Strengthening Agriculture and Food Security Decisions with Earth Observations and Machine Learning

Dr. Catherine L. Nakalembe

Assistant Research Professor
Department of Geographical Sciences
University of Maryland

NASA Harvest Africa Program Lead
Group on Earth Observations Global Agriculture Initiative (GEOGLAM)
NASA SERVIR Applied Sciences Team Member and Agriculture and Food Security Thematic Lead

NASA Harvest

HARVEST
EARTH DATA
FOR INFORMED AGRICULTURAL DECISIONS

NASA's Food Security and Agriculture Program, led by UMD

Goal: enable and advance the adoption of satellite **Earth observations** to benefit f**ood security**, **agriculture**, and human and environmental **resiliency**

NASA's Contribution to GEOGLAM Global Agricultural Monitoring

Thematic and Cross-Cutting Areas

HARVEST
EARTH DATA
FOR INFORMED AGRICULTURAL DECISIONS

Yield & crop condition

Early warning & food security

Markets and Trade

Crop Type & Area

US Domestic

Africa

Public-Private Partnerships

Emerging technologies (Machine learning & AI, Cloud computing)

Group on Earth Observations Global Agricultural Monitoring Initiative (GEOGLAM) is to increase market transparency and improve food security by producing and disseminating relevant, timely, and actionable information on agricultural conditions and outlooks of production at national, regional, and global scales. It achieves this by strengthening the international community's capacity to utilize coordinated, comprehensive, and sustained Earth observations.

Outline

- Background on Earth Observations (EO) for Agricultural Monitoring
- Background on GEOGLAM Crop Monitor-An End User Driven Initiative
- Sustaining Capacity
- Framework for National & Regional Crop Monitoring
- Tools and systems
- Impact examples

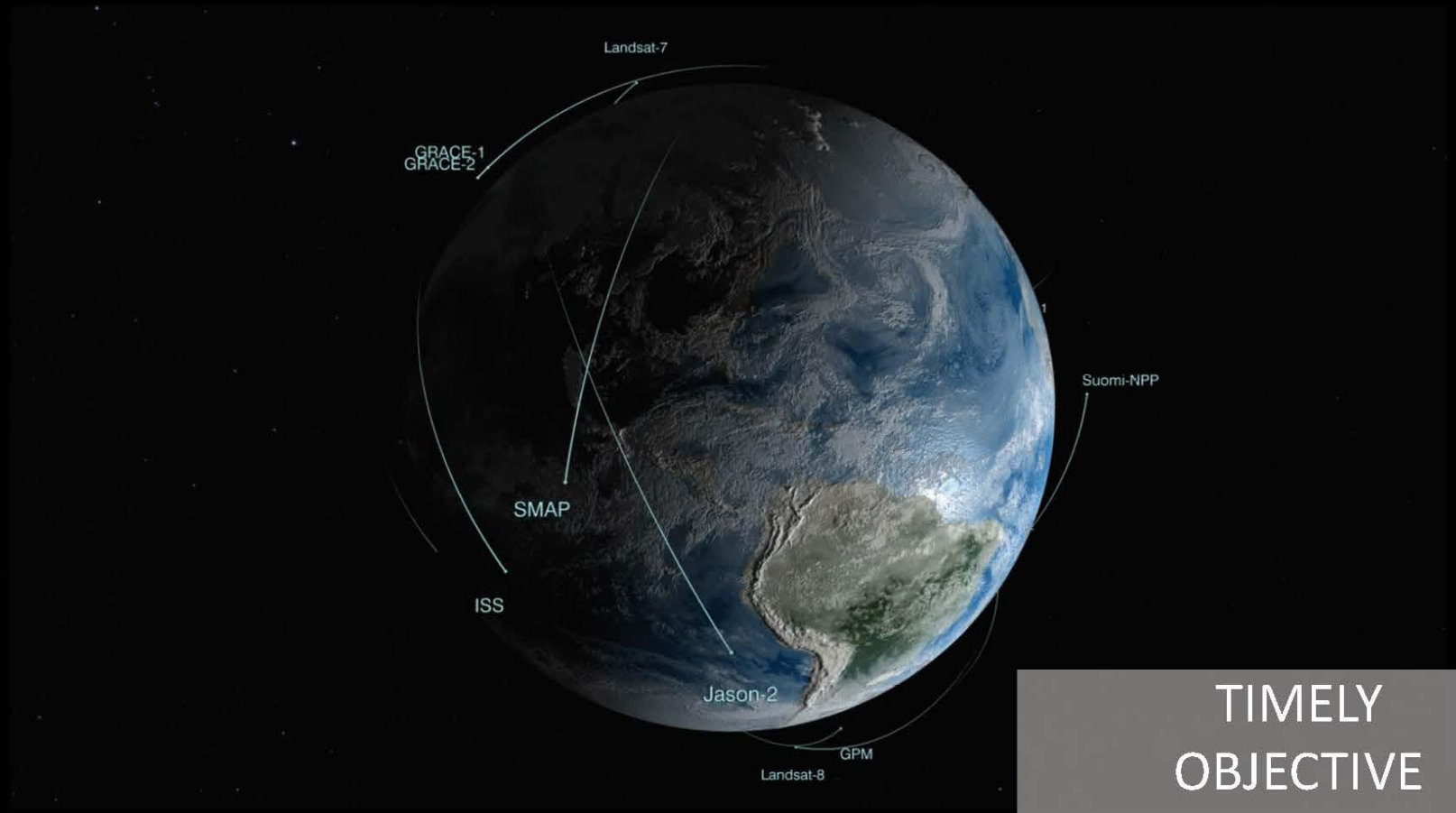
What value do Earth Observations add to Monitoring Agriculture and Food Security?


What value do Earth observations add
to monitoring agriculture and
to strengthening food security?

NASA Earth Science Division Operating Missions

Source: NASA's Earth Observing System Project Science Office

Updated: October 10, 2019

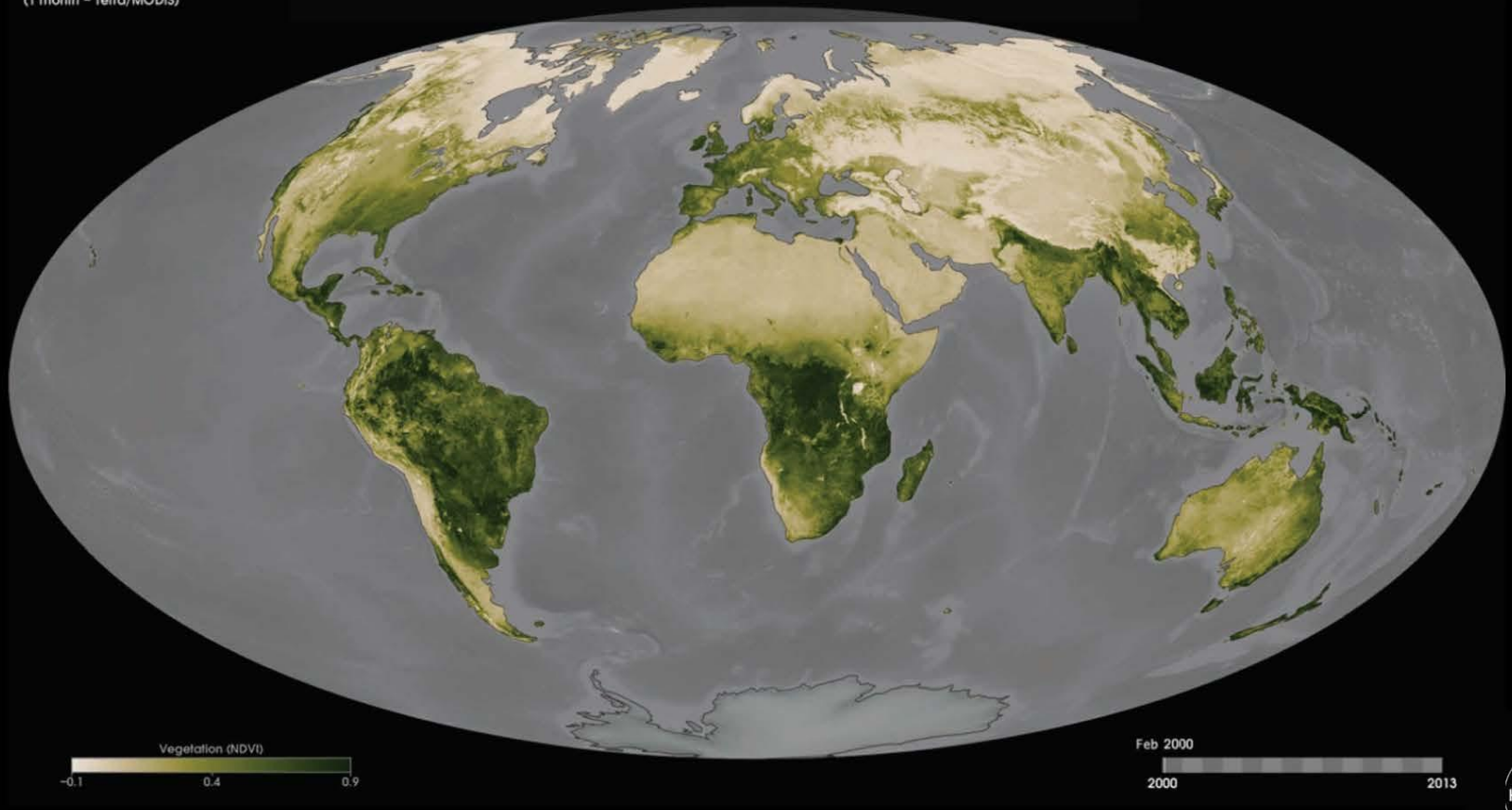


TIMELY
OBJECTIVE
REPEATABLE

HARVEST

GLOBAL COVERAGE LOCAL DETAILS

LONG, DENSE TIME RECORD



METHODS for DIVERSE LANDSCAPES

Northern Uganda

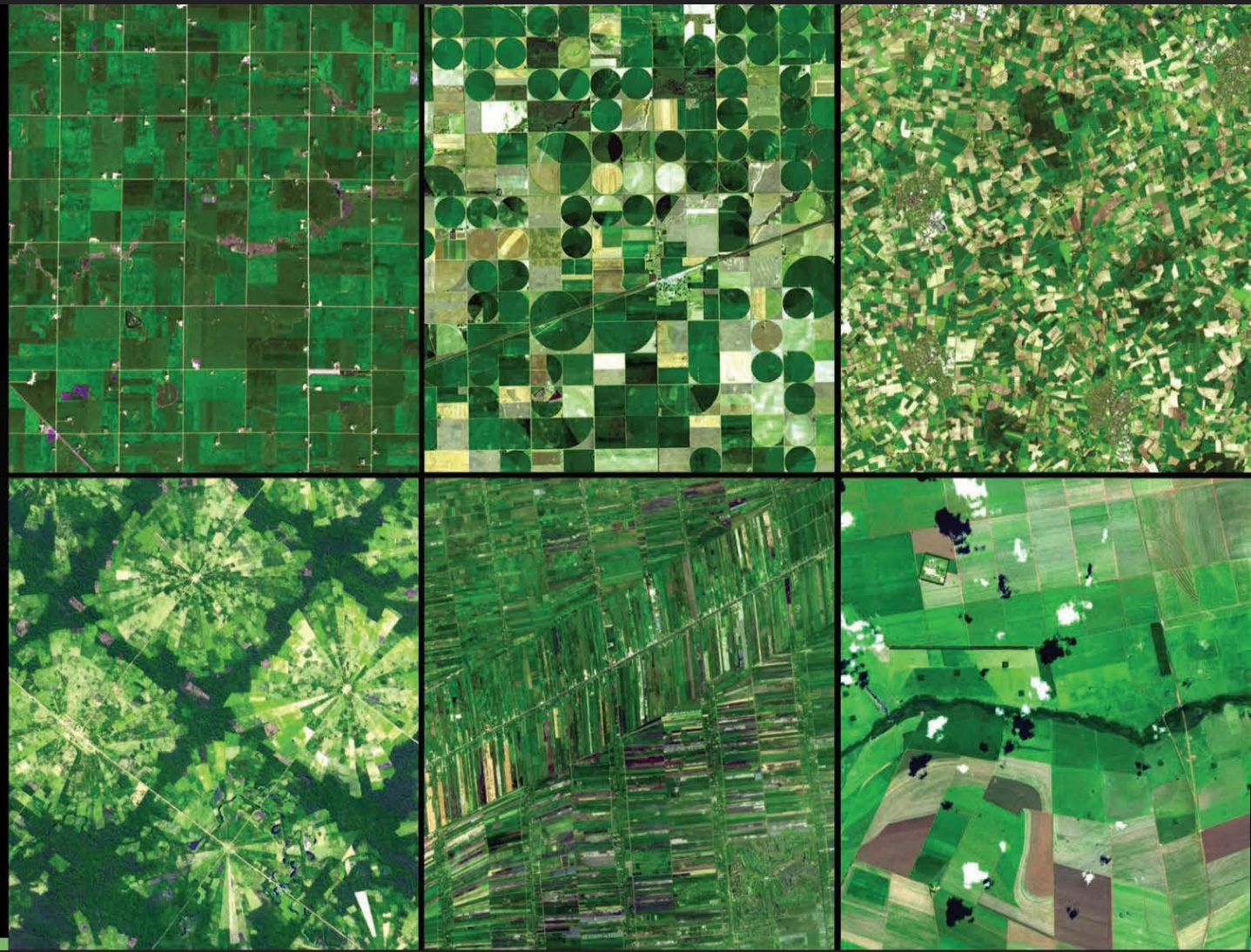
Western Kenya

Eastern France

METHODS

for

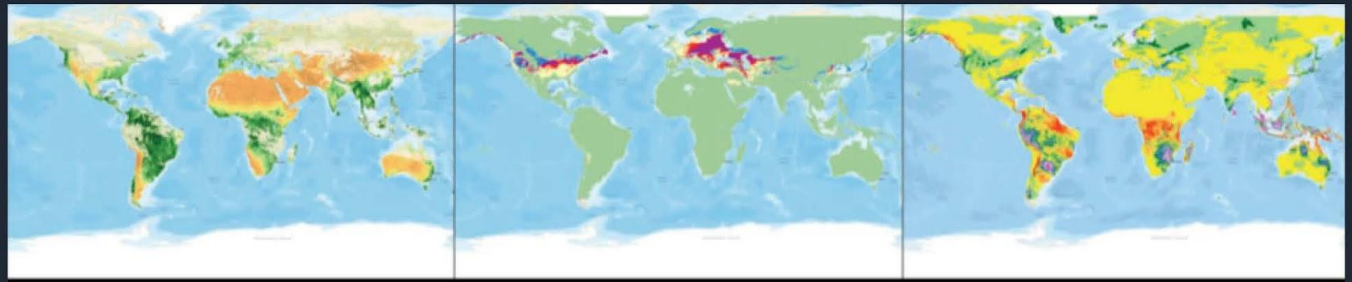
DIVERSE LANDSCAPES



LOW COST

INTEGRATION WITH OTHER DATA

SATELLITE DATA SERVE AS INDICATORS FOR CROP CONDITIONS



- NDVI anomaly
- Temperature Sum anomaly
- Rainfall Sum anomaly

- CHIRPS Rainfall anomaly
- Evaporative Stress Index
- Actual ET anomaly

- Soil Moisture anomaly
- Soil Water Index anomaly

Launch of Global Operational Crop Assessments:
AMIS Request to GEOGLAM

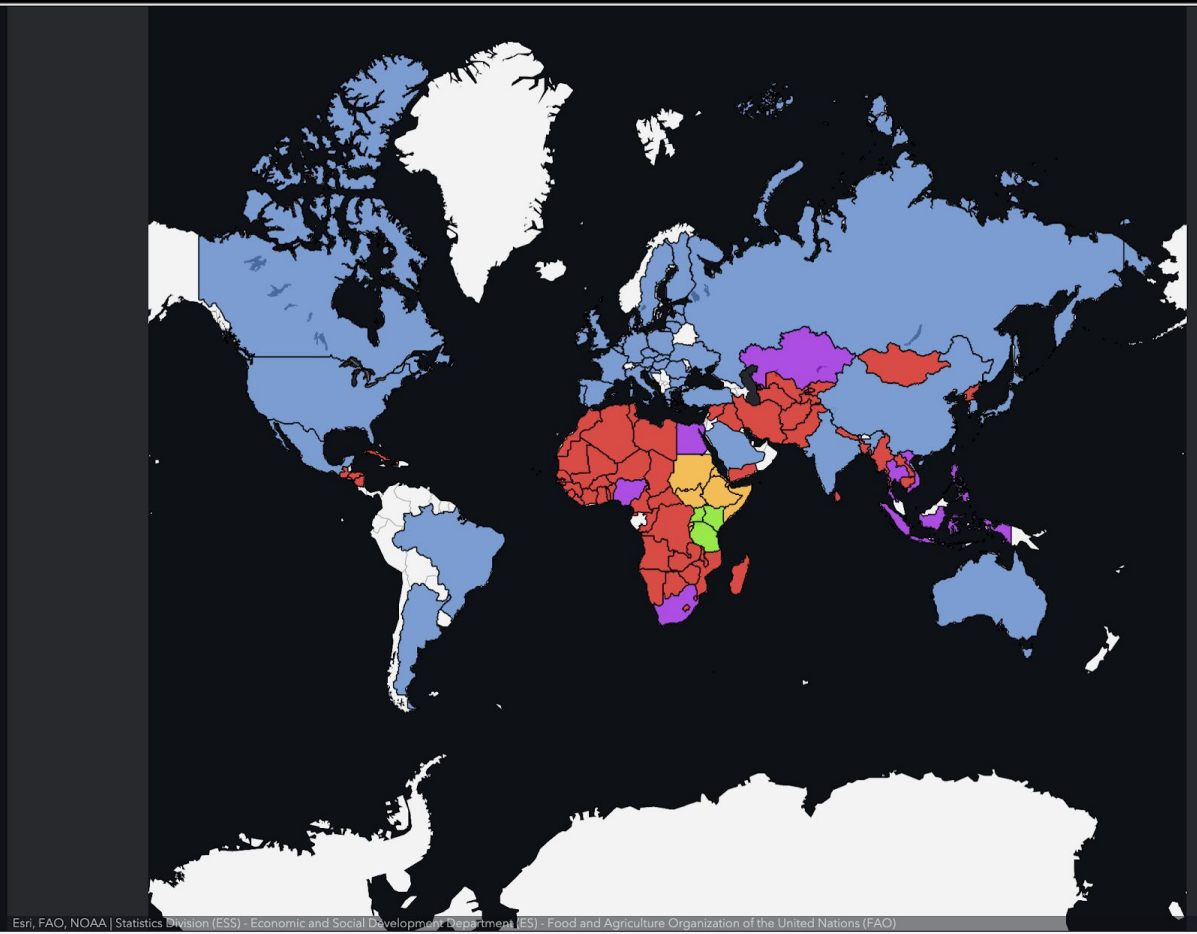
- Provision of timely and transparent monthly crop condition assessments in primary agricultural production areas
- Reflecting an international consensus, building on existing systems
- Four Major Crops: Wheat, maize, soybean, rice
- Focus: main production/export countries (AMIS Countries), stabilizing/ calming markets, avoid unexpected food price shocks
- Output: Crop Monitor, published in Market Monitor

Crop Monitor
a geoglam initiative

HOME ABOUT CROP CONDITIONS REPORTS EO DATA & TOOLS

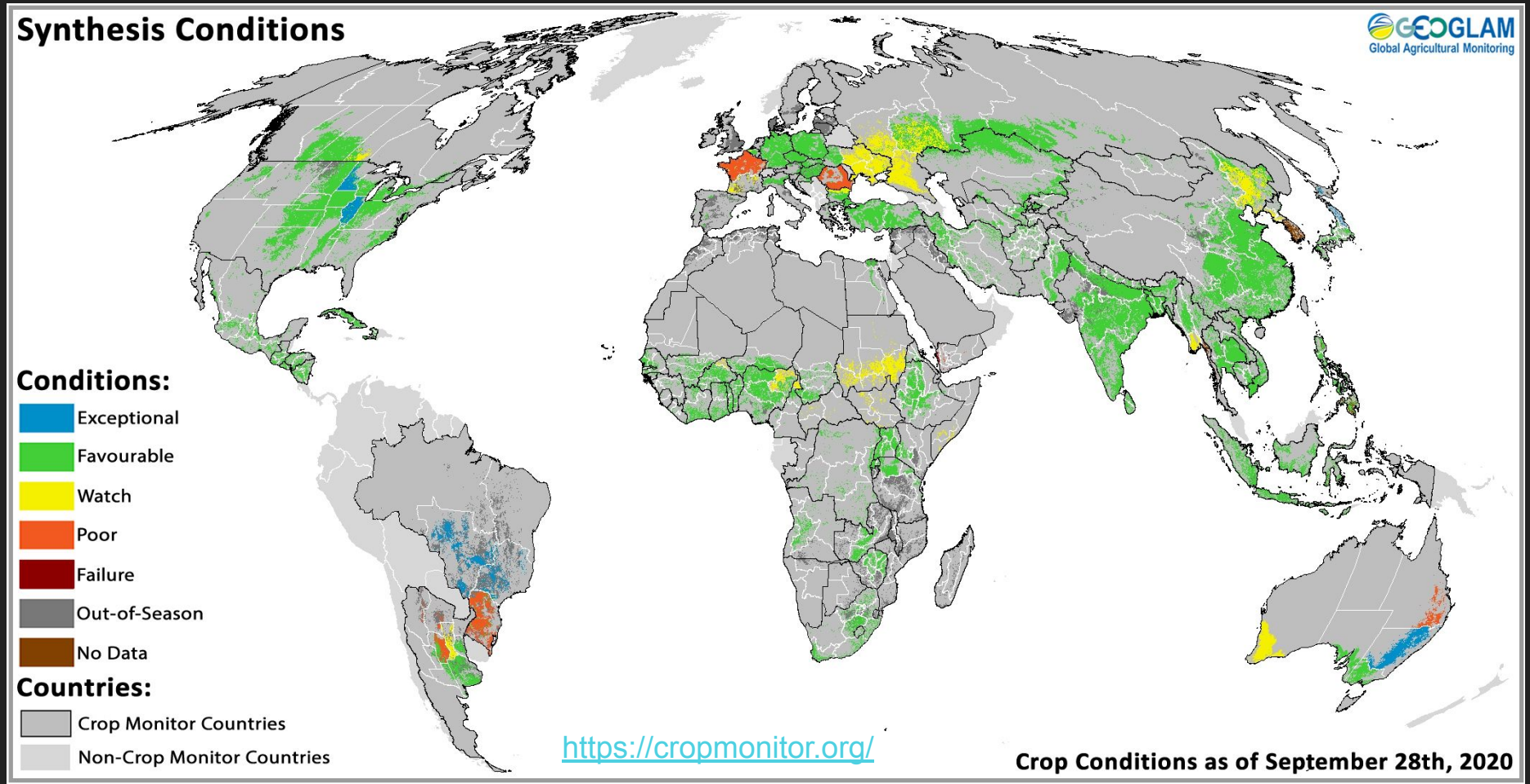
National and Regional Crop Monitors have been developed in partnership with national ministries and regional agencies to improve monitoring capabilities at different scales and to support national and regional interests. These monitors provide additional resources and information for the global Crop Monitor systems.

- AMIS Countries
- Early Warning Countries
- AMIS and EW Overlap Countries
- EW and IGAD ICPAC Countries
- National Monitors

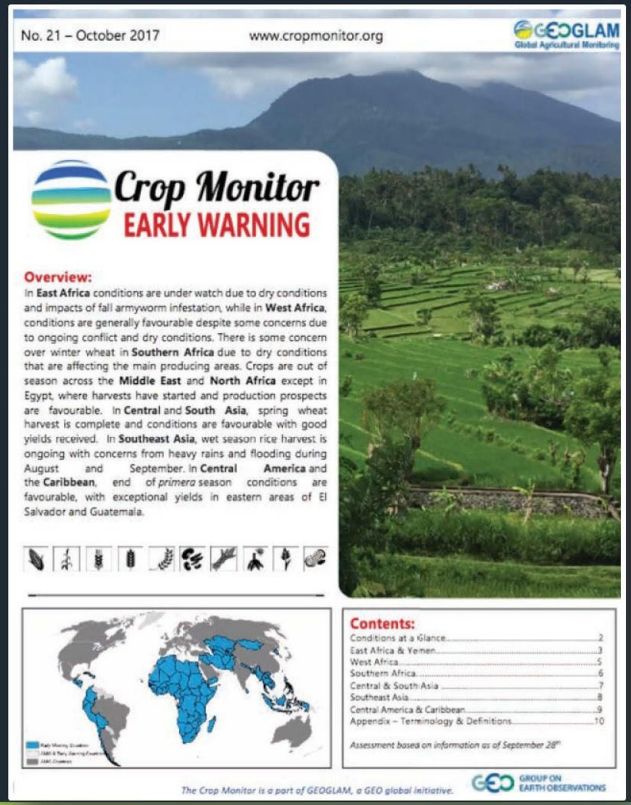


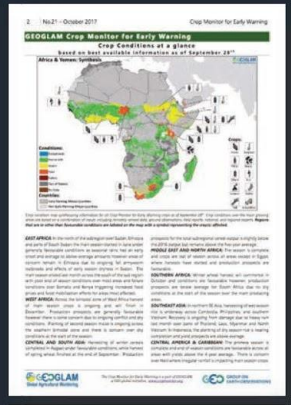
https://cropmonitor.org/index.php/crop-monitor-story-map

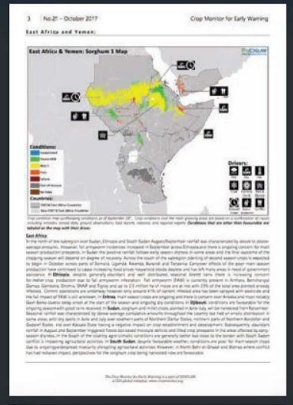
Current Crop Monitor for AMIS and Early Warning

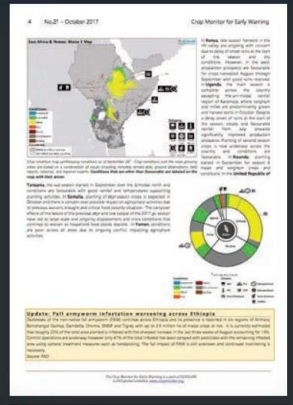


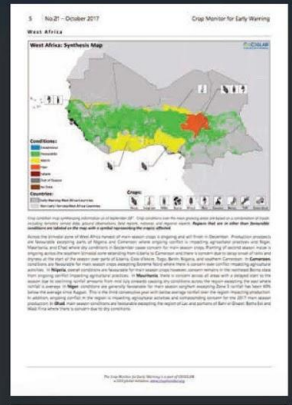
CROP MONITOR FOR EARLY WARNING BULLETIN

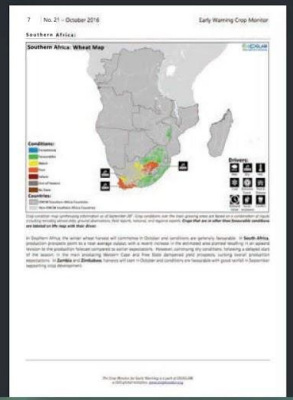


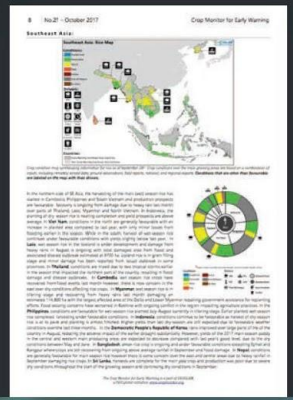


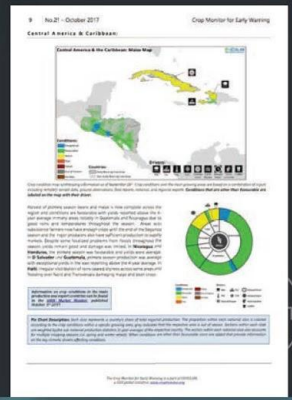












GEOGLAM Special Reports

SPECIAL REPORT www.cropmonitor.org GEOGLAM Global Agricultural Monitoring

Heavy rains and flooding in August affect primary rice producing areas in the Democratic People's Republic of Korea

Updated September 9th

Highlights

- The April to September main cropping season in the Democratic People's Republic of Korea (DPRK) has been one of the wettest rainfall periods since 1981 across the southern agricultural producing provinces in the country (Figure 1,2). The majority of this rainfall was received in August (Figure 3), causing widespread flooding and inundating main season crops ready for harvest starting in September.
- The main producing southern provinces have been the hardest hit from the record rainfall in August (Figure 3), causing flooding across parts of North Hwanghae Province, South Hwanghae Province, South Pyongan, North Pyongan, and Kangwon Province.
- In early August, heavy rainfall from Typhoon 4 followed by additional rainfall through the first two weeks of the month resulted in landslides and flooding across the South, damaging 39,296 hectares of farmland, particularly in the North Hwanghae and Kangwon.
- On August 27th, Typhoon Bavi made landfall over the coast of North Pyongan province, bringing further heavy rains and winds to the key rice-producing provinces of North Hwanghae and South Hwanghae and damaging standing crops.
- This was followed by additional rains and damage to eastern coastal areas from Typhoons Maysak and Haishen at the start of September.
- Rainfall totals this season have been higher in some areas than the record 2007 season when DPRK experienced widespread flooding over the main producing southwest provinces that make up the country's "Cereal Bowl" with severe food security outcomes.
- Forecasts indicate above-average rainfall is expected to continue through September which could increase the risk of further flood events during a time when harvests should be underway for main season crops.

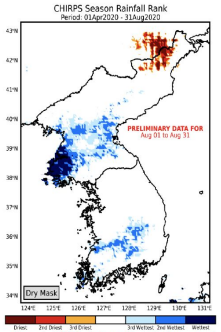


Figure 1. CHIRPS Rank graphic indicating seasonal rainfall totals for the April 1st to August 31st are ranked in the three wettest or three driest relative to the CHIRPS historical record (1981-2019). Source: UCSB Climate Hazards Center

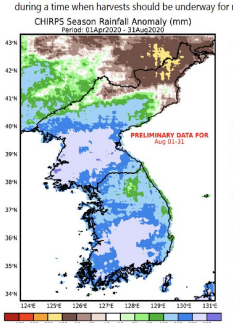


Figure 2. Seasonal Rainfall Anomaly for April 1st to August 31st over DPRK. Areas in light purple indicate where rainfall has been

Overview

The April to September cropping period in southern DPRK has been the wettest on record since 1981 across South Hwanghae, and among the top three wettest seasons in North Hwanghae, South Pyongan, and parts of North Pyongan, South Hamgyong, and Kangwon provinces. The majority of this rainfall fell in August (Figure 2). From August 1st to 6th, Typhoon 4 brought torrential rain to North and South Hwanghae, North Pyongan, and Kangwon provinces as well as Kaesong City and other areas of the country[1] which was followed by additional rains throughout the first two weeks of August. Heavy rainfall resulted in flooding and landslides and damaged 39,296 hectares of farmland, particularly in North Hwanghae and Kangwon, as reported by the official Korea Central News Agency (KCNA).[2] This figure includes damage to 600 hectares of rice fields in North Hwanghae, an important rice-producing province, just weeks before the autumn rice harvest.[3]

The heavy rains caused infrastructure damage in some areas and broke a levee in North Hwanghae which flooded surrounding cropping areas.[4] Rainfall in early to mid-August was followed by Typhoon Bavi, the season's eighth typhoon and one of this year's most powerful storms,[5] which made landfall over the coast of North Pyongan province on August 27th. The storm brought further heavy

SPECIAL REPORT www.cropmonitor.org GEOGLAM Global Agricultural Monitoring

Dry conditions for 2019-2020 season expected to continue across portions of Southern Africa

Updated January 17, 2020

Highlights

- The 2019-20 main season in Southern Africa started with a timely onset of the rains followed by erratic and below-average rainfall from mid-October to mid-December in the central and southern parts of the region.
- Persistent drier than normal conditions across parts of southeastern Angola, northeastern Namibia, Lesotho, Botswana, southwest Zambia, eastern Zimbabwe, southern Mozambique, Namibia, southern Madagascar and parts of South Africa (Figure 1) have affected crop establishment and growth.
- In some areas, extended dry spells with high temperatures have resulted in permanent crop wilting and replanting will be necessary.
- Reservoir and water levels are low across the drought-affected areas causing further concern for crop production.
- Short term forecasts indicate that northern areas along with parts of central Zambia, northern Zimbabwe, and central Mozambique are likely to receive above-average rainfall in mid-January.
- However, following this, the longer-term outlook is for overall drier than average conditions to continue across the drought-affected central and south and forecasts show the increased chance of below-normal rainfall from February to March.

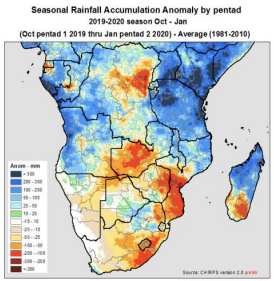


Figure 1. Seasonal rainfall accumulation anomaly from October 1 through January 10 compared to the long-term average from 1981-2010. Source: USGS/ EROS

Overview

In Southern Africa, planting of the 2019-2020 main season cereals started in mid-October and November with a generally timely onset of the rains in most areas. However, from mid-October to mid-December, rainfall was erratic across central and southern parts of the region with periods of long dry spells and above-average temperatures, followed by short periods of rain. These conditions resulted in poor germination and establishment in areas where crops had already been sown and notably over southern Mozambique, Zimbabwe and southwestern Zambia. In the north of the region, rainfall has been generally favourable and in some areas above-average, supporting crop development and growth.

While much of the north of the region has received sufficient rains, parts of southern **Angola**, northern **Namibia**, **Lesotho**, **Botswana**, southwest **Zambia**, eastern **Zimbabwe**, southern **Mozambique**, **Namibia**, southern **Madagascar** and parts of **South Africa** have received below-average rainfall and in some areas, dry conditions have been exacerbated by above-average temperatures. This follows last year's severe main season drought, which impacted water levels and crop yields across many of the areas currently affected by drought.

SPECIAL REPORT www.cropmonitor.org GEOGLAM Global Agricultural Monitoring

East Africa 2020 flood impacts on agriculture

Updated May 19th, 2020

Highlights

- The March to May (MAM) rainfall period was one of the wettest the region has seen since 1981 (Figure 1), following an already record wet 2019 October to December (OND) rainfall period.
- The early onset of rains and above-average rainfall since February promoted land preparation and planting activities for the MAM season across Somalia, Kenya, Tanzania, Uganda, Rwanda, and Burundi, along with the *Belg* season in Ethiopia.
- However, the abundant rains have also caused localized flooding, mudslides, flashfloods, and river overflows over the past months causing casualties, population displacement, infrastructure damage, and crop damage in parts of Kenya, Ethiopia, Somalia, Uganda, Tanzania, Rwanda, Burundi, and Yemen.
- Cropping conditions remain generally favourable as rains are expected to be beneficial to planting and crop development across much of the region; however, localized losses and crop damage are expected in areas worst affected by flooding (Figure 2).
- Abundant rains have also promoted the breeding and development of desert locusts and protracted the outbreak across the region, which continues to pose a significant threat to main season crops.
- Above-average rainfall is expected to continue across much of the region through May which will increase the flood risk across many areas and further protract the desert locust outbreak (See May Outlook Pg. 8).

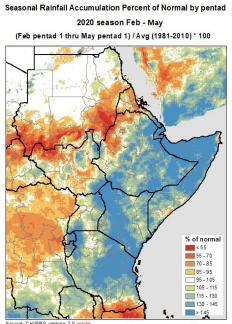


Figure 1. Seasonal rainfall accumulation anomaly for the Feb 1- May 5 period over Eastern Africa (source: USGS/ EROS).

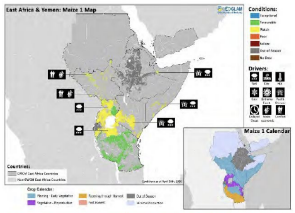


Figure 2. Crop condition map synthesizing conditions as of April 28th from the May CM4EW bulletin. (source: GEOGLAM CM4EW May Bulletin).

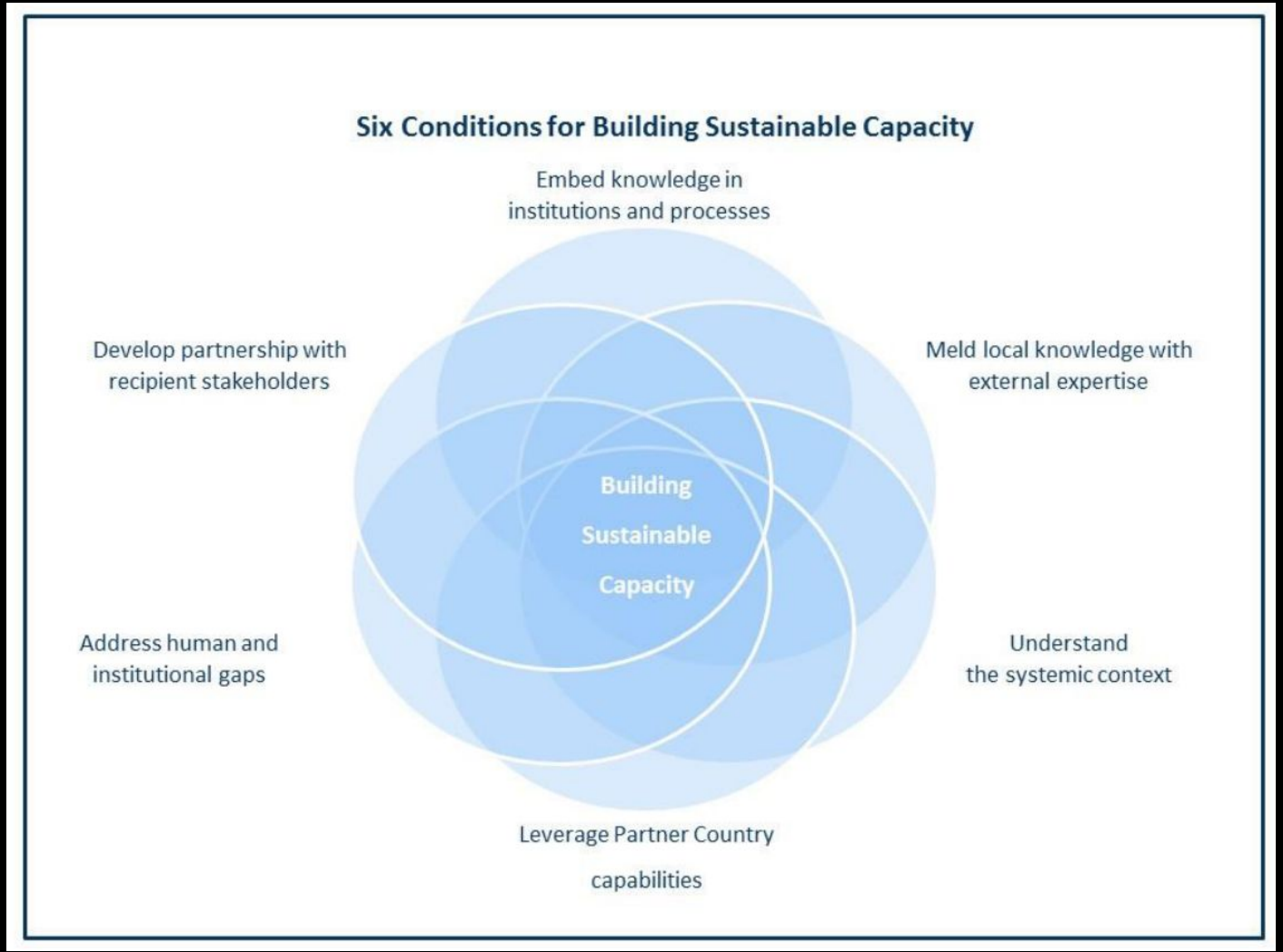
Overview

The January to March rainfall period in East Africa, which marked an early start to the normal March to May (MAM) rains, was one of the wettest the region has seen since 1981. Since the beginning of the MAM season in March, UNOCHA has estimated that at least 1.3 million people have been affected by flooding, an estimated 481,000 people have been displaced, and 360 people have died following disastrous floods across the region.[1] This followed an already record 2019 October to December (OND) rainfall period where above-average rainfall led to widespread floods, resulting in the displacement of hundreds of thousands of people and causing crop and livestock losses in worst-affected areas.[2] The above-average rainfall in late 2019 was mostly a result of one of the strongest positive Indian Ocean Dipoles (IOD) in a 60-year history that brought enhanced rains to East Africa; however, the IOD is now in a neutral state and is forecast to remain neutral through June 2020.

While the early onset and above-average seasonal rains have had significant beneficial impacts for agricultural production, water resources recharge, and environmental and hydro-power regeneration across the region, they've also resulted in localized flooding, mudslides, flashfloods, and river overflows over the past months causing casualties, high levels of population displacement, infrastructure damage, and crop damage over worst affected areas. In many cases, the floods have affected the highly populous and agricultural productive regions of East Africa. Since late January, the worst affected areas of flooding include parts of **Somalia, Kenya**,

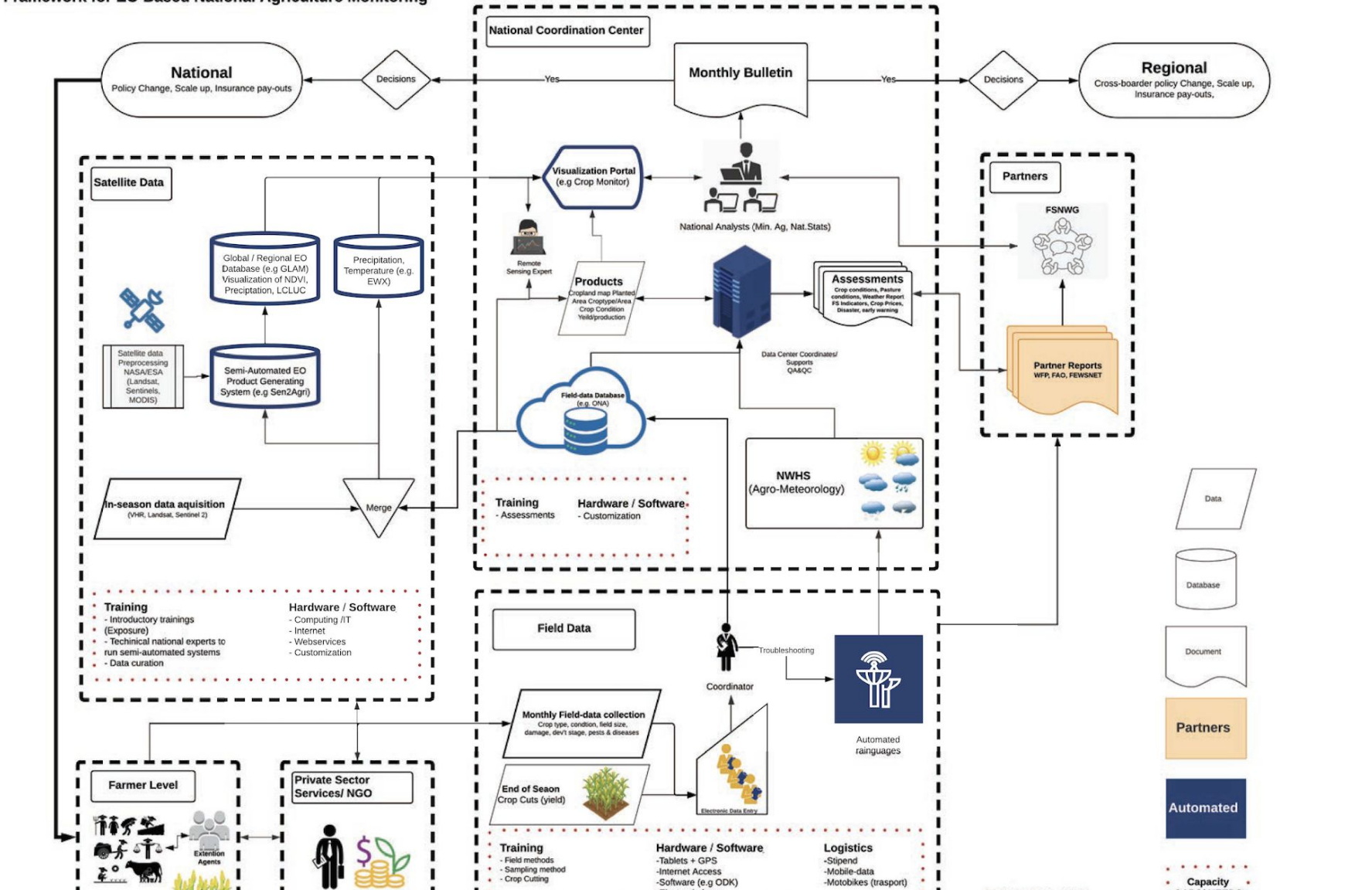
Key requirements for integrating & leveraging EO in Small-holder Ag. Monitoring

- Capacity (analyze, interpret, generate products)
- Satellite data (at the right temporal and spatial resolution)
- Automation (cloud computing, workflows..)
- **Field-data –consistent and continuous**
- Linkage to regional and international effort
- Linkage to farmer (unpacking the data/ information)
- Private sector (harness the value, and unpack)

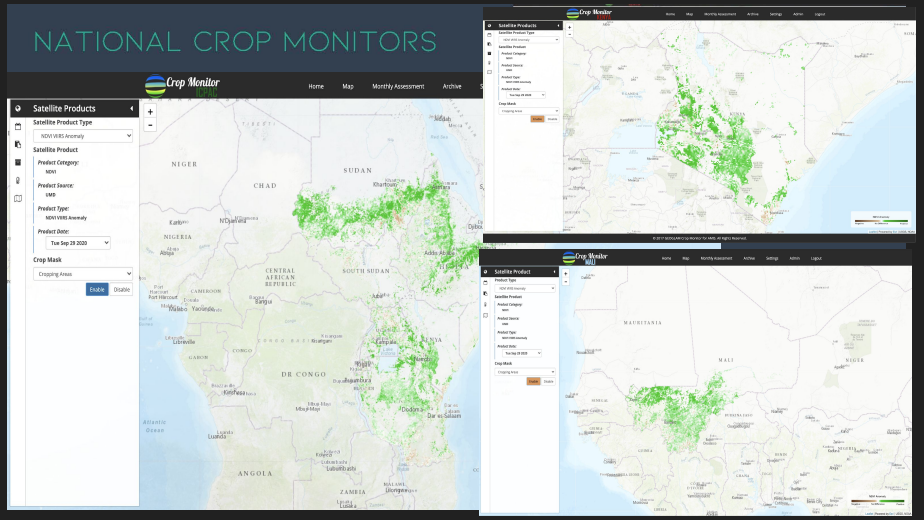


(Gerspacher et. al, 2017)

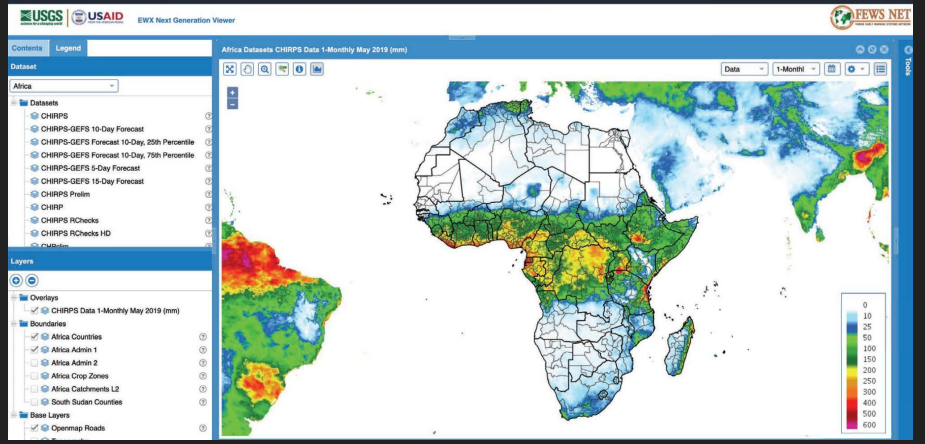
Framework for EO Based National Agriculture Monitoring



NATIONAL CROP MONITORS

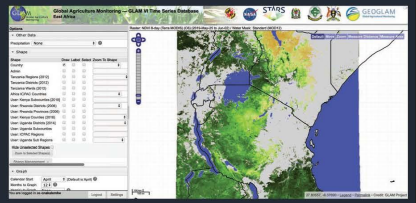


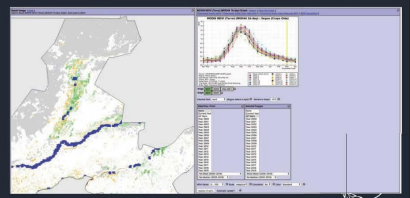
Early Warning eXplorer (EWX)



2. GLAM SATELLITE DATA PORTAL

- User-friendly, **automated** portal directly connected to **free** NASA image data feed through the internet
- Provides automated global 8-day and 16-day maps of crop condition.
- Customizable any admin level
- Generates graphs showing the development of crop condition in time
- Automatically highlights critical areas in the country
- Used for monitoring and reporting by OPM Uganda, MoA Kenya, Tanzania and Rwanda
- Used in support of Disaster Risk Financing at OPM - Local Server to be purchased and further developed under DRF





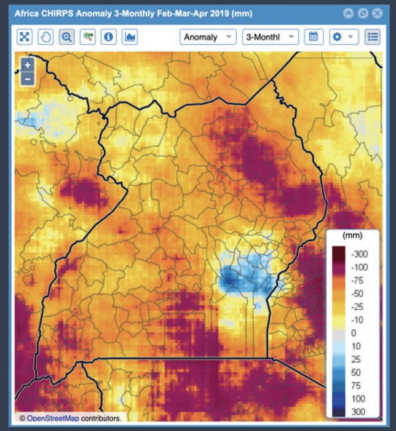
FIELD DATA- TOOLS

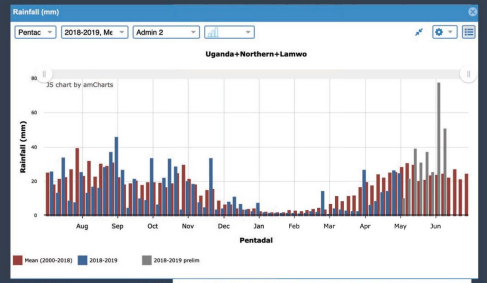
Pre Season
- Farmer ID
- GPS
- Field Area
- Irrigation type
- Management Methods
- Landcover
- Seed Type
- Crop Damage
- Staple Food Market Price

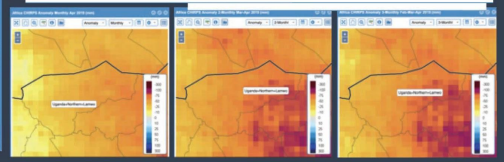
In Season
- Planting Date
- Projected Yield
- Maize height
- drought/flood damage
- pests/ disease with photos
- staple food market price
- Irrigation
- Management Methods
- Farmer Assessment

End of Season
- Actual yield
- Cause of damage
- Farmer Assessment
- Yield
- Storage

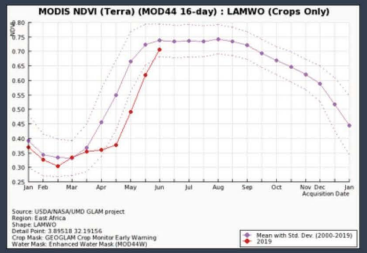
EARLY WARNING EXPLORER

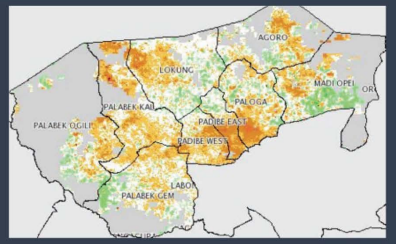


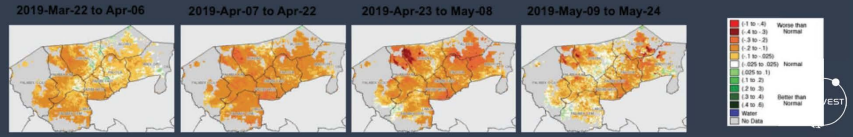




GLAM SATELLITE DATA PORTAL

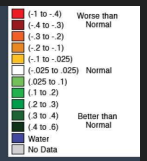


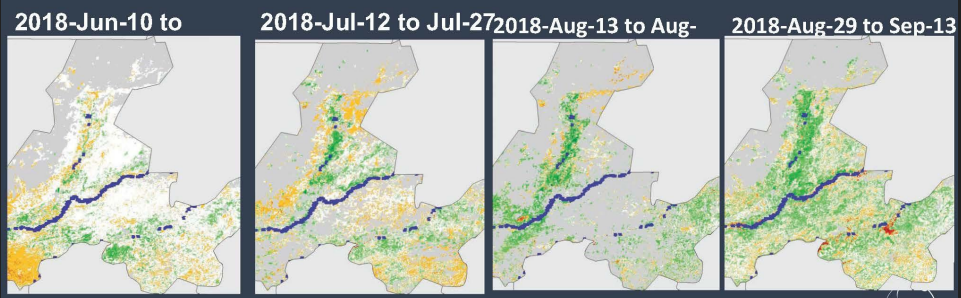




GLAM SATELLITE DATA PORTAL

Segou 2018





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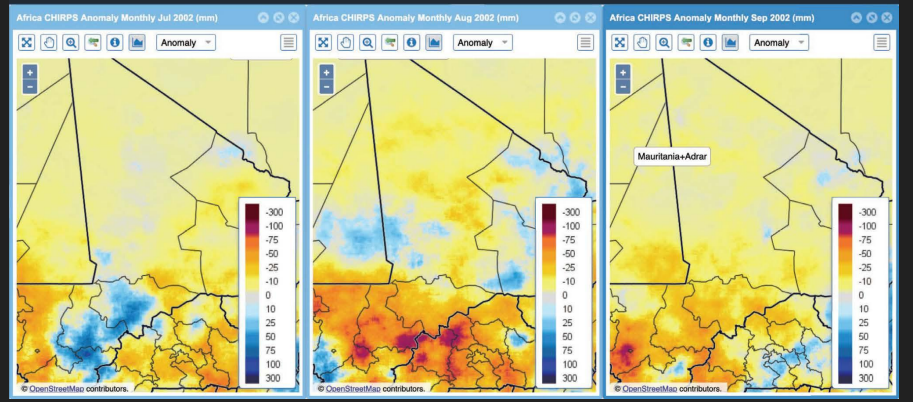
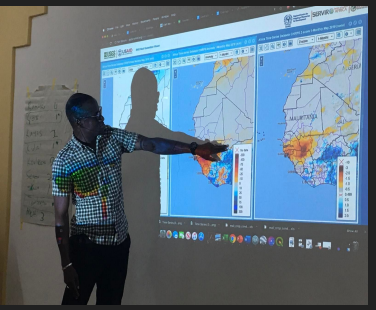
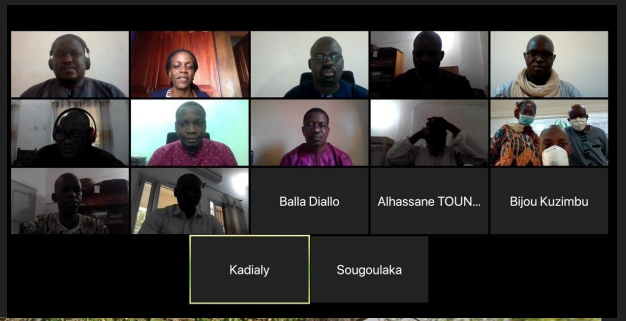
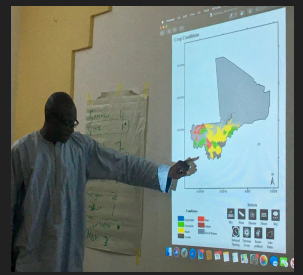
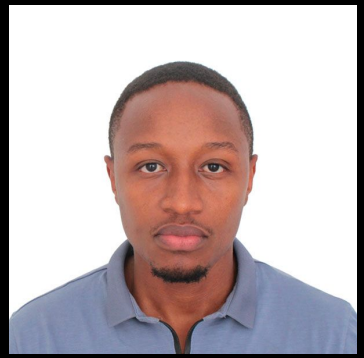




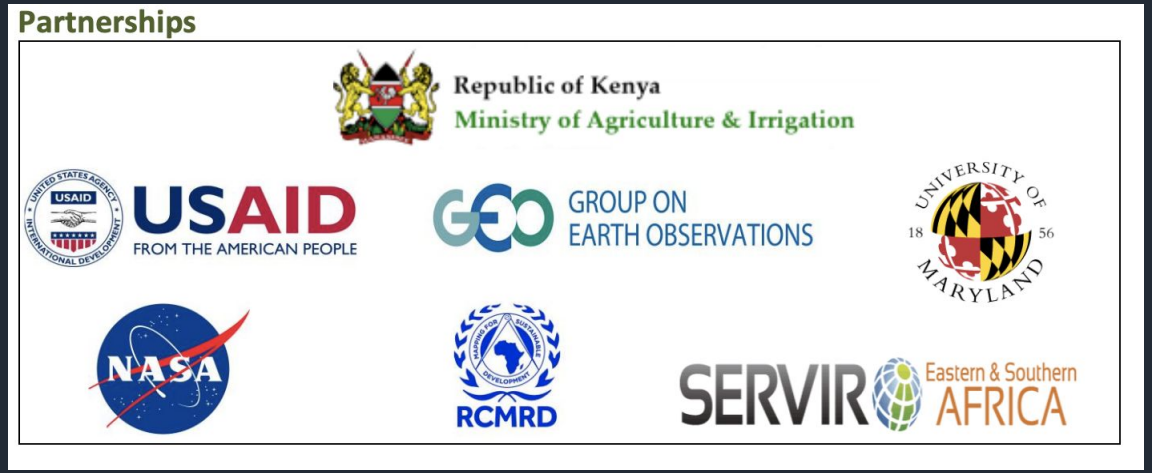


Addressing Human and Institutional Gaps

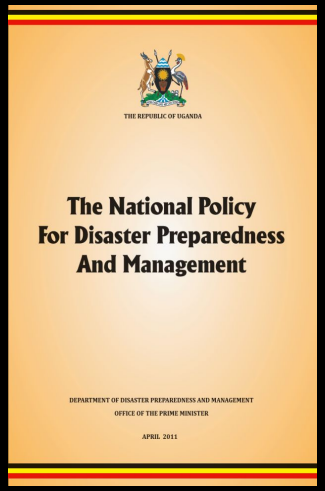


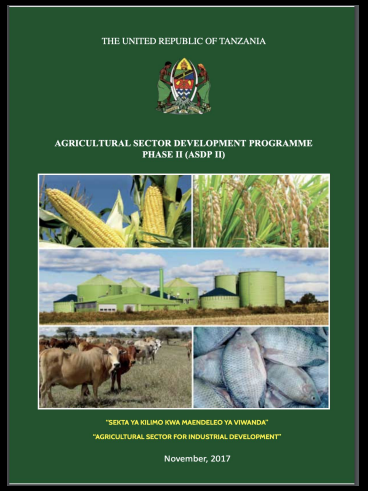


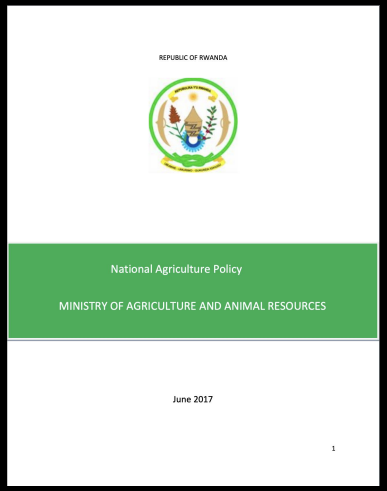
Melding Knowledge with external local expertise



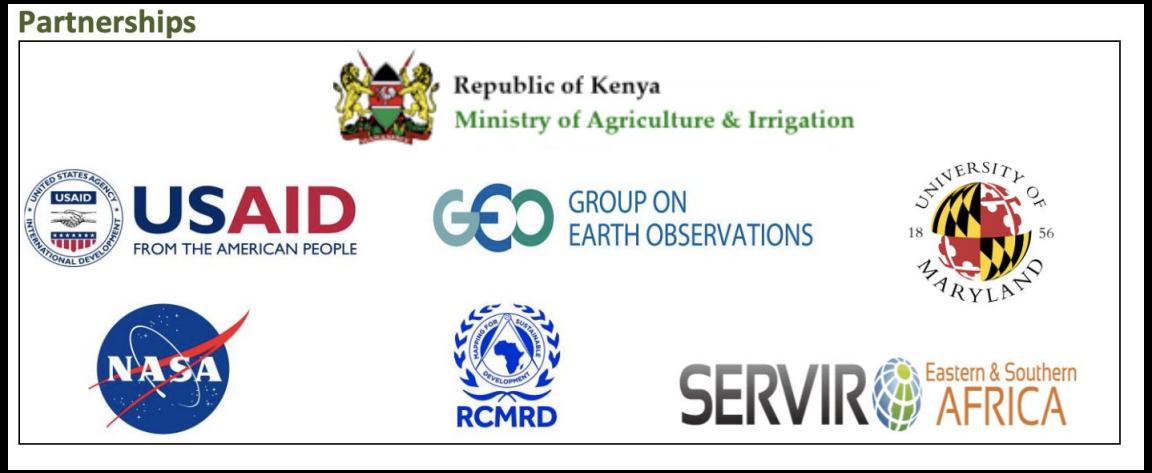
Developing partnership with recipient stakeholders





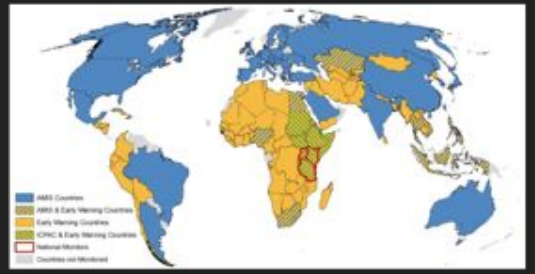


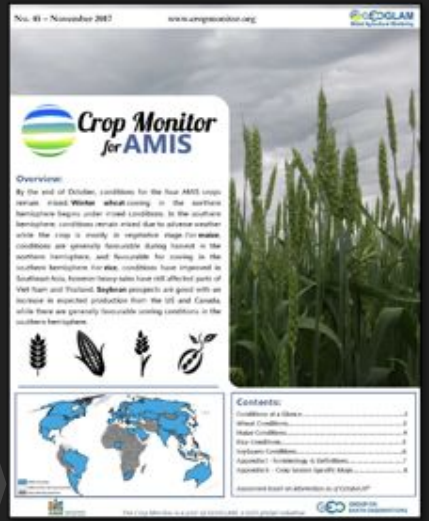
Understanding the policy context

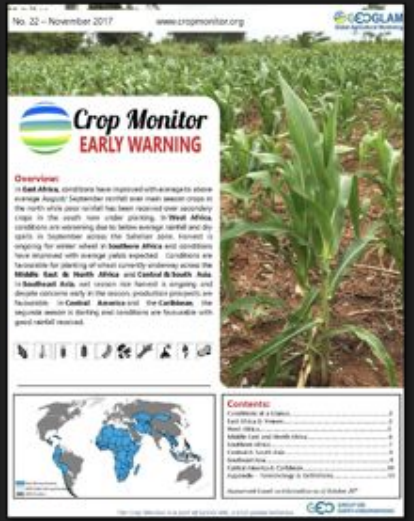


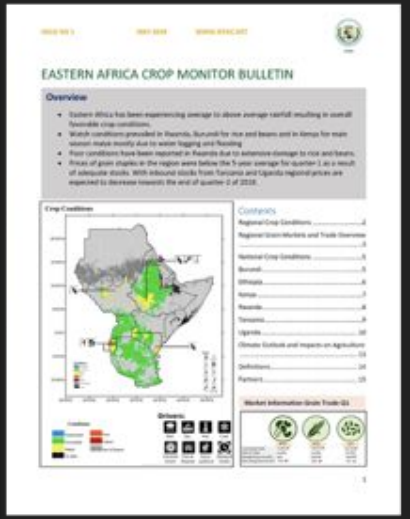
Leveraging capabilities

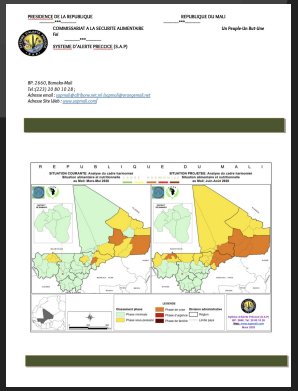
Embedding Knowledge in institutions and processes

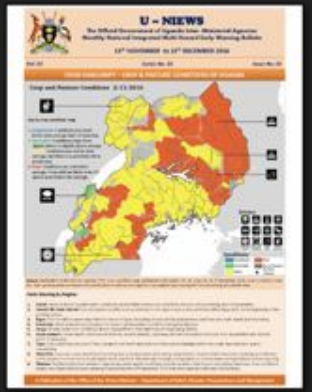


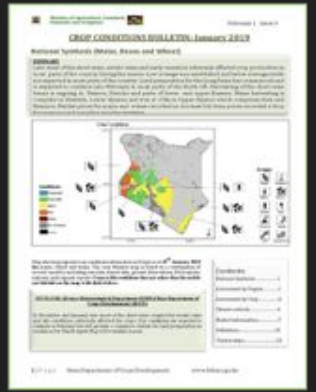


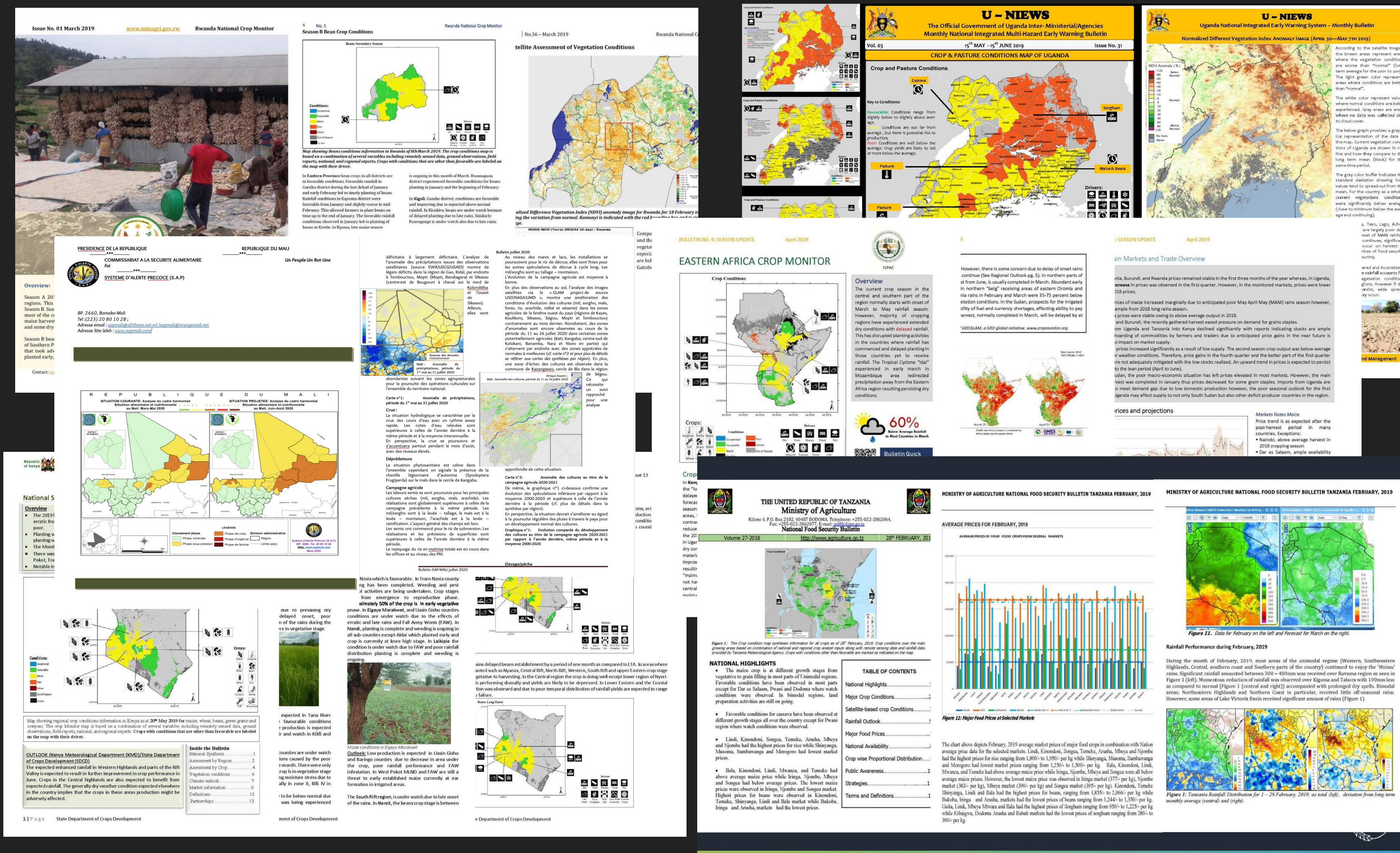











Issue No. 01 March 2019
www.minagri.gov.rw
Rwanda National Crop Monitor
Season B Bean Crop Conditions
U – NIEWS
The Official Government of Uganda Inter- Ministerial/Agencies Monthly National Integrated Multi-Hazard Early Warning Bulletin
CROP & PASTURE CONDITIONS MAP OF UGANDA
U – NIEWS
Uganda National Integrated Early Warning System – Monthly Bulletin
PRESIDENCE DE LA REPUBLIQUE
REPUBLIQUE DU MALI
COMMISSARIAT A LA SECURITE ALIMENTAIRE
SYSTEME D'ALERTE PRECOCE (S.A.P)
Bulletin juillet 2020
EASTERN AFRICA CROP MONITOR
BULLETIN NO. 4: SEASON UPDATE
April 2019
Overview
National Highlights
THE UNITED REPUBLIC OF TANZANIA
Ministry of Agriculture
National Food Security Bulletin
MINISTRY OF AGRICULTURE NATIONAL FOOD SECURITY BULLETIN TANZANIA FEBRUARY, 2019
AVERAGE PRICES FOR FEBRUARY, 2019
Rainfall Performance during February, 2019
NATIONAL HIGHLIGHTS
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Republic of Kenya
OUTLOOK (Kenya Meteorological Department (KMD)/State Department of Crops Development (SDCD))
Inside the Bulletin
State Department of Crops Development

Improving baselines

Monitoring Smallholder Agriculture is Tough

Why: Food Security

- For subsistence
- Low inputs = low productivity
- Pests and diseases
- Policy

Why: Very Complex systems

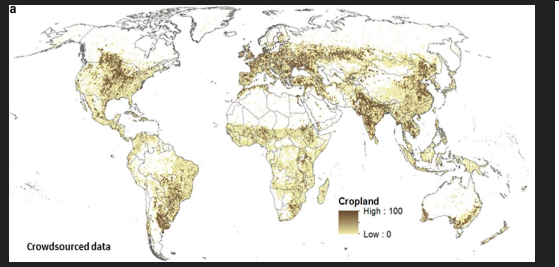
- Average field size <1 ha
- Mixed fields
- Land-cover (Agroforestry, pasture)
- Irregular field boundaries
- Intercropping (mixed fields)
- Rainfed → cloudy growing seasons

Karamoja, Uganda

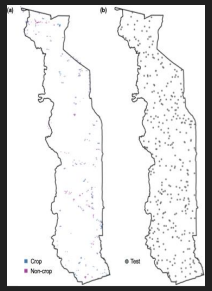
Segou Mali

In some cases meets the livelihood needs of over 70% of the population

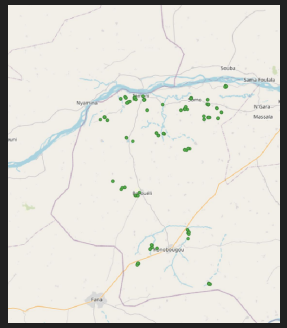
ML for cropland mapping

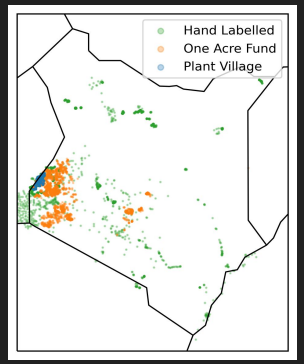


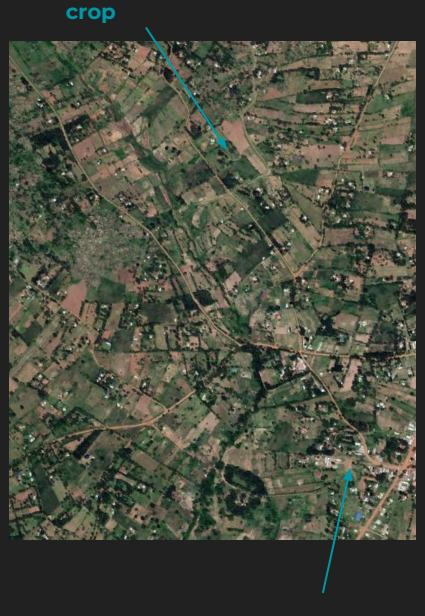
Bayas et al., 2017

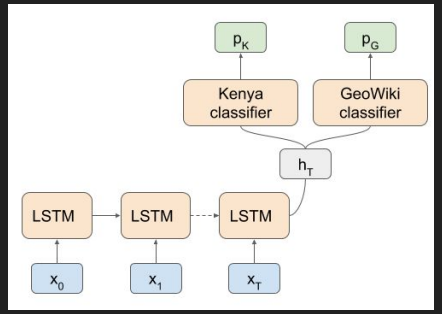


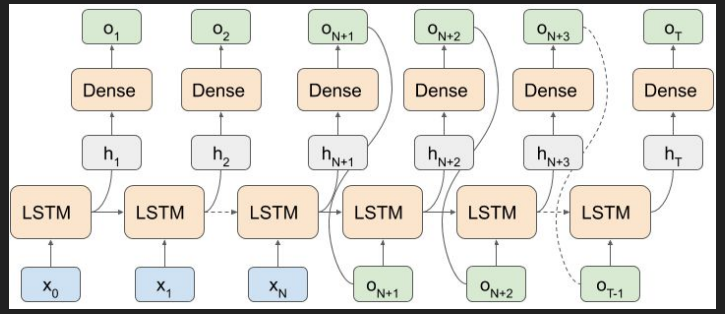
Kerner & Tseng et al., 2020





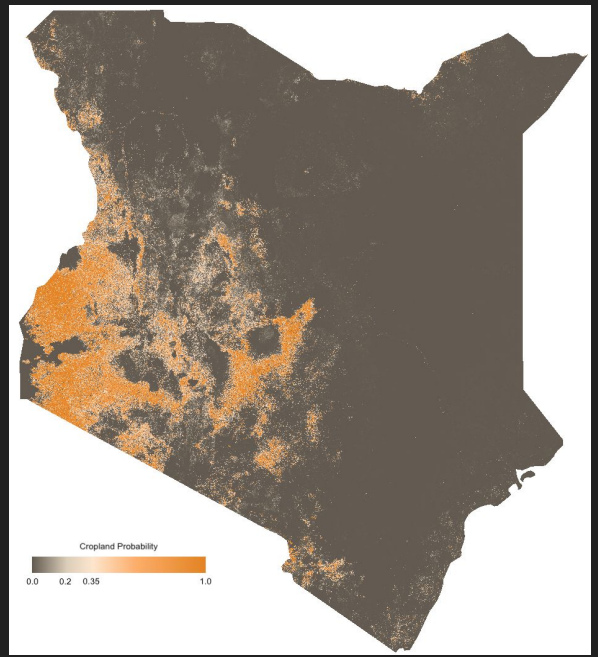






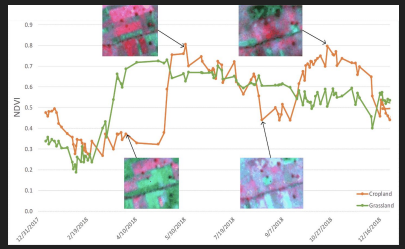
Supporting smallholder farmers in Togo

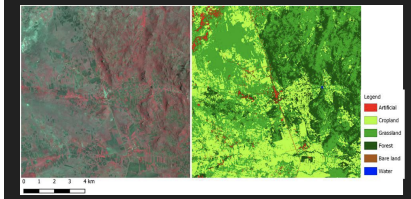
Annual and in-season mapping of cropland at fieldscale with sparse labels- Kenya



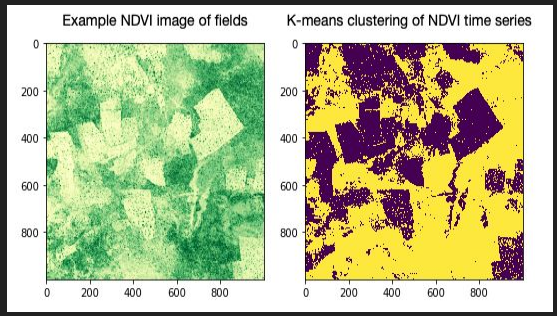
Harvest 2019 (10m)

VHR Cropland mapping in Uganda and Mali





TOP: NDVI profiles for a double crop and natural vegetation in the Namalu region in Uganda derived from Planet's Dove Classic **Bottom: False-color composition** Planet acquired on 31 March 2018) and **land cover map** (***right***) for the Namalu region in Uganda



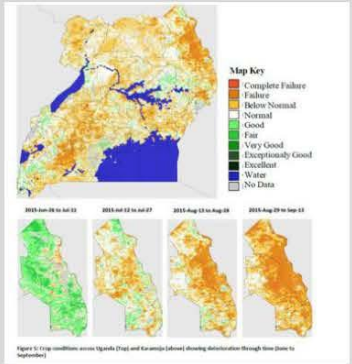
Initial experiments using (unsupervised) k-means clustering on the Planet L3H NDVI time series to separate crops from other land cover, Segou Mali

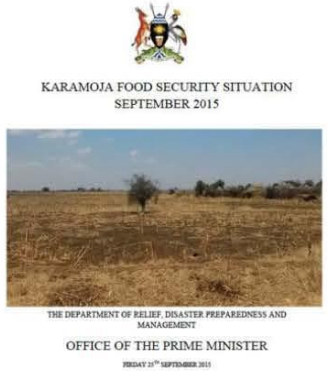
Skakun et. al 2019

Impact Examples

EO SUPPORTED IMMEDIATE DECISION AND ACTION

- Food security report presented to Inter-Ministerial Committee September 25, 2015
- First trucks of relief food dispatched September 26, 2015





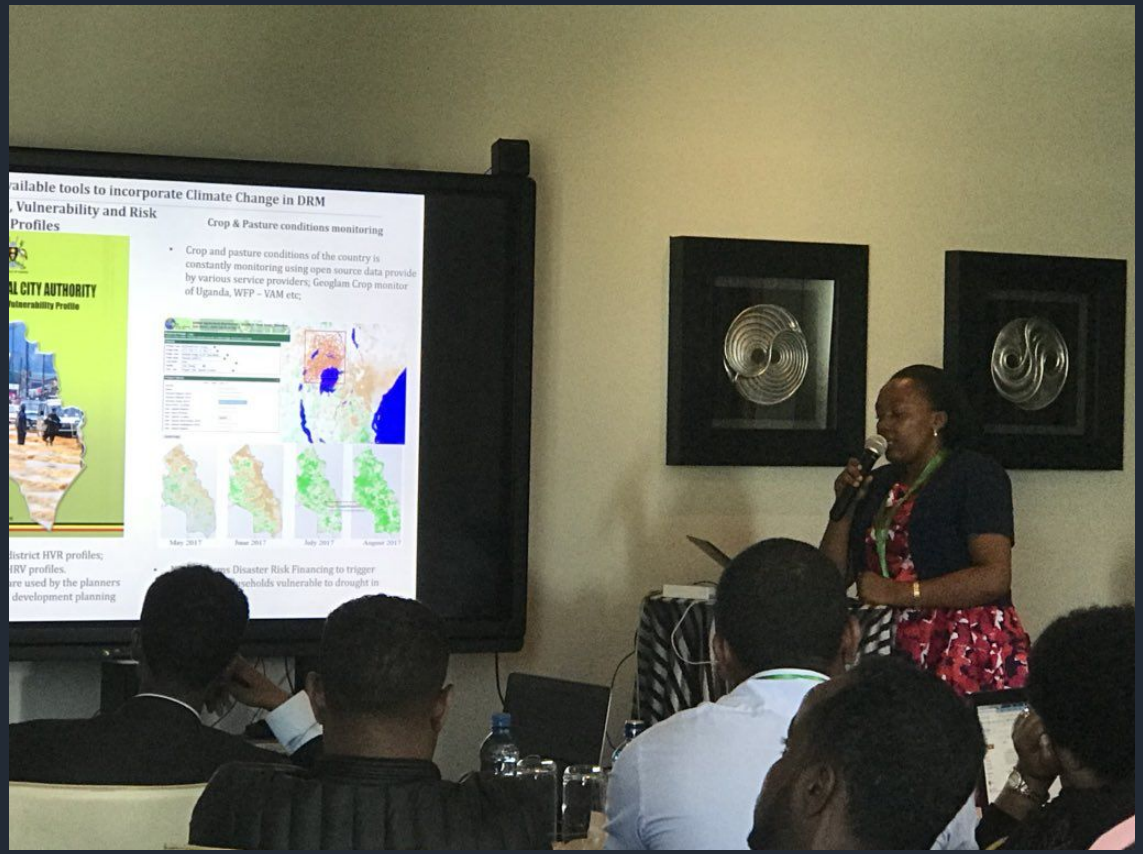
KARAMOJA FOOD SECURITY SITUATION
SEPTEMBER 2015

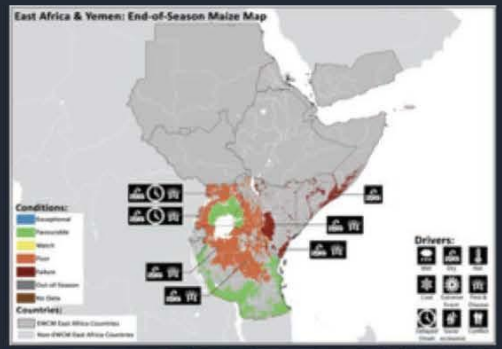
THE DEPARTMENT OF RELIEF, DISASTER PREPAREDNESS AND MANAGEMENT

OFFICE OF THE PRIME MINISTER

FRIDAY 25TH SEPTEMBER 2015

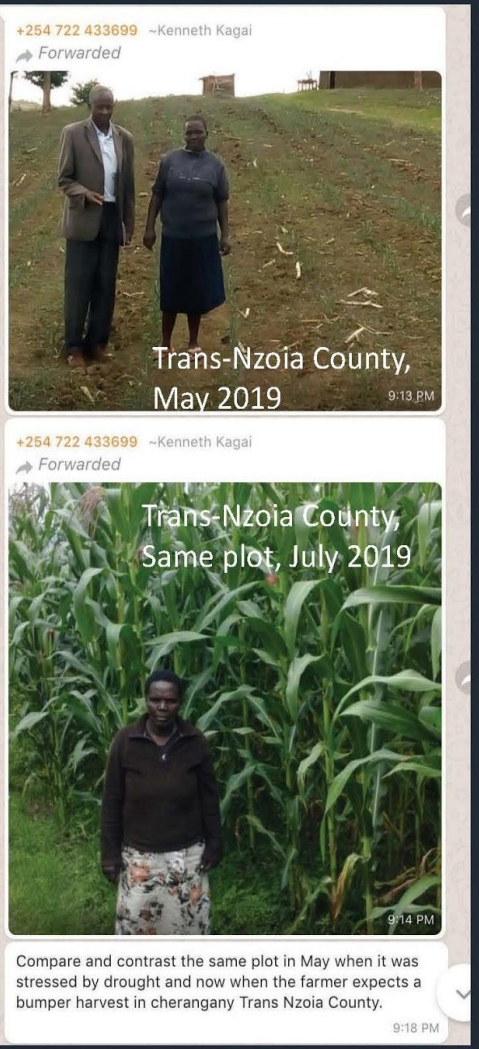
Disaster Risk Financing -Uganda

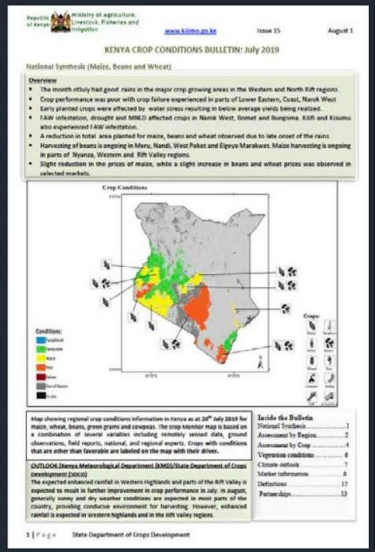




- Relies on GLAM and Early warning explorer to inform scaling the DRF program in Uganda.
- Has supported over 300,000 people in the Karamoja region
- Government of Uganda realized a saving of US $2.6 M (51%) for FY ending 2016/17

KENYA EXAMPLES OF 2019 SEASON VARIABILITY IN KENYA




KENYA CROP CONDITIONS BULLETIN: July 2019

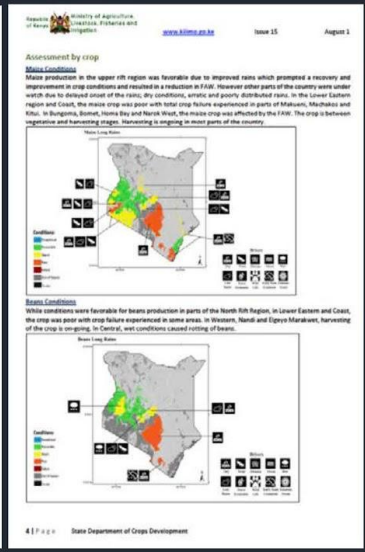
National Synthesis (Maize, Beans and Wheat)

Overview

- The month ofJuly had good rains in the major crop growing areas in the Western and North Rift regions.
- Crop performance was poor with crop failure experienced in parts of Lower Eastern, Coast, Narok West
- Early planted crops were affected by water stress resulting in below average yields being realized.
- FAW infestation, drought and MMLD affected crops in Narok West, Bomet and Bungoma. Kilifi and Kisumu also experienced FAW infestation.
- A reduction in total area planted for maize, beans and wheat observed due to late onset of the rains.
- Harvesting of beans is ongoing in Meru, Nandi, West Pokot and Elgeyo Marakwet. Maize harvesting is ongoing in parts of Nyanza, Western and Rift Valley regions.
- Slight reduction in the prices of maize, while a slight increase in beans and wheat prices was observed in selected markets.

Crop Conditions

Inside the Bulletin


Assessment by crop

Maize Conditions

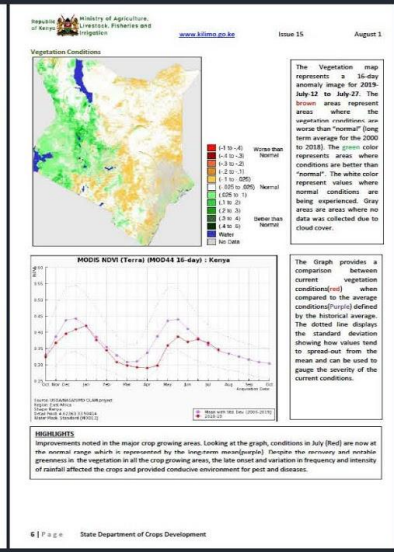
Maize production in the upper rift region was favorable due to improved rains which prompted a recovery and improvement in crop conditions and resulted in a reduction in FAW. However other parts of the country were under watch due to delayed onset of the rains; dry conditions, erratic and poorly distributed rains. In the Lower Eastern region and Coast, the maize crop was poor with total crop failure experienced in parts of Makueni, Machakos and Kitui. In Bungoma, Bomet, Homa Bay and Narok West, the maize crop was affected by the FAW. The crop is between vegetative and harvesting stages. Harvesting is ongoing in most parts of the country.

Maize Long Rains

Beans Conditions

While conditions were favorable for beans production in parts of the North Rift Region, in Lower Eastern and Coast, the crop was poor with crop failure experienced in some areas. In Western, Nandi and Elgeyo Marakwet, harvesting of the crop is on-going. In Central, wet conditions caused rotting of beans.

Beans Long Rains


Vegetation Conditions

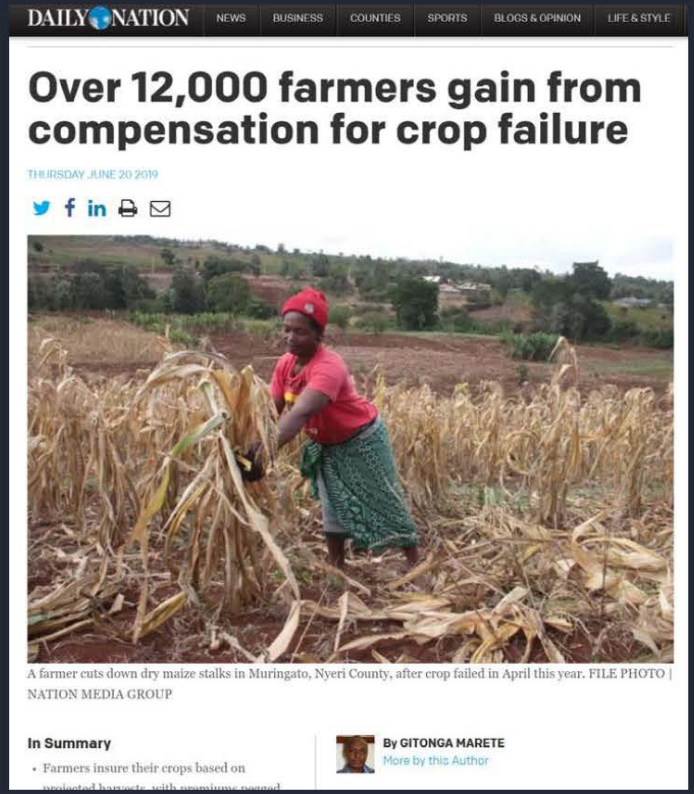
MODIS NDVI (Terra) (MOD44 16-day) : Kenya

HIGHLIGHTS

Improvements noted in the major crop growing areas. Looking at the graph, conditions in July (Red) are now at the normal range which is represented by the long-term mean(purple) .Despite the recovery and notable greenness in the vegetation in all the crop growing areas, the late onset and variation in frequency and intensity of rainfall affected the crops and provided conducive environment for pest and diseases.

KENYA

- The Kenya Crop Monitor is helping streamline data collection
- Kenya SDA synthesizes crop conditions through a combination of field assessments and earth observation data.
- Information about crop conditions is supplemented with climate outlook and market information.
- The resulting maps provide an understanding of crop conditions and drivers of less than favorable conditions.
- The service facilitates a crop modeling framework to assess drought and yields.
- Supporting the **Kenya Government crop insurance program** by developing a geospatially informed sampling frame.
- The sampling frame
- Over **70% cost reduction and reduced sampling time** - increasing efficiency and reducing bias in sample selection. Overall, the service supports enhanced food security decisions from the local to regional levels.



DAILY NATION NEWS BUSINESS COUNTIES SPORTS BLOGS & OPINION LIFE & STYLE

Over 12,000 farmers gain from compensation for crop failure

THURSDAY JUNE 20 2019

A farmer cuts down dry maize stalks in Muringato, Nyeri County, after crop failed in April this year. FILE PHOTO | NATION MEDIA GROUP

In Summary

- Farmers insure their crops based on

By GITONGA MARETE
More by this Author

RCMRD SERVIR Eastern & Southern AFRICA USAID FROM THE AMERICAN PEOPLE NASA UNIVERSITY OF MARYLAND

Some Key Lessons

- Usefulness and Applicability

  Clear use case for remote sensing, smart phone and internet tools for agricultural monitoring
- Easy and quick adaptability and uptake
  - Tools developed and adapted with end-user in mind
- Feasibility and Affordability

  New technologies are **easy and feasible to implement** and deliver **higher quality data at lower cost**
- Sustainability

  a) Inclusion of bulletin and electronic field data collection in government procedures

  b) Partnerships between government, universities, private sector (PPP) are critical for sustainability

Summary

- Weather and climate impacts are likely to worsen as climate change progresses- exacerbating vulnerabilities in most developing countries.

- Earth Observations form a strong, reliable and strategic basis for informing programs and policies that can inform planning, implementing and managing programs that can directly lead to better outcome for farmers.

- As climate change progresses timely and accurate data become even more critical

Thank you

Email: cnakalem@umd.edu

Twitter @CLNakalembe