National Aeronautics and Space Administration

Drought tipping points for food security early warning

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Program: SURP

"Early warning triggers for drought tipping points are identifiable with remote sensing."

INTRODUCTION

PROJECT OBJECTIVES

1. Evaluate the accuracy of food security early warning systems.
2. Establish data requirements to enable detection of drought tipping points.
3. Identify and test tipping points by comparing them with recent events.

Drought remains one of the largest sources of uncertainty in food security early warning systems, accounting for two thirds of missed crises. Improvements in food security metrics and increasing availability of remote sensing offer an opportunity to improve famine early warning.

Multiple space assets on soil moisture **(SMAP)**, precipitation **(TRMM/GPM)**, snow cover **(MOD10)**, groundwater **(GRACE/ GRACE-FO)**, vegetation health **(MODIS)**, chlorophyll fluorescence **(OCO-2)** and evapotranspiration **(MODIS, ECOSTRESS)** have great potential for identifying subtle signals prior to a drought tipping point. We assess the abilities of these products to detect food tipping through five recent well-known food crises across Africa and Southeast Asia.

Fig 1 I Major droughts associated with the 2016 and 2017 El Niño/La Niña events: northeastern Kenya; Karamoja, Uganda; southern Zimbabwe; southern Mozambique; western Cambodia.

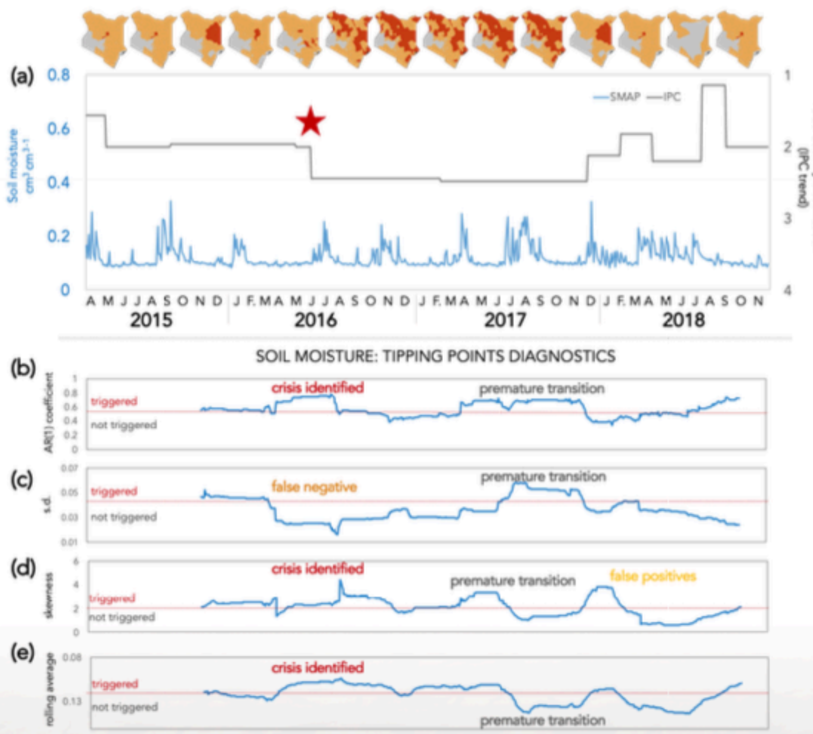

Fig 2 I Remote sensing products offer dense datasets and have great potential for identification of subtle tipping point signals
(a) The identified food insecurity tipping point occurred in June 2016 and lasted for 18 months. Over 1.3 million people were affected. Food security conditions improved in December 2017 and continued to improve until September 2018 when food security started to deteriorate again.
(b-e) Four tipping points diagnostic approaches used in the literature: increasing autocorrelation at lag-1, increasing variance, skewness and rolling averages/threshold exceedance. For these approaches, some signals are clearer than others in detecting food security transitions triggered by droughts. There is also a lag in detecting improving food security conditions due to the delay of soil moisture trends translating to food security outcomes.

CONCLUSIONS

Soil moisture measurements have thus far performed well in providing famine early warning signals, especially by combining autocorrelation and rolling averages. This offers an unprecedented opportunity to significantly improve efficiency of humanitarian early warning. The work conducted here has direct value to NASA's Applied Sciences Program focus areas on Disasters, which aims to improve prediction of natural disasters, and Water Resources, which encourages the use of remote sensing to improve analysis of drought.

METHODS & RESULTS

Across all case studies, the **rolling average** diagnostic (e) detects the transition towards a crisis and identifies and maintains the trigger for 12 months. There is a lag of six months between improvement in rolling averages and improvements in food security trends due to the lag between improving soil moisture and improving vegetation conditions for livestock grazing. Increasing autocorrelation (b) also detects the transition towards a food crisis and an early transition towards improvement in food security trends. Therefore, combining rolling averages with autocorrelation offers a strong signal for detecting food crises: when autocorrelation is high and the rolling average is low, a transition towards a food crisis is detected. When autocorrelation *and* rolling averages are both high, an improvement in food security conditions ensues.

Standard deviation (c) does not yield clear indications of a phase transition, whereas skewness (d) identifies a transition towards a crisis but with a lag of one month.

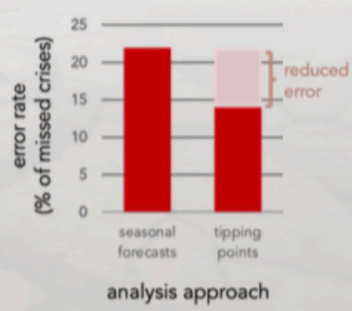

Fig 3 I By monitoring autocorrelation and rolling averages of soil moisture, the accuracy of predicting food crises increases by 36% compared to seasonal forecasts.

PUBLICATIONS RESULTING FROM THIS SURP/*This work constitutes the bulk of the doctoral dissertation
[1] Krishnamurthy, P.K., Fisher, J.B. and Kareiva, P.M. "Drought tipping points: Can remote sensing provide improved early warning drought signals for food security?" Submitted to: *Remote Sensing of the Environment.*
[2] Krishnamurthy, P.K. and Choularton, R.J. "Evaluation of famine early warning skill" In preparation for submission to: *Global Food Security.*
[3] Krishnamurthy, P.K. Fisher, J.B. and Kareiva, P.M. "On the brink: remote sensing indicators of food security tipping points" In preparation.

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