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# Refugee Watch: An Open-Source Framework for Climate Forecasting and Humanitarian Analytics in Displacement Settings

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## Abstract

The global refugee crisis presents complex challenges where displacement intersects with climate vulnerability, leaving millions without access to basic necessities and undermining agricultural self-sufficiency. Climate-related extremes further exacerbate the challenges of self-sufficiency through on-site agricultural activities. To address this pressing issue, we introduce *Refugee Watch*, a proof-of-concept educational framework designed to facilitate climate resilience research. This reproducible tool enables seamless integration of real-time dataset updates, as well as accessible deep learning and statistical forecasting via [Posit Cloud](#). Its source code is shared at our [GitHub](#). This educational platform aims to provide researchers, social scientists, and policymakers with a crucial entry point for visualizing climate data and informing evidence-based strategies to support refugees adapting to climate change. By leveraging this tool, stakeholders can develop effective interventions to mitigate the impacts of climate extremes on vulnerable populations.

## 1. Introduction

The global refugee crisis has reached unprecedented levels, with conflicts, persecution, and climate-driven disasters displacing over 100 million people worldwide (Tappis et al., 2021; UNHCR, the UN Refugee Agency; Ferris & Kirisci, 2016). This staggering figure underscores the urgency of innovative, interdisciplinary solutions to address both immediate hardships and long-term resilience for displaced populations.

On the ground, refugees endure profound traumas: the loss of homes, family members, and lifelong savings, com-

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pounded by limited access to basic necessities such as safe water, nutritious food, and adequate shelter. In conflict zones, critical infrastructure like electricity, healthcare, and educational resources remain scarce or inaccessible (Gilmour & Bou-Orm, 2025). Children and adolescents in these camps are thus most vulnerable, with dire living conditions that threaten their physical, emotional, and psychological well-being. These conditions can scar individuals across their lifespan (Ünver & Fiş, 2025; Veronese et al., 2021) and perpetuate intergenerational cycles of vulnerability (Mahamid et al., 2025).

Climate change intensifies these challenges, further undermining refugees’ capacity for self-sufficiency. Extreme weather events like droughts, floods, and heatwaves disrupt agricultural activities and resource availability in temporary settlements. The United Nations High Commissioner for Refugees has labeled current drought-related demands as “unprecedented” (Nations, 2023), anticipating immense challenges in sustaining agricultural farms in the coming decades.

Ensuring the resilience of refugee populations in the face of climate change requires low-cost solutions that integrate climate data with social science research and agricultural management. As a step in this direction, we develop *Refugee Watch*, an open-source Python-based framework for acquiring and visualizing earth observation datasets (EOD). Implemented using the `Streamlit` package and hosted on Posit Cloud, our prototype is accessible at this [link](#) and archived on [GitHub](#). EOD has proven predictive of economic conditions in data-scarce regions (Jean et al., 2016), motivating its integration into humanitarian monitoring frameworks. To support anticipatory planning, we integrate probabilistic forecasting via Prophet and deep autoregressive modeling via DeepAR, evaluating their utility for anticipating climate-driven resource stress in displacement settings.

Despite growing recognition that digital technologies can support refugee health outcomes (Matlin et al., 2025), few open-source tools integrate climate forecasting with displacement data for actionable humanitarian analytics. Ultimately, our work aims to pioneer climate-resilient solutions for refugee support, foster refugee advocacy, and facilitate collaborations among data scientists, policymakers, and

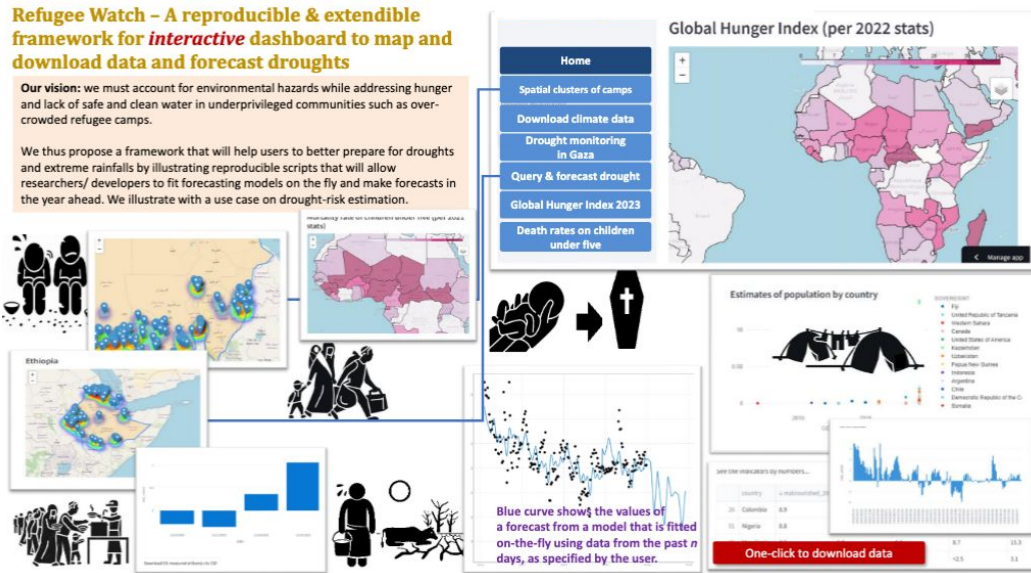


Figure 1. Overview of the proposed framework. Forecast results produced with Prophet are displayed at the bottom center. The top-right inset shows a choropleth map with zoom controls (“+/-”), providing an interactive view. A link is included to explore an example.

interdisciplinary researchers. By democratizing access to geospatial analytics and simplifying deep learning and statistical modeling, we envision “Refugee Watch” as a bridge between technical expertise and frontline humanitarian action, a crucial step in protecting vulnerable populations amidst rising global instability.

## 2. Methods

### 2.1. Data

We employed various data sources for this prototype to illustrate a variety of functionalities offered through Streamlit; of note:

**Natural Earth Data** (Earth, 2009) is a public resource for users to download rasterized and vectorized geographical maps.

**ClimateSERV2.0** (Pulla, 2019) is a web-based application developed by SERVIR that provides researchers and decision-makers to download and visualize historical data on rainfall, vegetation condition, temperature. It also offers 180-day forecasts on various weather variables.

**Wiki:** other data includes manually curated dataframes extracted from Wiki page on refugee camp.

### 2.2. Streamlit for ease of adoption by novice

Our educational framework consists of a set of simplistic Python scripts that was written for Python learners. This is made feasible through the use of a multipage implementation strategy so that future developers can easily extend

or remove pages as needed. Reusable functions are found under `utils.py` that implement immediate download of data from ClimateSERV and querying of geo-coordinates of locations. Our prototype permits interactive visualizations of dataframes, time-series data, heatmaps, etc.

We illustrate three approaches to download data to users’ local computers: 1) static resource from our GitRepo, 2) on-demand requests to ClimateSERV, and 3) automatic data-pull from ClimateSERV. In the first approach, data pull happens as soon as the web app loads on a browser, i.e. as resources that would be automatically pulled from our GitHub repository. In the second approach, user explicitly requests data through our prototype by changing the input parameters and clicking on the “download” button. Lastly, data is automatically requested from ClimateSERV when the app loads on user browser and subsequently cached so that the download will not reoccur as long as the cached data remains in users’ computer cache. In our prototype, data from ClimateSERV is retrieved using the Python package `ClimateSERV2.0` with default parameters.

### 2.3. Accessible statistical & deep autoregressive models

We facilitate on-demand model-fitting and immediate deployment of forecasting models in the following two ways.

The first option is accessible at `Fit_Prophet`. It provides an interface to employ a statistical approach that accounts for seasonal trends, as implemented through `Prophet`. Forecasting results are provided within five minutes when fitting with few years of data points. An example of the fitting result is shown in Figure 1 (central box). Note that the choice

of Prophet over other statistical methods such as “autoregressive integrated moving average” was justified in prior benchmarks (Kolari & Sanz, 2022).

The second option is accessible at `Fit_DeepAR`. It employs Deep Auto regressive models using (Salinas et al., 2020) as implemented using `Pytorch-forecasting`.

The two models are intentionally complementary rather than competing alternatives. Prophet offers interpretable seasonal decomposition accessible to non-technical users, while DeepAR supports probabilistic multi-series forecasting for more advanced workflows. Direct benchmarking between them is therefore not an objective of this work; the framework is designed to expose both to practitioners across a range of technical backgrounds. Future researchers may adapt the codebase to incorporate and benchmark additional models provided by PyTorch or Prophet.

## 2.4. Interactive widgets

To lower the barrier for non-technical users, `Streamlit`’s widget ecosystem is used throughout the prototype. Rather than enumerating all available components, we highlight those most consequential for humanitarian analytics workflows.

**Geospatial displays.** Choropleth maps and heatmaps allow users to visualise refugee camp distributions and climate variables at a glance. Camp density maps are rendered with zoom-enabled widgets; an example focused on sub-Saharan Africa is available in the prototype. Geo-coordinates are queried automatically from user-supplied place names in English, removing the need for manual lookup.

**Climate data access.** Three retrieval modes are supported: static snapshots pulled from the repository on page load, on-demand downloads triggered by user-specified parameters, and cached automatic pulls from `ClimateSERV` at startup. The caching mechanism is particularly important for large requests, such as 20-year rainfall and vegetation records, where repeated downloads would be prohibitive in low-bandwidth settings.

**Model interaction.** Sliders allow users to adjust training set size before fitting either the Prophet or DeepAR model, making the effect of data quantity on forecast quality directly observable, a feature designed to build intuition for practitioners unfamiliar with machine learning. Radio buttons enable switching between climate variables (precipitation, temperature, vegetation index) without reloading the page.

**Tabular summaries.** Sortable tables expose numeric outputs from both historical records and model forecasts, enabling practitioners to identify seasonal anomalies or rank camps by climate stress without writing any code.

Full documentation of all widgets and their parameters is

available in the repository `readme.md`.

## 3. Results

To assess usability and early-stage engagement, we conducted a formative evaluation via four one-on-one demonstrations and semi-structured interviews (Nielsen, 1994). Participants included one non-programmer PhD candidate with a background in design science (P1) and three postdoctoral fellows in computer science or engineering (P2–P4), providing perspectives spanning usability, visual design, and technical depth.

Findings are summarised in Table 1 and discussed below.

**Learnability.** Domain-specific terminology posed a barrier for non-technical users: P1 was unfamiliar with the term *choropleth*, suggesting that inline glossaries or tooltips would lower the entry barrier for social scientists and policymakers.

**Widget usability.** P3 noted that while several widgets were visually appealing, not all were immediately intuitive. P4 found one forecasting plot difficult to interpret, pointing to a need for clearer axis labelling and narrative annotation of model outputs.

**Engagement and narrative.** The most encouraging signal came from an unscripted moment: while examining the heat map, P2 offered substantive commentary on the density of camps in southern Sudan, demonstrating that the visualisations can prompt genuine domain reflection rather than passive consumption. P4 suggested that integrating refugee testimonials alongside statistical content could deepen emotional engagement, consistent with participatory design recommendations for humanitarian tools (Matlin et al., 2025).

**Feature requests.** P2 expressed interest in mapping medical facilities within camps, highlighting a gap between the app’s current climate focus and the broader data needs of practitioners.

**Limitations of the evaluation.** A current limitation in geographic querying is the framework’s reliance on `Nominatim`, an `OpenStreetMap`-based geocoder whose coverage reflects the uneven global distribution of OSM contributors. Conflict-affected regions such as Sudan are significantly under-mapped relative to East Africa, where sustained contributions from the Humanitarian `OpenStreetMap` Team (HOT, 2024) have produced reliable camp-level indexing. As a result, queries for camps in poorly mapped regions fail silently, degrading user experience precisely where the tool is most needed. Planned mitigations include manual coordinate entry as a fallback and cross-referencing against verified UNHCR displacement datasets for camp locations.

Another limitation is the small evaluation sample and



in displacement settings are not a convenience, they are a prerequisite for timely response. We release *Refugee Watch* as a foundation for that work, and invite the research community to critique, extend, and deploy it.

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