee populations.
  - Built-up products tend to greatly underestimate refugee settlement areas.
- What are the consequences?
  - Inaccurate population estimates may contribute to cascading data impacts in public health programming, development monitoring, food security monitoring, disaster risk reduction efforts, etc.

Citations

- *Enhanced data and methods for improving open and free global population grids: putting 'leaving no one behind' into practice* by Freire et al. (2020)
- *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)
- *The spatial allocation of population: a review of large-scale gridded population data products and their fitness for use* by Leyk et al. (2019)
- *Impacts of large-scale refugee resettlement on LCLUC: Bidi Bidi refugee settlement, Uganda case study* by Nakalembe et al. (2022)
- *Implications for Tracking SDG Indicator Metrics with Gridded Population Data* by Tuholske et al. (2021)
- *Satellite-Based Human Settlement Datasets Inadequately Detect Refugee Settlements: A Critical Assessment at Thirty Refugee Settlements in Uganda* by Van Den Hoek & Friedrich (2021)
- *Spatially disaggregated population estimates in the absence of national population and housing census data* by Wardrop et al. (2018)
- Aggregating Population Data in GEE from Spatial Thoughts (blog)

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: BBC

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  - jamon.vandenhoek@oregonstate.edu
  - www.conflict-ecology.org
- 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 3 of the training:

Detecting Agricultural and Vegetation Changes In and Surrounding Refugee Settlements