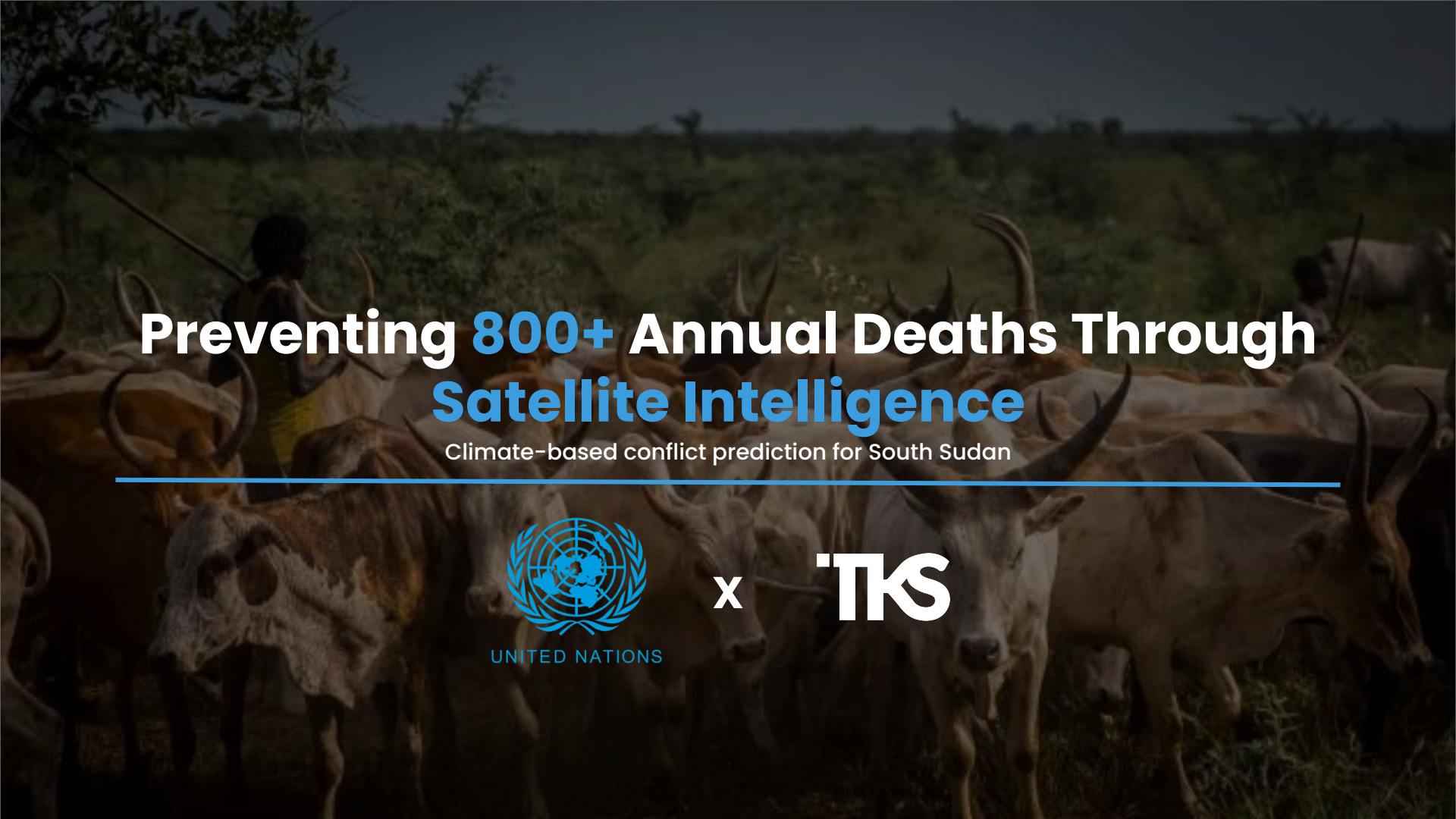


Preventing 800+ Annual Deaths Through Satellite Intelligence

Climate-based conflict prediction for South Sudan

UNITED NATIONS

x

TKS

Executive Summary

Problem

Climate floods force 12M cattle into shrinking grazing zones, creating violent convergence UN can't predict or prevent.

- **Trigger**: Since 2019 floods submerge traditional routes yearly, 1.35M are affected in 2025, with 590K in Unity/Jonglei flooding zones most severely impacted.
- **Human cost**: 395 killed, 281 injured, and 166 abducted in just 3 months (Apr-Jun 2023); 80% civilian casualties from cattle clashes.
- **Zero prediction**: Only 2 weather stations for 619K km², no capacity to see convergence 2-4 weeks ahead.
- **Repetition trap**: Unity/Jonglei has been hit by floods + violence every rainy season since 2019, trapping 12M cattle in predictable cycles.

Climate blocks traditional routes → cattle are forced to converge → violence erupts 2-4 weeks later → UN responds too late.

Solution

Build an AI-powered predictive model using vegetation monitoring and water detection from satellites to forecast forced cattle convergence.

- **Foresight:** The ML model analyzes Sentinel-2 NDVI/NDWI (10m, 5-day updates) to forecast cattle movement 2–4 weeks ahead under real pastoral conditions.
- **Flood-resilient:** Sentinel-1 SAR + Sentinel-2 MNDWI detect water extent through clouds, flags when <20% traditional grazing routes remain viable.
- **Human-in-loop app:** Scouts photograph hotspots → instant NDVI match verifies predictions before UNMISS deployment.
- **Self-improving**: Every field confirmation retrains model, turning 100s of patrols into continuous accuracy gains (>75% Year 1 → >90% Year 3).

Impact

Foresight cuts violence by 50%+, protects 12M cattle livelihoods, prevents 100,000s from displacement.

- **Operational**: 2–4 week early warnings → 5x patrol efficiency, stops raids before they kill (like 2025 Maper's 12+ deaths avoided).
- **Humanitarian**: 590K flood-affected stay home, schools/health posts open, and the pastoral economy survives climate shocks.
- **Proven**: >90% prediction accuracy by Year 3, 764 incidents already stopped by similar mobile systems, scales nationwide.
- **Economic**: $1.2B security budget shifts from crisis response to prevention, protects 12M cattle economy.

50% fewer cattle clashes. 100,000s lives stabilized.

A Family's Reality

"Everything is Gone." – Tut Patai, Unity State, 2022

Since his father introduced him to cattle keeping as a child, Tut Patai's entire life revolved around his herd. For 45 years, hundreds of cattle provided his family with wealth, food, and identity.

Then the floods came.

In September 2022, unprecedented flooding submerged Unity State. Tut Patai lost over 120 cattle. Now, **only one sick cow and her calf remain.**

"Because of the floods I have lost all my cattle. They don't have enough to eat because the grass is underwater."

Every day, he wades through floodwaters to collect grass for his two surviving animals.

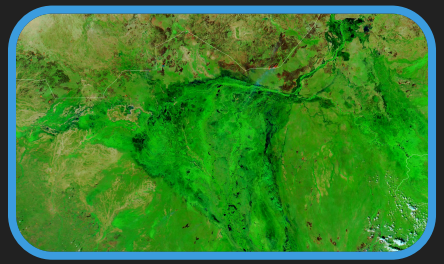
220,000 people affected across Unity State in 2022. The worst flooding in 60 years.

Problem Overview

The Climate Conflict Cycle

01. The Trigger

South Sudan experienced its sixth consecutive year of severe flooding in 2025, affecting over 1.35 million people and displacing nearly 375,600. The persistent inundation around the Sudd wetlands and Nile River basin destroyed farmlands, devastated homes, and disrupted essential services across eight states. Flood extent continues to increase, eliminating traditional cattle migration routes and grazing areas that communities have relied on for centuries.



02. The Mechanism

When flooding eliminates traditional grazing zones and destroys farmlands, 12 million cattle are forced into shrinking areas with water and vegetation. Herders follow their cattle into these zones—even contested territories—because cattle represent wealth, food security, and cultural identity. Multiple herder groups converge in the same resource-scarce areas, creating inevitable competition over limited resources.

03. The Consequences

Persistent flooding has created critical food insecurity, increased waterborne disease risk, and destroyed the 2025 harvest in central and northern South Sudan due to combined drought and river flooding. Eight states have been devastated by homes destroyed, farmlands swept away, and essential services disrupted, creating a major humanitarian crisis. When resource scarcity forces multiple armed herder groups into the same shrinking zones, violent conflict over cattle, water, and grazing land becomes inevitable.

Track the climate trigger, predict the convergence, prevent the violence.

Status Quo

Zero Prediction Capacity

TRADITIONAL SYSTEM (Pre-2015)

Predictable seasonal migration

- Dry season (Nov-May) → **lowland pastures**
- Wet season (Jun-Oct) → **highlands**
- Routes used for centuries

Community management

- Elders knew the patterns
- Pre-migration negotiations
- Controlled cultural raiding

Functional early warning

- Indigenous knowledge reliable
- Seasonal patterns consistent
- Communities prepared

THE TRANSITION (2015-2019)

Climate instability begins

- Rainfall patterns become erratic
- Isolated flooding events increase
- Seasonal timing shifts unpredictably

Conflict militarizes

- Raiding escalates from cultural practice to armed violence
- Government capacity weakens post-independence

Traditional systems break down

- Elders' seasonal predictions fail
- Pre-migration negotiations struggle without reliable forecasts
- No new monitoring infrastructure built

CURRENT REALITY (2019-Present)

Climate disruption

- **4+ consecutive years** of unpredictable flooding
- Traditional routes blocked at wrong times
- Pastures underwater OR dried up

Forced convergence

- Multiple groups pushed into same shrinking zones
- Militarized violence (AK-47s replace spears)
- **200+ killed in single raids**

Zero prediction

- Indigenous knowledge unreliable
- **Only 2 weather stations** for 619,745 km²
- UN responds AFTER violence erupts

Climate broke the system. The UN still responds after violence, not before.

Click Here to Learn More>>

Case Study

May 2025 Maper Raid – The Predictable Pattern

APRIL 2025: FLOOD CRISIS BLOCKS CATTLE ROUTES

Heavy seasonal floods submerged 65K hectares of grazing land across Unity + Jonglei states. NDVI crashed to <20% viability across 200km² pastoral corridors – satellite data shows collapse. 590K people affected nationwide, worst in Unity/Jonglei high-ground zones. 12M cattle + herders forced into 3 shrinking high-ground zones (mathematically certain overlap).

MAY 25: MAPER MASSACRE – DINKA vs NUER CATTLE RAID

- → **12+ killed** (mostly young men defending herds)
- → **30+ injured**, 200 cattle stolen
- → 12 families lost entire livelihoods overnight
- → Attacks happened exactly where flood-blocked herders had to converge for last dry pasture

UNMISS Response:

- → Force Commander visits post-massacre
- → 1,200 troops redeployed reactively to secure area after deaths occurred

APRIL 15
Crisis begins
Flooding starts

APRIL 28
Routes collapse
65K hectares lost to floods

MAY 10
Convergence point
12M cattle start moving

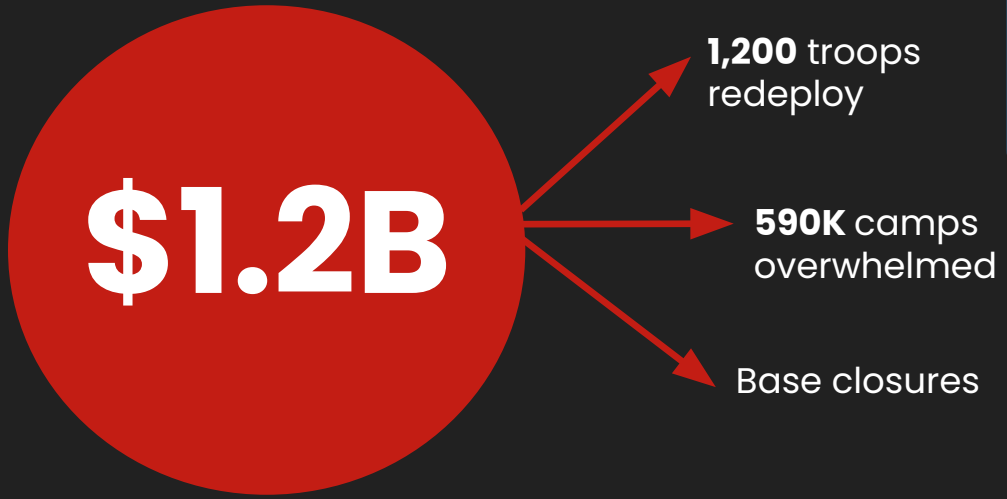
MAY 25
Massacre occurs
12+ fatalities, 30+ survivors

Click Here to Learn More>>

Economic Perspective

UNMISS: $1.2B Budget → Reactive Crisis Response

UNMISS spends $1.2 billion yearly protecting South Sudan, with over half going to reactive emergency response. Pastoral violence from climate-driven cattle convergence is predictable, but currently unprevented. This cycle consumes resources that could protect more lives strategically.



UN Costs List:

- → **590K displaced** = camps/services overwhelmed
- → **1,200 troops** redeploy post-Maper massacre
- → IOM/WFP pipelines strained by seasonal crises
- → Pariang/Koch bases closing (pastoral flashpoints)

$1.2B buys reaction. Climate demands prevention.

The Opportunity

What We Already Know

THE DATA

Climate creates patterns

- → Sixth year of flooding
- → Visible from space

THE PATTERN

Violence follows 2-4 weeks

- → Predictable timeline
- → Consistent convergence

THE COST

$1.2B reactive spending

- → Unsustainable approach
- → Prevents nothing

THE WINDOW

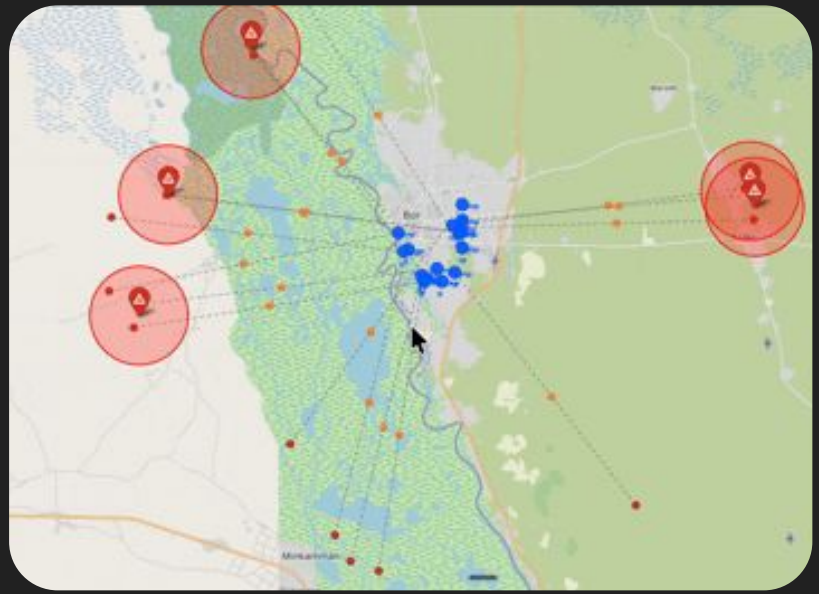
2-4 week warning exists

- → Actionable timeframe
- → Intervention possible

We have the data. We have the window. **We need the system.**

Recommendation

Predicting & confirming 2-4 week cattle movement via ML model + mobile app.



Interactive map displaying Foresight's predicted cattle movement patterns and conflict risk zones

01.

We recommend a **geospatial machine learning model (Foresight)** for cattle movement detection and prediction, integrated directly with Google Earth Engine (GEE) and Sentinel-2 satellite imagery.

This model transforms raw satellite data into actionable conflict predictions 2-4 weeks in advance, analyzing **two key pull factors** of cattle movement - **NDVI (grazing quality)** and **NDWI (water availability)** - at 10-meter resolution to forecast migration patterns under real pastoral conditions.

02.

To maximize the impact of Foresight's predictions, we've developed a **companion confirmation app** that empowers UN peacekeepers and field scouts with **real-time validation capabilities**.

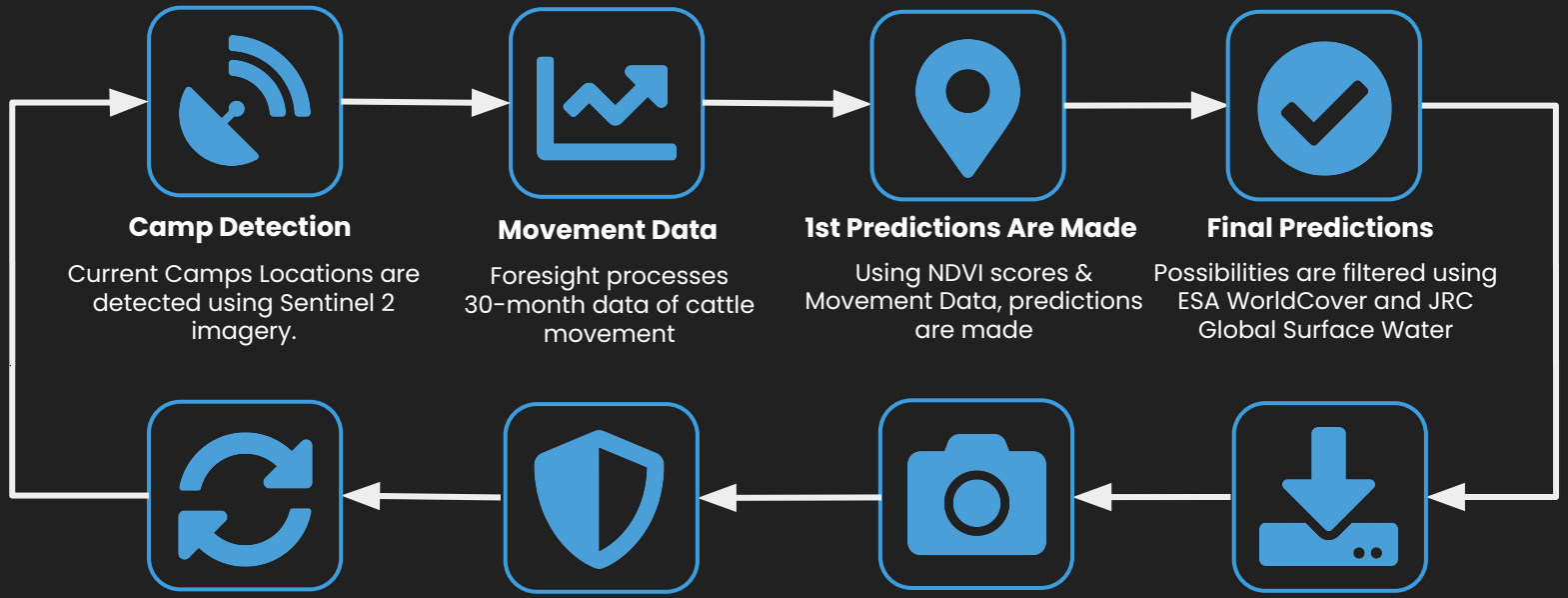
By **photographing** the surrounding landscape, users can instantly verify current vegetation and grazing conditions against Foresight's NDVI-based predictions, creating **a human-in-the-loop verification system** that ensures every AI prediction is ground-truthed before deployment or intervention decisions are made.

This real-world feedback continuously refines the model over time, making Foresight increasingly precise and reliable with each field confirmation.

Click Here to Learn More>>

How it Works

Technical Foundation Loop.



Camp Detection

Current Camps Locations are detected using Sentinel 2 imagery.

Movement Data

Foresight processes 30-month data of cattle movement

1st Predictions Are Made

Using NDVI scores & Movement Data, predictions are made

Final Predictions

Possibilities are filtered using ESA WorldCover and JRC Global Surface Water

Predictions Sent to App

Foresight's predictions are exported as a CSV file to the confirmer app, Foresight.

Peacekeepers Confirm

UN peacekeepers will click photos of the area to confirm the prediction

Ready to Stop Conflict

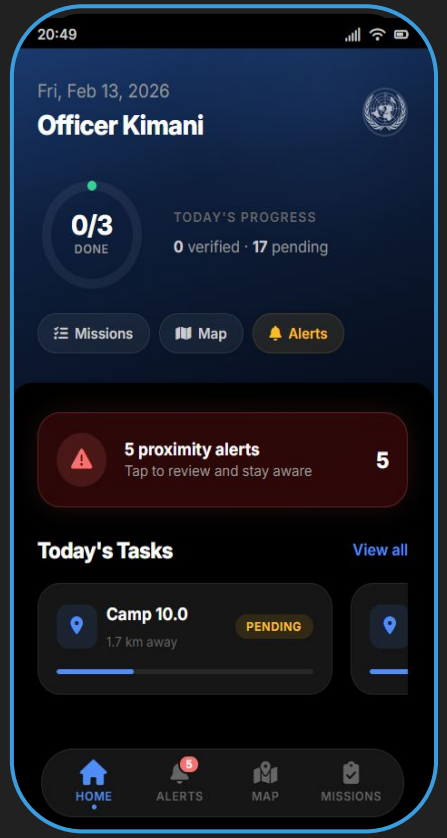
Once confirmed, Peacekeepers can arrive to predicted locations early to stop Conflict.

Confirmations Sent Back

Confirmations of Photos are sent back to a model to detect if NDVI scores match

Demo

Introducing Foresight, our Confirmer App

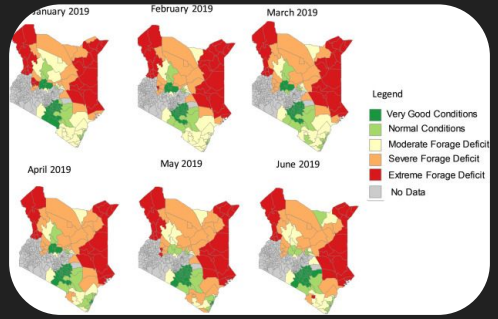


Click Me!

Validation

Learning from Kenya

Kenya has already proven that satellite-based livestock prediction and conflict early warning systems work—operationally, at scale, in the same region.



Monitoring forage conditions using PLEWS

CEWARN appraises regional response work.

KENYA PLEWS: SATELLITE LIVESTOCK PREDICTION (2015-Present)

Kenya's Predictive Livestock Early Warning System uses satellite NDVI monitoring to forecast where pastoralist communities will move based on vegetation and water availability. By tracking environmental constraints, PLEWS predicts livestock migration patterns weeks in advance, enabling government and humanitarian organizations to prepare resources before crisis hits rather than respond to emergencies.

Why it works:

- ➜ Same satellite technology (Sentinel-2 NDVI)
- ➜ Same pastoral context (cattle-dependent communities)
- ➜ Proven accuracy: Operational for 9+ years

KENYA CEWARN: CONFLICT PREVENTION (2003-Present)

The Conflict Early Warning and Response Mechanism combines field monitors with local peace committees to detect conflict risks early and enable rapid intervention.

Why it works:

- ➜ Ground-level monitoring + community validation
- ➜ Connected to actual responders (not just data collection)

We're adapting 20+ years of proven success specifically for South Sudan.

Aniket Prabhudesai

Member of Technical Staff - Guidance, Navigation, and Control @ MDA

Validation
Expert Opinion

"Using satellite imagery for this specific use case is **definitely reasonable**. It provides more value than just observing water fluctuations or vegetation changes. You're given a **direct correlation** between environmental changes and cattle movements."

What This Validates:

✓ Technically sound methodology – Satellite + ML proven for pastoral monitoring

✓ Tracking environmental constraints specifically for cattle movement is more predictive than general monitoring

✓ The NDVI/NDWI approach provides actionable intelligence for conflict prevention

Validation

Researcher’s Opinion

Predictive models transform South Sudanese pastoralism.

“A new approach was developed to evaluate the implications of the spatiotemporal variability of green vegetation for the dispersion of livestock that is required to access quality forage in semi-arid Africa. Maximum NDVI… was used to measure forage quality.”

Journal of Land Use Science, 2014
http://dx.doi.org/10.1080/1747423X.2014.965280

Taylor & Francis
Taylor & Francis Group

Variation in vegetation cover and livestock mobility needs in Sahelian West Africa

Matthew D. Turner[a]*, Bilal Butt[b], Aditya Singh[c], Leif Brottem[d], Augustine Ayantunde[e], and Bruno Gerard[f]

[a]Department of Geography, University of Wisconsin, Madison, WI, USA; [b]School of Natural Resources and the Environment, University of Michigan, Ann Arbor, MI, USA; [c]Department of Forest and Wildlife Ecology, University of Wisconsin, Madison, WI, USA; [d]Department of Political Science, Grinnell College, Grinnell, IA, USA; [e]International Livestock Research Institute, B.P. 1496 Ouagadougou, Burkina Faso; [f]International Maize and Wheat Improvement Center (CIMMYT), Texcoco, Estado de México, Mexico

(*Received 5 January 2014; final version received 1 September 2014*)

A new approach was developed to evaluate the implications of the spatiotemporal variability of green vegetation for the dispersion of livestock that is required to access quality forage in semi-arid Africa. Maximum NDVI (Normalized Difference Vegetation Index) at 1 km^2 resolution was determined for concentric rings (0–31 km radii) around 227 individual sample locations within the study area for 14 dates (between 1 April to 1 November) annually over the 2000–2010 period. A sigmoidal curve was fitted to points within the maximum NDVI × distance radii space to determine the asymptote distance (AD) – the radius at which further dispersion from the sample location does not lead to significant gains in access to green forage. AD was found to: increase with latitude (or increasing aridity); decline as the rainy season proceeds; and show no trend over the 2000–2010 period. These results introduce much-needed empirical data to current debates surrounding the scales of governance to support livestock mobility.

Keywords: equilibrium ecology; rangeland management; NDVI; climate change;

1. Introduction

Arid and semi-arid rangelands of Africa have consistently been identified as among the most vulnerable regions of the world with respect to climate change (Ericksen et al., 2012; Millennium Ecosystem Assessment, 2005). It has been increasingly argued that mobile livestock husbandry, involving the movement of livestock across open rangelands in response to changing water and forage conditions, plays an important role in reducing both environmental impacts of rural production systems (Behnke, Scoones, & Kerven, 1993; Ellis & Swift, 1988; Scoones, 1994; Turner & Hiernaux, 2008) and the region’s vulnerability to climate change (Adriansen, 2008; Amanor, 1995; Galvin, 2009; McCarthy & Di Gregorio, 2007; Niamir-Fuller, 1999). The new recognition of the ecological and economic roles of mobile pastoralism in semi-arid Africa coincides with observed declines in livestock mobility not only within semi-arid Africa but globally due to a number of factors including land-use competition, rangeland fragmentation, pasture enclosures, labor scarcity, poverty-induced sedentarization, and insecurity (Fernandez-Gimenez & Le Febre,

*Corresponding author. Email: mturner2@wisc.edu

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Original Research

Estimating Grazing Potentials in Sudan Using Daily Carbon Allocation in Dynamic Vegetation Model ☆

Niklas Boke-Olén [a], Veiko Lehsten [a], Abdulhakim M. Abdi [a], Jonas Ardö [a], Abdelrahman A. Khatir [b]

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https://doi.org/10.1016/j.rama.2018.06.006

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Abstract

Livestock production is important for local food security and as a source of income in sub-Saharan Africa. The human population of the region is expected to double by 2050, and at the same time climate change is predicted to negatively affect grazing resources vital to livestock. Therefore, it is essential to model the potential grazing output of sub-Saharan Africa in both present and future climatic conditions. Standard tools to simulate plant productivity are dynamic vegetation models (DVMs). However, as they typically allocate carbon to plant growth at an annual time step, they have a limited capability to simulate grazing. Here, we present a novel implementation of daily carbon allocation for grasses into the DVM Lund-Potsdam-Jena General Ecosystem Simulator (LPJ-GUESS) and apply this to study the grazing potential for the Kordofan region in Sudan. The results show a latitudinal split in grazing resources, where the northern parts of Kordofan are unexploited and southern parts are overused. Overall, we found that the modeled grazing potential of Kordofan is 16% higher than the livestock usage reported in the Food and Agricultural Organization of the United Nations, indicating a mitigation potential in the form of a spatial relocation of the herds.

Introduction

Livestock provide an important source of income and nutrition for pastoral and

NDVI-driven models guide livestock mobility.

“You can argue: because NDVI-based grazing potential is quantitatively comparable to real livestock use, it is reasonable to extend this to an ML model that predicts where herds will move next, using NDVI (for forage) plus NDWI (for water).”

Addressing The Challenges

Risks & How We Mitigate Them

NATIONWIDE SCALING

Once selected, Foresight is being directly scaled across all conflict-prone pastoral regions of South Sudan, moving beyond our Jonglei prototype. This expands protection from 1,000+ annual deaths in Jonglei to an estimated **3,500+ lives nationwide**.

At less than 0.04% of the UNMISS budget, Foresight Is immediately deployable as one of the most cost-effective humanitarian interventions ever proposed. A full nationwide rollout could be operational within **12 months of selection.**

DATA QUALITY & NATURAL LIMITATIONS

Cloud cover and **seasonal flooding** in South Sudan may **temporarily limit** Sentinel-2 imagery quality. This can potentially **reduce prediction accuracy**, pushing camp location estimates off by 1-2 km.

BUILT-IN-DATA VALIDATION

Our multilayer water filtering system combines NDWI thresholding, ESA WorldCover and JRC Surface Water masks to eliminate unreliable predictions

Median composite processing across multiple satellite passes minimizes the impact of temporary cloud cover on detection accuracy.

Click Here to Learn More>>

Risks

Predictions are reliable only when satellite data is available.

Foresight's accuracy depends on consistent access to cloud-free Sentinel-2 imagery and stable environmental conditions. Prediction quality can degrade during South Sudan's rainy season (May-October) when cloud cover exceeds 30%, or when rapid environmental changes like flooding alter grazing patterns unexpectedly.

1 Satellite Imagery Degradation

The most common error where cloud cover, atmospheric interference, or sensor issues corrupt NDVI/NDWI calculations without obvious warnings. Detected by comparing current imagery quality metrics against historical baselines and validating predictions with ground reports from peacekeepers.

2 Google Earth Engine Failures

These faults, including computation timeouts, API rate limits, and authentication failures, arise within the Google Earth Engine environment and can prevent the model from generating predictions when processing large regions or multiple time periods simultaneously

3 Complete Prediction Failure

The rarest but most critical error occurs when the entire prediction pipeline fails due to infrastructure issues, requiring manual intervention. However, peacekeepers can rely on the last successful prediction (updated weekly) until the system is restored, minimizing operational disruption.

Click Here to Learn More>>

Implementation Plan

Foresight: Building Predictive Protection

PHASE 1: PROOF OF CONCEPT (Months 1-3)

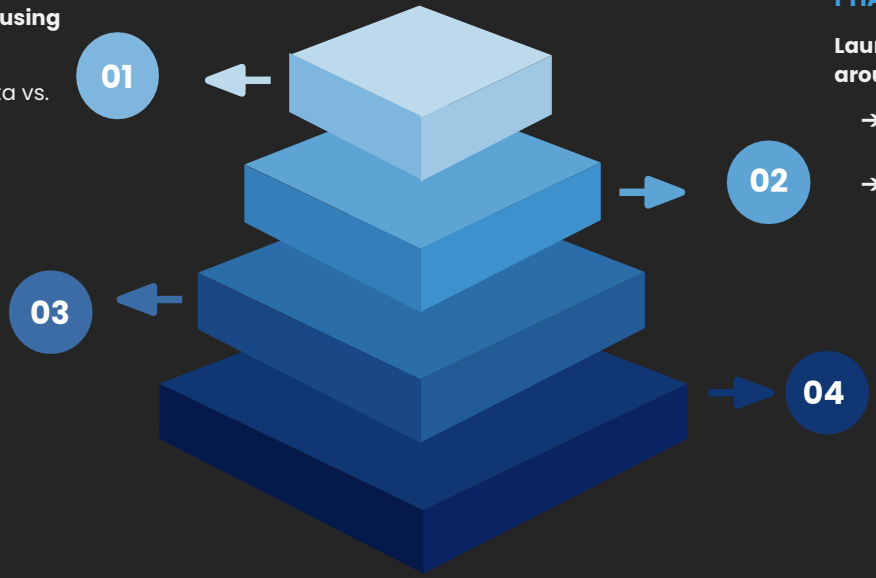
Test if Foresight can predict past conflicts using satellite data around Bor.

- → Analyze 2019–2024 Bor conflict data vs. Sentinel satellite imagery
- → Target >80% accuracy predicting flood-blocked routes that caused violence

PHASE 2: PILOT DEPLOYMENT (Months 4-9)

Launch Foresight pilot with UNMISS peacekeepers around Bor.

- → Deploy 5×5 km Bor prototype across Lakes, Jonglei, Unity States
- → Build a dashboard + train peacekeepers to validate predictions on ground



PHASE 3: NATIONAL SCALE-UP (Months 10-21)

Scale Foresight nationwide using NVIDIA GPUs to process all South Sudan.

- → Process 5–10 TB satellite data on NVIDIA clusters for full 619K km² coverage
- → Generate predictions <6 hrs every 5 days + integrate with all UN agencies
- → Train national counterparts and transition ownership to South Sudanese institutions

PHASE 4: CONTINUOUS IMPROVEMENT (Months 22+)

Make Foresight smarter and hand it to South Sudanese institutions.

- → Continuously improve accuracy with field feedback + expand predictions
- → Secure funding through proven lives saved and transition to local ownership

By 2029, Foresight protects 3,500+ lives yearly at <0.04% of the UNMISS budget.

Impact

Turning Climate Signals into Early Peace Action

Foresight transforms scattered climate signals into actionable intelligence for UN peacekeepers. Instead of reacting to violence after it erupts, operations shift to prevention.

- From **reactive → predictive:** Foresight forecasts cattle convergence 2–4 weeks ahead using Sentinel-2 NDVI/NDWI data.
- Patrols shift from "everywhere" to **5-7 high-risk hotspots** per season, updated **every 5 days**.
- Peacekeepers pre-position at predicted flashpoints, **negotiate grazing access** before herds arrive.
- Operational gain: Same budget covers **5x** more critical ground, fewer surprises like 2025 Maper raid (12+ deaths).

Blind Response → Precision Peacekeeping

Impact

Precision Deployments, Less Harm

Pastoral families face **repeated displacement** from climate shocks and cattle raids that destroy livelihoods. Foresight creates **stability** where crises once defined every season.

- ➔ **No surprise raids** = kids stay in school, not fleeing violence or pulling water.
- ➔ **Herds protected** = families keep milk, meat, income – 12M cattle means entire pastoral economy survives floods.
- ➔ **Communities stay intact** vs. 590K scattered into camps with no services, revenge cycles, lost grazing rights.
- ➔ Real difference: Seasonal migration becomes routine, not crisis displacing 100,000s yearly.

From Crisis Migration → Stable Livelihoods

Impact

How We Measure Impact

Success is measured by hard metrics: violence prevented, accuracy proven, costs slashed. Foresight delivers quantifiable results from pilot to nationwide scale

- **Prediction accuracy**: Target >75% in pilot (Month 1), >90% at scale (Months 20+)
- **Violence reduction:** 50% decrease in cattle-related casualties in covered regions
- **Early warning lead time:** Consistent 2-4 week window maintained across seasons
- **Ground-truth validation:** 100% human-in-the-loop ensures verified predictions before action
- **Continuous improvement:** Model accuracy +10% per season with each field confirmation
- **Cost-effectiveness:** 5x cheaper than emergency response (prevention vs. crisis cleanup)

Metrics → Results → Lives Saved | Scalable from Pilot to Nationwide

Tawfic Shnoudeh | Thriloush Jasotharan | Armaan Sharma | Prassan Aggarwal | Pavan Suresh

Dear United Nations Team,

Thank you, we are truly grateful for the opportunity to collaborate with the UN on exploring innovative solutions that address the challenges of predicting cattle convergence. As we examined UN's leadership in peace infrastructure, we were inspired by the potential impact of deploying peacekeeping operations that prevent conflicts before they escalate.

This experience has been incredibly rewarding. Through understanding UN's values and ambitions, and by exploring predictive machine learning models, we gained valuable insights that will continue to shape our approach to building responsible, scalable technology.

Thank you for the opportunity to work on such a meaningful challenge. We appreciate the chance to engage with the United Nations' vision and look forward to the continued advancement of peacekeeping AI innovation.

Prassan | Armaan | Thriloush | Pavan | Tawfic

Video Message

x

All Details You Need

Appendix

Why is climate change the issue?

Climate Change Analysis

How is this product economically friendly?

Economic Analysis

What is the technology behind it all?

Technology Walkthrough

What are researchers validating about this certain idea

Validation Analysis

How can we integrate this product with UNMISS?

Implementation Process

What could go wrong?

Risks and Mitigation

What's the full Maper timeline?

2025 Maper Raid

Where did this information come from?

Sources

x