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Urgent and critical need for Sub-Saharan African countries to invest in Earth observation-based agricultural early warning and monitoring systems

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Introduction

Weather and climate impacts are likely to worsen as climate change progresses, thereby exacerbating vulnerabilities in most Sub-Sahara African (SSA) countries. Extreme weather events such as floods, landslides, droughts and cyclones are common occurrence worldwide. Teleconnections show that large scale events in one region can have significant impacts in other regions. For example, after Cyclone Idai made landfall in Mozambique on March 15, 2019, it ravaged through Southern Africa, causing catastrophic winds and flooding in several countries. Idai was identified by the UN as one of the deadliest storms on record that occurred in the Southern Hemisphere. The cyclone caused an estimated 1 297 deaths, 2 262 people were reported missing; it affected more than 3 million people in total and caused an estimated \$ 2 billion in damages [1]. A few weeks later (April 25, 2019), cyclone Kenneth made landfall in northern Mozambique, and it affected 170 000 people, who were already experiencing armed violence [2]. Simultaneously, farmers in Eastern Africa who had been anticipating good rainfall waited vainly for the rain. Idai removed moisture from Eastern Africa at the onset of the growing season. Consequently, parts of Kenya and Somalia experienced total crop failure [3]. Figure 2 summarizes the major events in Eastern and Southern Africa in 2019 and their impacts.

Even with continuous weather forecasts by regional and national agencies, the updated information did not reach the farmers for making appropriate decisions. In Eastern Africa, farmers sowed seeds and worked in their fields in anticipation of good precipitation. Many farmers in Kenya faced losses as reported in the end of season section of the September 2019 Crop Monitor for Early Warning report for Eastern Africa [3] (Figure 1). The report confirmed poor and failed crops across multiple countries in Eastern Africa as a result of the widespread crop failure and several countries needed aid [4]. Furthermore, the rainy seasons of March–May and October–December are flooding and landslide seasons in Eastern Africa [5]. From October to December 2019, flash flooding and landslides occurred in Kenya, Uganda, Rwanda, and Burundi, leading to at least 265 deaths.

In 2019, the strong positive Indian Ocean dipole (IOD) led to the wettest October–November period on record since 1981 in Eastern Africa. Rainfall in parts of Kenya, Somalia, Tanzania, Uganda, Burundi, and Ethiopia was 300 % more than average [6, 7]. This increased rainfall led to increased green vegetation, even in desert areas creating perfect conditions for desert locusts to breed. Cyclone Pawan, which made landfall

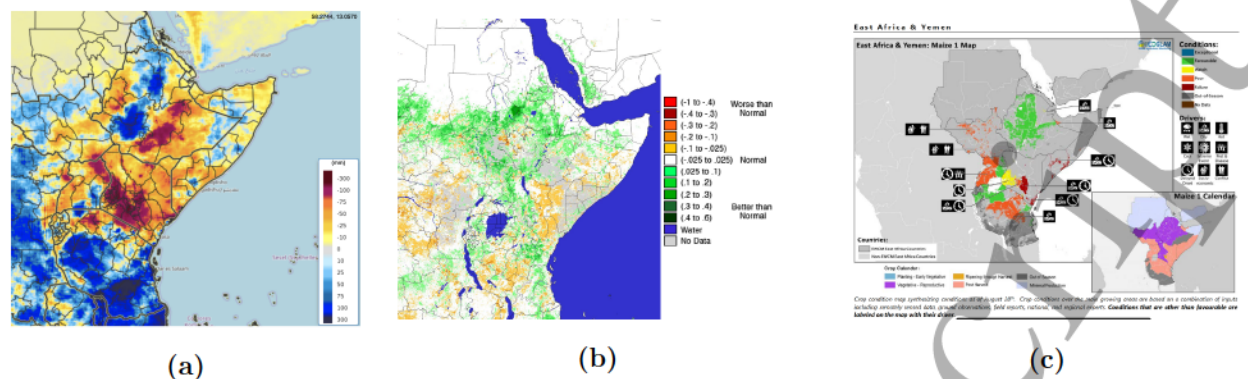


Figure 1: (a) 2019 March to May rainfall anomaly leading to reduction in vegetation conditions by early July shown in; (b) Normalized difference vegetation index (NDVI) anomaly from 2019-Jun-10 to Jun-25 and widespread crop failure as reported at the end of August in (c) The End of season section of the crop monitor for early warning report for East Africa showing crop failure in Central Kenya and Somalia and poor production in Uganda. Source GEOGLAM Crop Monitor

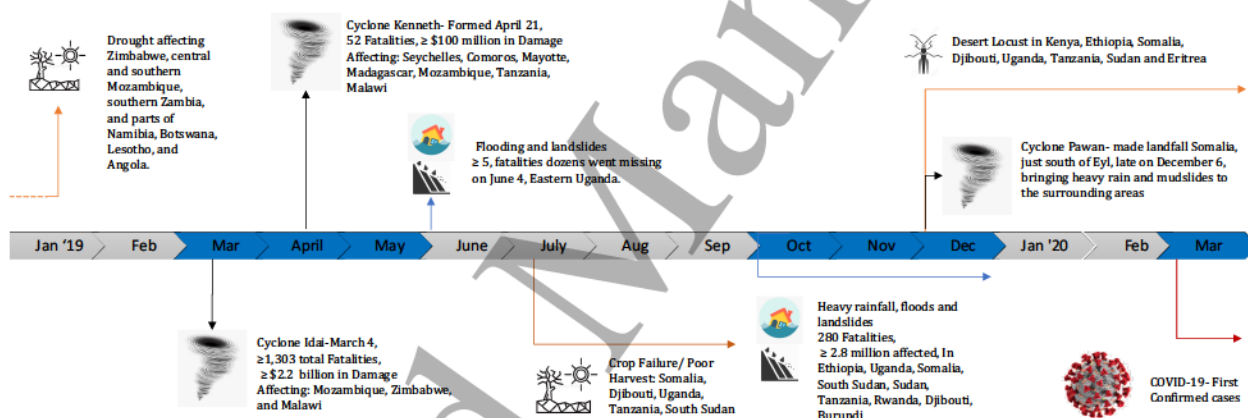


Figure 2: Concatenation of extreme events in East and Southern Africa in 2019

in Somalia on December 2, 2019, further improved locust breeding conditions fueling the worst invasion in 25 y for Somalia and Ethiopia and worst in 70 y for Kenya [8]. Good rains led to wet soils and vegetation conditions which were favorable for the increase of locust numbers through concentration, multiplication, and gregarization [9]. Despite being forecast, the current locust invasion could not be controlled because it originated in insecure areas that could not be accessed due to conflict. By February, the swarms had spread to ten countries in Eastern Africa, threatening food supplies for millions of people. The March to May rainy season is making things worse and according to the United Nations food and agricultural organization the current locust invasion represents an unprecedented threat to food security and livelihoods [10]. Eastern and Southern African countries impacted by floods, crop failure and landslides also represent some of the weakest health systems in the world and are now grappling with COVID-19 that could push more than 83 million people into undernourished, adding to an estimated 690 million worldwide [11].

Why Earth observations (EO)

In this context, the importance of Earth observations (EO)-based monitoring should be discussed.

Satellites and remote sensing technologies are powerful tools for capturing insights across expansive areas spanning countries and regions. Innovation and commercialization of the space sector along with the advent

of cloud computing and proliferation of very high resolution data have unlocked unprecedented amounts of high resolution data for every sector. This type of targeted information can provide critical and timely life-saving data and information to aid early warning of droughts [12, 13], crop failure [14, 15], pest such as locusts [9], immediate assessment of flooding and landslides [16], emergency operations [17] and adaptation planning.

However, the immediate focus of national and international agencies always encompasses rescue operations, which provide safe drinking water, shelter, and food, sometimes for many months after the event, such as in the case of Idai [1]. When the situation is improved, little importance (signaled by investments) is given to efforts to improve monitoring and early warning systems, which may have reduced the impacts through early warning and increased the response efficiency of targeted operations. First responders often operate with little to no information on the extent, severity, impact of events. Without coordinated response, sometimes they fall victim of the disaster. Moreover, the collected data if any and other relevant information or updates rarely reach the impacted communities, except in the case of the current COVID-19 pandemic. In many African countries the COVID-19 pandemic has led to strong public-private partnerships, companies are partnering with government to raise funds, deliver messages, provide personal protective equipment to frontline workers and support low income households through direct donations.

Today, the technology to predict, track, assess, and inform efforts to reduce potential catastrophic impacts of extreme events exists. The majority of the required satellite data at high temporal and spatial scales are freely available including cloud processing in Google Earth Engine and many developed and middle income countries have been taking advantage of these tools for decades and have policies in place backed by funding (e.g. The EU Space Policy). However, these policies and programs are largely missing and barely any investments are being made by national governments in SSA to build the capabilities and institutions needed to successfully use the information and data to help farmers or respond to disasters in an informed way. Dependence on international organizations' donations and expertise further complicates these issues as many solutions are rarely long lasting. It is not enough that international organizations develop the programs and/or bring the tools. As long as the integration is driven and funded externally on a project to project basis the change and impact will continue to be haphazard and never consistent or sustained. Many SSA countries do not yet have the full technical know-how and have not invested to participate independently in space-related activities [18]. Africa needs to grow scientists, engineers, researchers, data scientists, and related professionals who will actively contribute to finding solutions to continental problems [18]. The African Space Policy set goals in the effort to create coordinated and integrated space program, however there are immediate short-term investments at national level that can support huge leaps, fill data gaps, save lives and millions in response efforts. These investments are urgent, cost far less than satellite programs. But these need to be systematic to take advantage of current advances in EO. Therefore countries in SSA developing EO systems to support agriculture and food security should invest in the following actions:

- (i) developing and supporting the requisite human capital of African EO specialists to develop home grown solutions and leverage recent advancements and strategic support from international partners, through targeted training programs
- (ii) stronger partnerships between government and Universities with direct and clear funding streams to support research developing local solutions
- (iii) develop models, tools and the capacity to measure progress, impacts and to support design and implementation of appropriate mitigation, response and adaptation programs.
- (iv) consistent representative digital ground data through networks of observers to provide the data required to train EO-based systems. The machine learning community is hungry for data labels to develop and train models that are desperately needed for monitoring and measuring smallholder agriculture, but these can't be collected on a project to project basis.
- (v) clear mechanisms for data sharing to ensure mutual benefit. The lack of open and clear data sharing policies have largely impeded research and model development
- (vi) developing and implementing communication strategies for threat levels, with strong emphasis on reaching impacted communities
- (vii) permanent budget lines for early warning and assessment as well as sustained investment and sustenance of computing and internet infrastructure that are critical for rapid and timely assessments and early warning. This can be done by establishing centers at local universities

For years, the science community has predicted that Africa will be the most impacted by climate change [19]. The experience of 2019 presents a confirmation of this prediction and a warning for national governments in Africa to augment their national monitoring, information, and response systems. EO-based information will help them to prepare for and manage extreme weather events. Furthermore, it will help local authorities to better respond to disasters and farmers to better manage their crops, thereby reducing the devastating impact on their livelihoods. Systems need to be defined not only by establishing policies, but also by providing staff and equipment for sector specific monitoring centers. Identification and development of long-term strategies to address issues such as capacity gaps can be achieved by employing technical experts to establish the operations of such centers. The growth of National space programs will also depend on the openness and accessibility to data from national satellites which is largely missing [20].

While agencies like NASA and ESA are investing in applied research, capacity development and toward delivering last mile systems and products including NASA SERVIR (joint USAID/ NASA initiative), GMES and Africa, NASA Harvest, the promise of these programs stops at the capacity of the recipient institutions to take full advantage of the methods, data, tools and systems. Operational systems such as the Early Warning Explorer, The European Commission's Anomaly Hotspots of Agricultural Production System and the Global Agriculture Monitoring System represent just a fraction of the existing systems that are freely accessible and readily customizable EO products. These products can be readily integrated into workflows to support national monitoring and forecasting of agricultural activities, droughts, and rainfall informing disaster risk financing, crop insurance and agricultural development programs. However, to realize the full potential of satellite remote sensing has to offer, governments need to invest and build stronger partnership with local. university training programs to ensure new graduates can fill human resource gaps.

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Data Availability

The data that support the findings of this study are openly available at the following URLs GLAM, and EWX Next Generation Viewer

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