COVER PAGE

Food Security, Decision Making and the use of Remote Sensing in Famine Early Warning Systems

Abstract

Famine early warning systems use remote sensing in combination with socio-economic and household food economy analysis to provide timely and rigorous information on emerging food security crises. The Famine Early Warning Systems Network (FEWS NET) is the US Agency for International Development's decision support system in 20 African countries, as well as in Guatemala, Haiti and Afghanistan. FEWS NET provides early and actionable policy guidance for the US Government and its humanitarian aid partners. As we move into an era of climate change where weather hazards will become more frequent and severe, understanding how to provide quantitative and actionable scientific information for policy makers using biophysical data is critical for an appropriate and effective response.

1. Introduction

Remote sensing is the use of environmental sensors placed in orbit to observe the earth. The sensors provide a daily global assessment of ecosystem health and the impact of weather on the land. These observations have formed the foundation of early warning systems by providing quantitative assessments of variations in food production across large areas. Famine early warning systems use satellite remote sensing information in combination socio-economic and household food economy analysis to provide timely and rigorous vulnerability information identifying emerging food security problems. Food security is the ability of all people to access enough food to live an active and healthy life.

This article focuses on how remote sensing-derived information can be used in an early warning system to provide early, actionable and relevant information to decision makers charged with responding to food security emergencies. It will describe both the broad outlines of remote sensing data used to identify weather related declines in production as well as the way food security analysis is conducted so that an understanding of the impact of these declines on overall food security of a region can be determined. Early warning organizations seek to use scientific information and interdisciplinary analysis to directly inform policy and budget decisions that lead to an appropriate response to crises (Buchanan-Smith and Davies, 1995). As we move into an era with a rapidly transforming climate that will touch upon our lives in a myriad of ways, understanding how such organizations work in the face of complex weather and climate related disasters is an important first step to building systems that will respond to needs as they arise.

1.1 The Famine Early Warning Systems Network

The US Agency for International Development (USAID) designed the Famine Early Warning System (FEWS) in 1986 to provide information on the food security status of communities in semi-arid regions of the West African Sahel. Research conducted during and after famines in Africa in the 1970s and 1980s (von Braun et al., 1998) demonstrated that early and effective intervention could break the link between climate extremes and famine (Wisner et al., 2004). The development of remote sensing systems to monitor environmental conditions provided for the first time a way to monitor current climate variations over an entire continent for very little expense (Tucker, 1979). Before the advent of remote sensing systems, information on growing conditions was difficult to get and extremely localized, with large areas away from cities and roads left unmonitored. By combining a new understanding of the cascade of events that lead to famine (Watts, 1983) with remote sensing information for identifying and investigating widespread weather-related food production deficits, the foundation for effective early warning systems was in place.

Estimating the impact of climatic hazards is more challenging than simply analyzing the necessary physical evidence of an ongoing drought or the severity of a flood. There is large variation in the amount of climatic stress that vulnerable groups can endure before real and widespread destruction of livelihoods occur (Dilley, 2000). Although the physical characteristics of crop yield reductions due to rainfall deficits can be specified, determining the impact of this reduction in the place and time that it occurs is dependent on the context. For example, a 50%

reduction in millet production in Mali due to erratic rainfall that occurs after several years of good harvests is far less likely to result in sufficient food insecurity to warrant intervention than the same reduction after several years of below-average production. Just as important as the timing element is its spatial extent. Drought occurring in cropping areas has a different impact than those in pastoral lands, and the size of the area affected also can have a significant impact on food security. These complexities make interpreting climate data and linking it effectively to humanitarian intervention very challenging (Moseley, 2001). Thus FEWS NET has cultivated a broad cadre of experienced personnel, both social and physical scientists, internationally experienced experts as well as locally based personnel with experience in health, agriculture and nutrition to help it determine the food security situation in each country it works in (Table 1).

1.2 FEWS NET's Structure

The most visible parts of FEWS NET are its field offices and field representatives in roughly 31 countries, and a contractor in Washington D.C. office located near USAID that manages and technically directs them. The contractor is responsible for integrating FEWS NET's global early warning information, resources and training activities, in the field and in Washington D.C., and delivering finished products to information-gathering and decision-making processes of USAID (in Washington and the field), as well as to a broad range of international partners. At the time of this writing, these offices are in the following locations (Figure 1):

- Africa: Regional offices in Niger, Kenya, and South Africa. National offices in Senegal, Mauritania, Mali, Burkina Faso, Niger, Chad, Northern Sudan (located in Khartoum), Southern Sudan (located in Nairobi), Eritrea, Ethiopia, Somalia (located in Nairobi), Kenya, Uganda, Angola, Tanzania, Rwanda, Malawi, Mozambique, Zambia, Zimbabwe, and South Africa (for coverage of Lesotho, Swaziland and Botswana).
- Central America: Guatemala
- Caribbean: Haiti
- Central Asia: Afghanistan

FEWS NET is composed primarily of local experts who work with specialists in the United States who coordinate their reporting. The field offices produce most of the reports, but the US contractor manages and coordinates all reports so that a similar message is conveyed to decision makers (Figure 2). The organization estimates local food availability, access, and utilization with a wide variety of datasets, including remote sensing data, ground measurements of food production measuring "supply", and a wide range of other indicators meant to measure "demand" (the ability of a population to purchase food) in concert with political and economic pressures that may affect a region's food security (Brown, 2008b). Although FEWS NET's early and actionable information can motivate intervention to break the link between climate extremes and famine (Davies et al., 1991, Wisner et al., 2004), it does not respond itself.

FEWS NET works to create coalitions through finding groups at the local, regional and international level with common interests, and form alliances to strengthen their combined ability to push for the desired outcomes. The coalition should include countries' international aid agencies (bilateral aid) such as US Agency for International Development, UK Department for International Development, EuropeAid, and the European Commission's Directorate General for Humanitarian Aid (ECHO), multilateral institutions such as the World Bank and African Development Bank, and development charities such as Oxfam, Save the Children and Care. All of these players have influence in the decision process to provide humanitarian assistance, however none have the resources to go it alone. They must find a way to work together through collaboration and coalitions to obtain their goals. FEWS NET provides data and analysis which form the basis for understanding the nature and severity of the problem, and thus increase the likelihood that an appropriate and timely response arrives in the region at risk when it is needed . Remote sensing plays a key role, as it is often the earliest indicator that there may be a problem, and is usually the least controversial, providing a focus point for negotiations and discussions among the many parties who must come to an agreement before a response can occur.

1.3 FEWS NET's Conceptual Frameworks

Famine early warning systems are implemented by organizations that use social and political information about the ways people gain access to food, combined with spatially extensive biophysical information to determine the onset of severe food insecurity. In order to create policy-relevant information, FEWS NET must know how events will affect food security. Perturbations in the climate or rainfall are only one of many factors that are important. Figure 3 shows a summary of studies in household food security in southern Africa, where climate/environment was just one of 33 drivers of food insecurity mentioned as important by householders (Cooper et al., 2004, Gregory et al., 2005). The impact of sudden drought, for example, is felt on top of ongoing long-term stresses and the inability to cope with such shocks and to mitigate long-term stresses means that the coping strategies, such as short-term employment, may not be available, and thus the impact for one household may be far greater than another. FEWS NET needs to know and understand about the entire complex picture as well as all the potential shocks to the system in order to provide accurate and useful information about how to intervene.

Regardless of its cause, famine is a slow-fuse disaster, a social catastrophe that takes many months or years to develop, the consequence of multiple failures on many levels before famine takes hold (von Braun et al., 1998). Early warning of this process should, therefore, be straightforward, but because there is little agreement on exactly how to measure changing food systems, and because famines can occur not only when there is no food but when food is plentiful, it is not.

If it takes such a long time to occur, then why are early warning systems needed? Early warning of such a slow, multi-year process involves two aspects: first an adequate capability to detect and document a crisis, and advance preparation by international, national and local organizations for an effective response to an identified crisis. The role of early warning systems is to identify and allow governments the time and information needed to deter these crises from occurring, preventing the destruction of the lives and livelihoods of countless people as well as the social and economic systems on which they depend. Thus, effective early warning revolves around prior agreement as to what constitutes a crisis, and what responses will occur when such crises occur. These responses tend to be very expensive, both economically and politically, and they will not occur if there is not consensus on what needs to happen. Alternatively, if no response occurs, that can also be extremely expensive in the long run. Agreement on what is a proper response and how quickly a response should occur is difficult to achieve, especially given the diversity of local, national, and international actors involved. Famine early warning systems provide the forum both for agreement on the signs of an impending crisis, and the platform for mobilizing the preparation for response on multiple levels (Buchanan-Smith, 2000).

When the U.S. government responds to disaster internationally, the primary institution for managing humanitarian assistance is the U.S. Agency for International Development (USAID). Provision of this assistance is a core activity of USAID and is recognized as a strategic goal (USAID, 2007). For prevention and mitigation of disasters, USAID specifically cites the Famine Early Warning System Network (FEWS NET) as the prime example of how it is achieving this strategic priority. USAID clearly values the role this early warning system plays in reducing risk of famine, hunger and food insecurity, and, ultimately, in reducing the human and financial toll of famine.

FEWS NET is only a small part of the overall larger geo-political system that has grown up around food aid, humanitarian programs and overseas development aid. Many who are familiar with USAID's programs believe that food aid is used too often and in too many places where it cannot ameliorate the long-term problems (Murphy and McAfee, 2005). FEWS NET works to ensure that decisions regarding food aid are made with the most accurate information possible about the impact of both action and inaction is available to the decision maker. That said, there is much that can be improved in the larger food aid system and with development assistance in general. Improved information for decision making through direct intervention in the negotiation process that surrounds each disaster is the focus of FEWS NET (Choularton, 2007).

1.3 FEWS NET and Remote Sensing

FEWS NET's personnel are predominantly social scientists, trained in the humanitarian response field, nutrition, anthropology, economics and other social sciences. They are deeply committed to improving the response to international food security crises. They are not, however, experts in remote sensing. Using satellite-derived remote sensing information to inform social science discourses requires an intense interaction between the physical scientists who develop and present the data and the social scientists who use it in their work.

To assist in the integration of geographic information and remote sensing information into standard products and monitoring, FEWS NET has funded four regional representatives through USGS who have expertise in geographic information systems and remote sensing and who can provide assistance in making accurate and effective maps, download and manipulate data and to provide training on new products for FEWS NET technical personnel. There are four USGS Regional Scientists placed in FEWS NET regional offices in the Sahel, Greater Horn of Africa, Southern Africa, and Central America. They provide technical assistance in the use of operational remote sensing products for food security analysis. These Regional Scientists play a very important role in the development of new tools and in understanding the problems and challenges of the FEWS NET representatives in the field in using remote sensing data.

FEWS NET has several key technical US Government partners that assist with providing, using and understanding biophysical data needed to evaluate growing conditions throughout the year. Partners in FEWS NET with USAID include the US Geological Survey (USGS), the National Aeronautics and Space Administration (NASA), and the National Oceanic and Atmospheric Administration (NOAA). NASA and NOAA collect and process satellite data that are used to monitor the vegetation condition (Normalized Difference Vegetation Index, or NDVI) and rainfall (Rain Fall Estimate, or RFE) across the entire African continent. The NDVI and RFE data are but two of the wide variety of tools used by FEWS NET to monitor agricultural conditions in Africa.

The four inter-agency agreements with the US Government agencies support FEWS NET's work:

- The Climate Prediction Center (CPC) at NOAA provides technical support in meteorology and climatology using satellite rainfall estimation products for

Africa, Central America and the Caribbean, and Central Asia.

- The International Programs office at the USGS EROS provides assistance in developing operational early warning applications and products that use satellite and remote sensing data. USGS also maintains the FEWS NET archive of tabular, vector, and raster datasets and make them available via the web.
- The GIMMS group at NASA Goddard Space Flight Center provides satellite-derived vegetation data products, particularly the Normalized Difference Vegetation Index imagery (NDVI), for early warning activities, as well as conducting research on ways to improve remote sensing estimates.
- The USDA provides FEWS NET with technically-qualified management personnel, as well as access to USDA expertise on agriculture, markets, early warning, and crop estimation. USDA conducts tours that estimate the accuracy of crop models and agriculture production statistics that FEWS NET often participates in.

2 Remote Sensing to Identify Food Production Deficits

FEWS NET has used remote sensing derived indices and information to estimate interannual variations in food production since its founding in 1986. Although the remote sensing data that FEWS NET uses are still too coarse to determine how a particular individual or community's fields are doing, it provides an overview of how the growing season is progressing over a region. FEWS NET currently uses a merged satellite-gauge product for its primary source of information on rainfall in the countries where it works. The product currently being used by FEWS NET is the Rainfall Estimate (RFE) 2.0, which uses several techniques to estimate precipitation while also using traditional cloud top temperature and station rainfall data. The RFE data is particularly useful for FEWS NET because it uses the WMO Global Telecommunication System (GTS) rainfall observation data taken from ~1000 stations which are assumed to be the true daily rainfall near each station for each day. Using these observations in the rainfall model produces a dataset which is far closer to the observed rainfall in all locations where observations are taken.

Vegetation estimates, although available at a higher spatial resolution, do not allow specific estimation of crop yields, as the information from crops, fallow vegetation and trees are combined together into a single observation. However, by comparing a given period of the current year with those from previous years when conditions were known, or with the mean of all previous years, a reasonably reliable estimate of the productivity of the growing season and ultimate yield can be developed. Spectral vegetation indices are usually composed of red and near-infrared radiances or reflectances (Tucker, 1979), and are one of the most widely used remote sensing measurements (Cracknell, 2001). They are highly correlated with the photosynthetically active biomass, chlorophyll abundance, and energy absorption by plants (reviewed in (Myneni et al., 1995)).

Data from the Advanced Very High Resolution Radiometer (AVHRR) sensor is available at coarse resolution (8 km) resolution (Figure 4) every 15 days since 1981 July, the longest record available to analysts interested in agricultural dynamics

(Tucker et al., 2005). By comparing the data from the current period to the average of the same period from the previous 25 years, a robust estimate of how the current season is doing compared to previous can be made. Figure 4 shows green areas where the June-August growing season in West Africa was above average and brown areas with below-average vegetation density. These anomalies have been shown to be related to variations in overall cereal production (Funk and Budde, 2008).

The Moderate Resolution Imaging Spectroradiometer (MODIS) and the European SPOT-4 Vegetation sensors are the two datasets most frequently used by FEWS NET for monitoring at higher resolutions than is possible with the AVHRR sensor (Huete et al., 2002). Moderate spatial resolution (250m to 1 km) and weekly (8, 10, and 16 day) time intervals from the MODIS (Figure 5) and SPOT Vegetation (VGT) sensors have demonstrated their utility in characterizing the structure, metabolism, and functioning of ecosystems (Huete et al., 2006, Maisongrande et al., 2004). FEWS NET uses primarily vegetation data from the AVHRR, MODIS and SPOT Vegetation data because they are global and have daily or twice-a-day coverage (Brown and De Beurs, 2008). Thus, using satellite remote sensing FEWS NET can determine if the cropping season in an area will be better or worse than last year or from the average (Hutchinson, 1998).

Table 2 provides a list the extensive number and type of data used by FEWS NET to summarize the current climatic situation. The data include precipitation gauges and gridded data from merged satellite models, vegetation data from a variety of sensors, gridded cloudiness products, global climate indicators, precipitation forecasts, modeled soil moisture, gridded fire products, snow extent products, hydrological models for flood forecasting, and seasonal forecasts. These data products were either developed directly by FEWS NET partners for FEWS NET or were adapted to their needs.

The table illustrates how gridded rainfall images produced every ten days have been used to drive a large number of models from a variety of disciplines, including agronomic models specifying the moisture requirements of a particular crop given an underlying soil type (Water Requirement Satisfaction Index or WRSI (Verdin and Klaver, 2002)) and the flooding potential given the soil water holding capacity and the amount of water that has fallen on a given catchment basin (Basin Excess Rainfall Model or BERM) (Senay et al., 2007), among many others. Models allow social scientists to ask questions regarding the direct effect of a particular rainfall deficit on the crop production instead of having to infer from rainfall or vegetation imagery the resulting impact.

Despite the rapid improvement of rainfall data's accuracy and resolution, vegetation Index data derived from satellites remains an important source of information for the FEWS NET program (Brown et al., 2006). Although rainfall has been used extensively to drive many other models, it can be less reliable in regions with few gauge measurements with which to calibrate the data. Rainfall data can be prone to errors in approximating the degree of cloudiness, the amount of rain that has fallen from these clouds or the intensity of the rainfall, inadequate capturing of orographic rainfall, and other effects which result in significant random error and non-negligible bias (Waymire, 1985, Xie and Arkin, 1997). Vegetation remote sensing measures directly the stable photosynthetic activity resulting from rainfall and is thus can be more precise (Tucker et al., 1991, Tucker et al., 2005). Because they measure very different things, both variables continue to be of value to hazard monitoring (Brown et al., 2007).

3. Example from Afghanistan of How Remote Sensing provides Early Warning of Food Insecurity

Hunger remains a significant problem in Afghanistan. Nearly 40% of the rural population cannot count on having sufficient food to satisfy their most basic needs. The Afghan diet, consisting mostly of grains, has little variety, creating a serious problem of malnutrition. The remote sensing tools used by FEWS NET in its ongoing responsibility to monitor and report on the food security situation in the country are unique for Afghanistan, since the agrometeorology in the region is completely different than in Africa or Central America, the other regions where it works. New operational monitoring products developed include data on temperature extremes, wind, accumulated rainfall in both liquid and snow form, crop models for pastoral, rain fed and irrigated crops, and the formation and melting of the annual snow pack, which provides the majority of the irrigation water for communities in the north.

Food security terminology emerged in Afghanistan in the late 1990s and is still evolving. A comprehensive national framework for understanding food security that includes multiple indicators does not exist. Nonetheless, two indicators have been used for assessing food insecurity in Afghanistan: 1) food consumption, and 2) dietary diversity. Food consumption looks at the quantity of food eaten over a seven day period, while dietary diversity measures the quality of food eaten over a seven day period. Generally, people tend to know what they eat instead how much they eat. Therefore, FEWS NET Afghanistan chose to use the dietary diversity indicator in its analysis. The most recent dietary diversity data from the vulnerability assessment conducted in 2005 showed that 24% of the Afghan population has very poor diversity in their food consumption, including 15% of urban, 25.8% of rural, and 38.3% of nomad populations (Figure 6).

Stunting, which primarily results from lack of access to food over a long period of time, is at a very high level in Afghanistan: 2004 nutrition data indicate more than half (54 percent) of preschool age Afghan children are stunted and 36 percent underweight. Thus FEWS NET refers to food insecurity in Afghanistan as chronic, not transitory (Smith and Haddad, 2000). Despite, or perhaps because of, the long term nature of the problem in Afghanistan, understanding and rapidly responding to variations in food production due to the weather is critical to alleviating crises. Addressing the long term vulnerability of the population will require development and stability which are beyond the scope and mandate of FEWS NET. Remote sensing data provides information which otherwise would be difficult to get in a timely manner due to the ongoing hostilities in the country and fragmented nature of governance.

Unlike regions in the tropics, Afghanistan has its wet season in the winter. Snow accumulates to become a primary source of water for agriculture during the summer (Figure 7). To measure how much water will be available for growing crops with irrigation water, FEWS NET monitors the rate of snow accumulation and during the spring, rate of melting. A new index from MODIS is used to estimate snow cover extent (Figure 8) is coupled with the Air Force Snow Water model that enables an estimation of the amount of water that is present in the snow pack. The (daily) snow water equivalent maps show the spatial distribution of the modeled water content of the snowpack and the spatial distribution of snow cover extent, and provide an indication of relative snow depth and water available for irrigation when the snow melts. Five years means were calculated for each day of the year based on data from the years 2003 to 2007 (USGS, 2008).

Daily snow maps are used to calculate snow cover depletion curves, which relate the percent of a basin or zone that is covered by snow to elapsed time during the snow melt season. The depletion curves help provide an indication of the temporal and spatial extent of seasonal snow pack available for irrigation. A steep decrease in snow-covered area can be indicative of either shallow snow pack or high melt rates. On the other hand, a slow decrease results from either a deep snow cover or slow melt rates, most likely due to low temperatures. Plotting snow cover versus degree days can help reduce this ambiguity, however these depletion curves measure the maximum extent of snow cover as a function of time without regard to air temperature (Figure 9). Also note that in these curves, current information is combined with forecasts for the next 6 days.

According to climatic records, precipitation in Afghanistan has declined for forty years. Annual precipitation averaged about 14 inches (350 mm) in Kabul in the 1960s. In the 1990s the average annual precipitation in Kabul was about 10 inches (250 mm). The resulting droughts and years of insufficient rainfall and snow runoff in Afghanistan have become more frequent. Small declines in precipitation and irrigation water reduce coping capacity for poor farmers who are already vulnerable due to social, political and economic upheaval due to conflict. In a country in which 85 percent of the people depend upon agriculture for at least part of their livelihood, knowing the availability of water is crucial to estimating how much assistance may be needed.

FEWS NET combines analysis of potential agricultural production variations derived from remote sensing with timing, food prices and demand in order to create a comprehensive analysis of the vulnerability to food insecurity and the need for response by decision makers. Food access in Afghanistan is more constrained than normal in 2008 for households that rely on the market due to the prevailing above average food prices. Wheat flour retail prices continue to rise, particularly in southern markets where Pakistan is the primary source of flour supplies because Pakistan has imposed restrictions on flour exportation. Additional pressure on flour prices is due to the increase in the international price of wheat during 2007 and 2008, which is the result of a number of factors, including agroclimatic conditions (drought) in key producing areas of Australia and Argentina, substitution in production from wheat to maize for biofuel processing in the United States, and increased grain and beef consumption in populous countries such as China and India as a result of high economic growth and increasing incomes per capita.

Snowfall during the 2007/08 wet season was below normal, which significantly reduced the availability of irrigation water for pre-winter cultivation in September and October of 2008. The deficits will also cause irrigation water scarcities for spring planting in March and April, reducing prospects for the main 2008 harvest that begins in May. Rainfall from February through April is critical for rainfed crops, which are primarily grown in the north.

A comparative analysis of 2000-2008 Normalized Difference Vegetation Index imagery indicates that the 2008 drought has been the most severe during 2008. Coupled with chronic food insecurity, high food prices and escalating civil insecurity in southern Afghanistan, this drought has led to widespread food insecurity affecting 35 percent of the Afghan population. In July, the Afghan government and the United Nations jointly appealed for $404.3 million in emergency aid. This appeal level was developed through an analysis conducted at FEWS NET which included this NDVI analysis. Thus remote sensing will continue to be at the forefront of analysis and monitoring of food security situation in Afghanistan.

4. Hazard Monitoring and Food Security Outcomes

Although remote sensing data is an extremely important resource for FEWS NET, it is a challenge to keep the focus on the food security outcome of the hazard that the data identifies, not on the hazard itself. FEWS NET uses a food economy approach and livelihoods analysis that identifies specific causes of a food security crisis for a particular group of people. Because evidence from remote sensing data is so compelling and has been used in some of the regions where FEWS NET works for several decades, it is much easier to focus on the easy to understand hazard and not on the complex and multi-dimensional consequences of the hazard. Thus the challenge for FEWS NET is to maintain its focus on the diverse and complex local situation while at the same time providing compelling evidence for action for decision makers.

Another challenge for FEWS NET is the difficulty of finding the resources, time and managerial focus it takes to maintain databases of all the geographic information required to conduct food security analysis. Everything from properly aligned GIS layers of administrative regions and livelihood zones to databases of historical livestock prices and local rain gauge datasets require management and maintenance. Although USAID does invest in some of this work, much of it is done informally and without explicit funding in the current task structure. Thus FEWS NET needs to reduce the number of steps it takes from data creation to data storage in order to be able to do more with fewer resources. Long term funding remains the primary obstacle, however, to ensure that archiving of currently existing datasets is done in a way to facilitate their integration into modern georeferenced web servers that can distribute the data to all who need it. Expansion of data sources and continual investment in ensuring that livelihood baselines, for example, are current is also required. Adequate funding of the FEWS NET activity would ensure that these tasks are not marginalized in the face of current demands on resources.

Remote sensing continues to be an important part of the work that FEWS NET does. It provides information that becomes the basis for coalition building during negotiations for humanitarian assistance. By finding groups with common interests, and then forming alliances to strengthen their combined ability to push for the desired outcomes, FEWS NET ensures a proper response to food security crises when they occur. FEWS NET's information gathering must provide the data needed to provide early warning of an impending crisis, and to advise local, national and international governments and organizations on programs to reduce the likelihood that a crisis may occur at all. By arming key participants in negotiations with clear, actionable evidence of need based both on sound analyses of problems of access to food as well as food availablilty, improved response can be ensured.

Captions

Fig. 1. FEWS NET country locations and levels of services, as of 2007.

Fig. 2. Six examples of FEWS NET reports available monthly or quarterly for decision makers at the local, nationa, regional and international levels.

Fig. 3. The seven most frequently cited drivers in 49 studies of household-level food insecurity in southern Africa, derived from 555 citations of 33 possible drivers. The drivers shaded in grey were noted as being chronic, while those in white indicate drivers that were experienced as 'shocks'. The shaded arrows indicate drivers that acted primarily via reductions in food production, while the white arrows indicate those which acted by restricting access to food. Derived from (Cooper et al., 2004, Gregory et al., 2005).

Fig 4. AVHRR data for Africa, anomaly for September 2008.

Fig. 5. MODIS vegetation and anomaly data

Fig. 6. Estimate percent of the population who are food insecure in Afghanistan from the National Risk and Vulnerability Assessment 2005, conducted by Government and Stakeholders from July-September 2005.

Fig 7. Seasonal calendar and critical events timeline

Fig. 8. MODIS snow cover extent difference from previous period for March 11-21, 2008, Afghanistan based on MODIS 8-day normalized difference snow index.

Fig. 9. Snow water accumulation/depletion curves for an individual basin.

Table 1. Use of remote sensing-based data by people in different communities, at different scales (from R. Choularton, FEWS NET web site).

Table 2. List of all remote sensing and socio-economic datasets used by FEWS NET

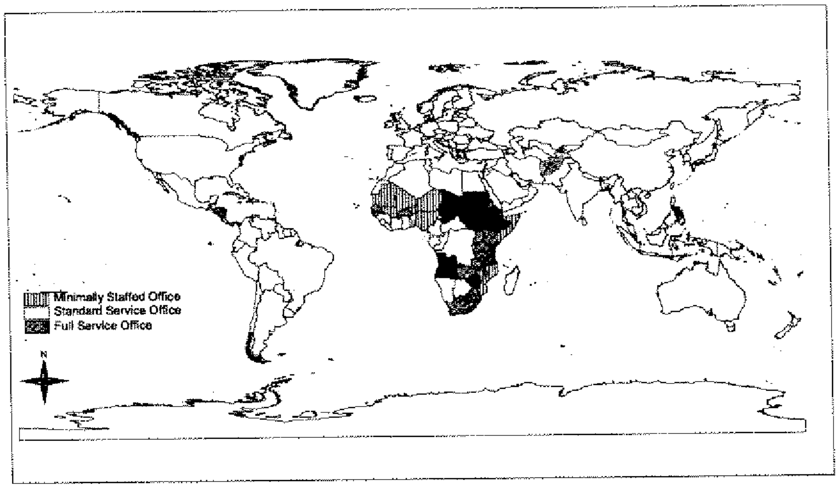
Minimally Staffed Office
Standard Service Office
Full Service Office
N

Figure 1.

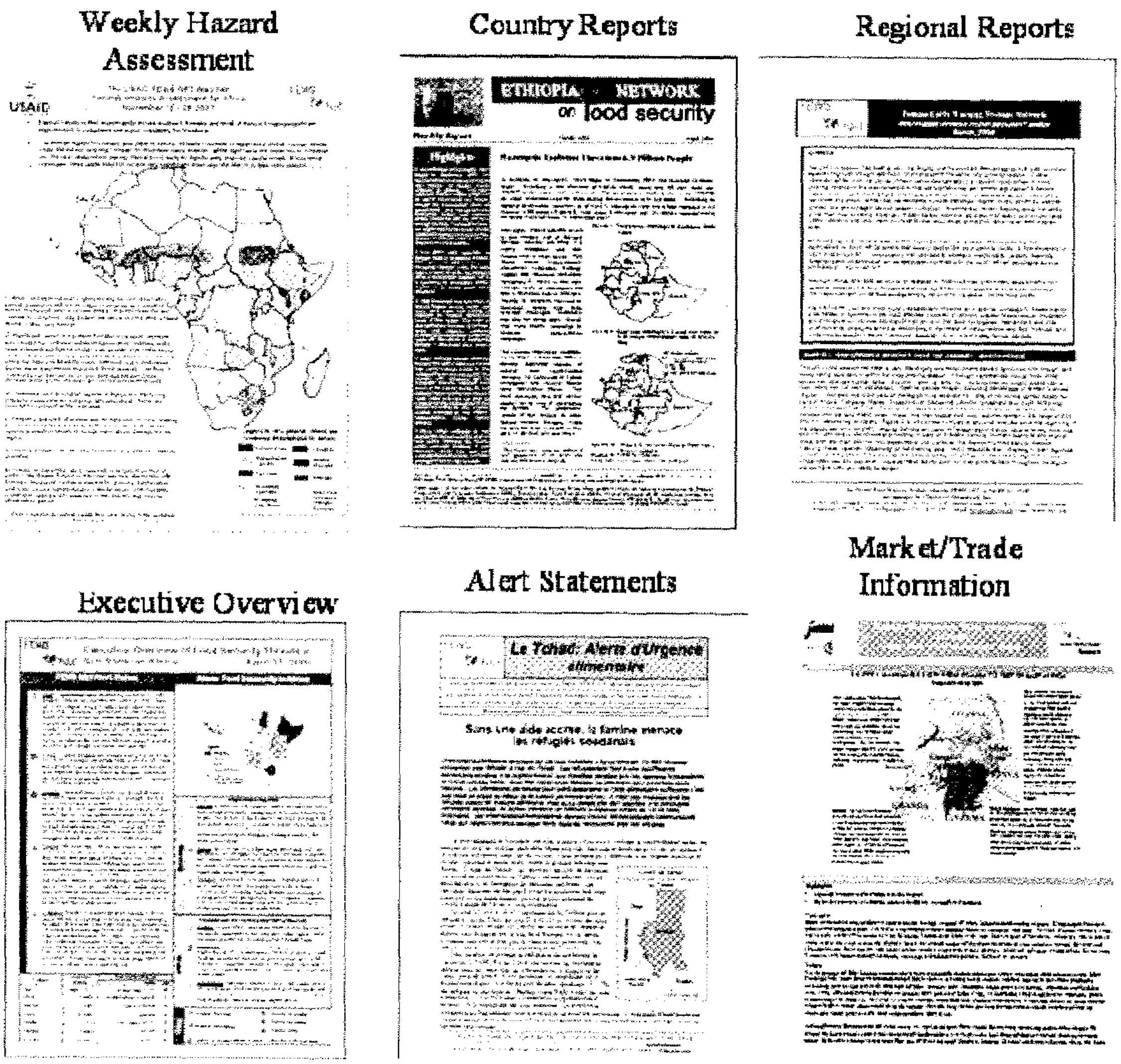
Weekly Hazard Assessment
Country Reports
Regional Reports
Executive Overview
Alert Statements
Market/Trade Information
USAID
ETHIOPIA NETWORK on food security
Le Tchad: Alerte d'Urgence alimentaire

Figure 2.

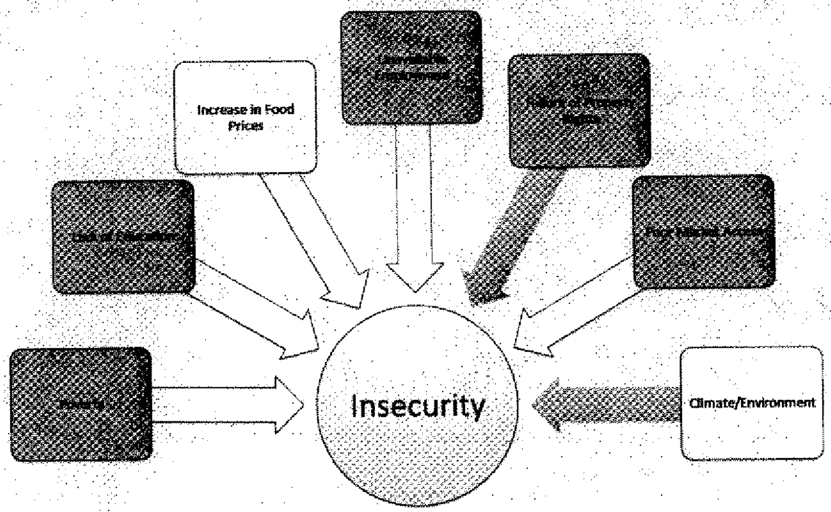

Figure 3.

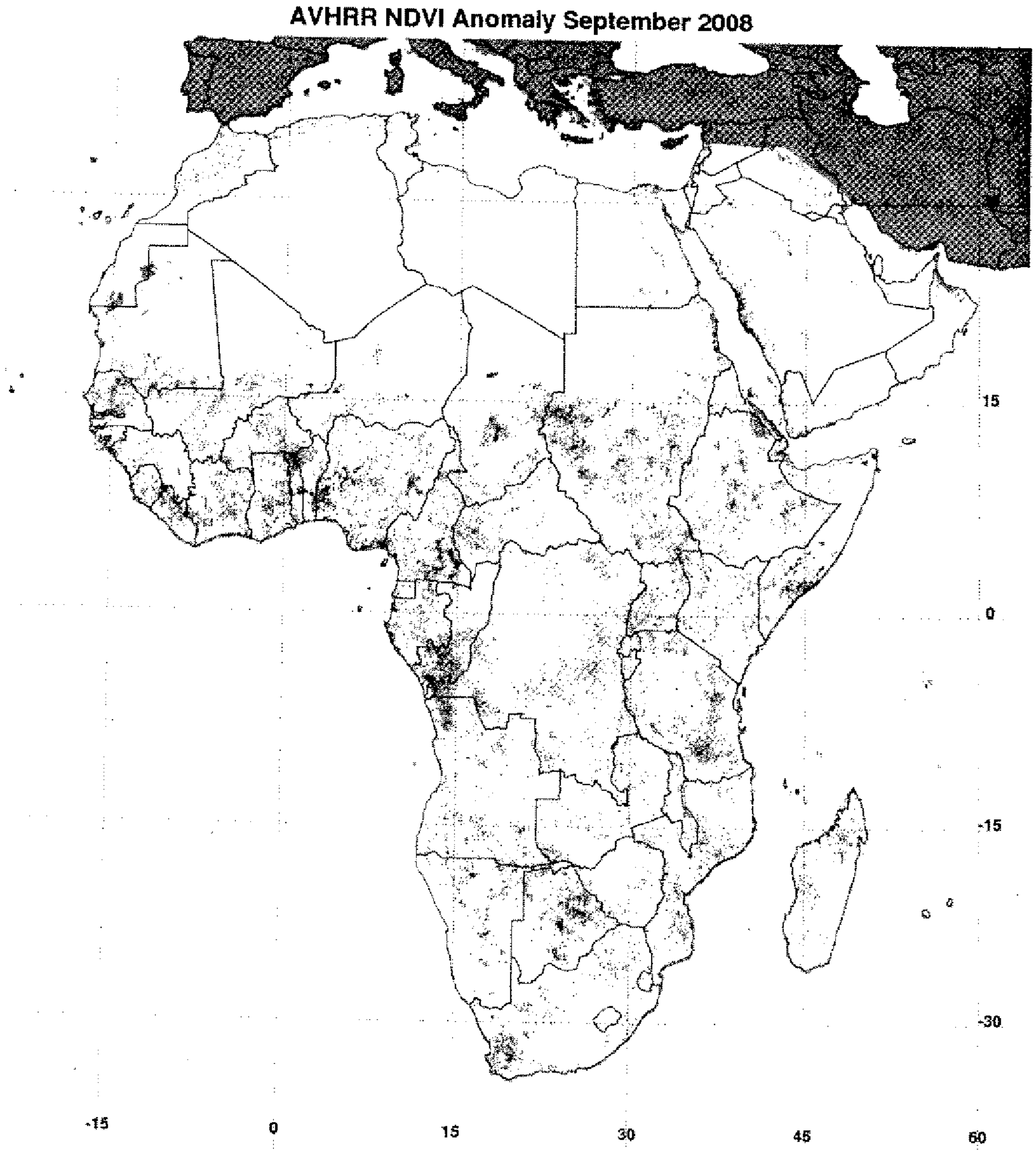

Figure 4.

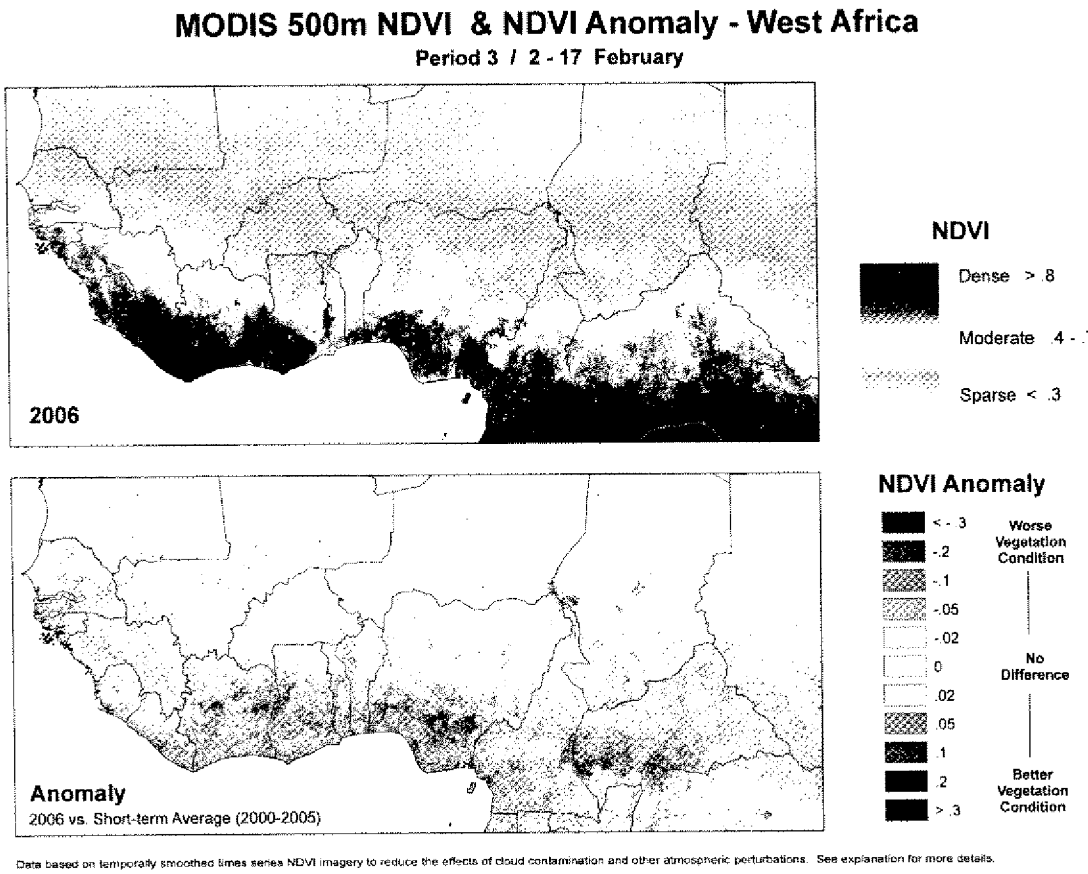
MODIS 500m NDVI & NDVI Anomaly - West Africa
Period 3 / 2 - 17 February
2006
NDVI
Dense > .8
Moderate .4 - .7
Sparse < .3
Anomaly
2006 vs. Short-term Average (2000-2005)
NDVI Anomaly
< -.3
-.2
-.1
-.05
-.02
0
.02
.05
.1
.2
> .3
Worse Vegetation Condition
No Difference
Better Vegetation Condition
Data based on temporally smoothed times series NDVI imagery to reduce the effects of cloud contamination and other atmospheric perturbations. See explanation for more details.

Figure 5.

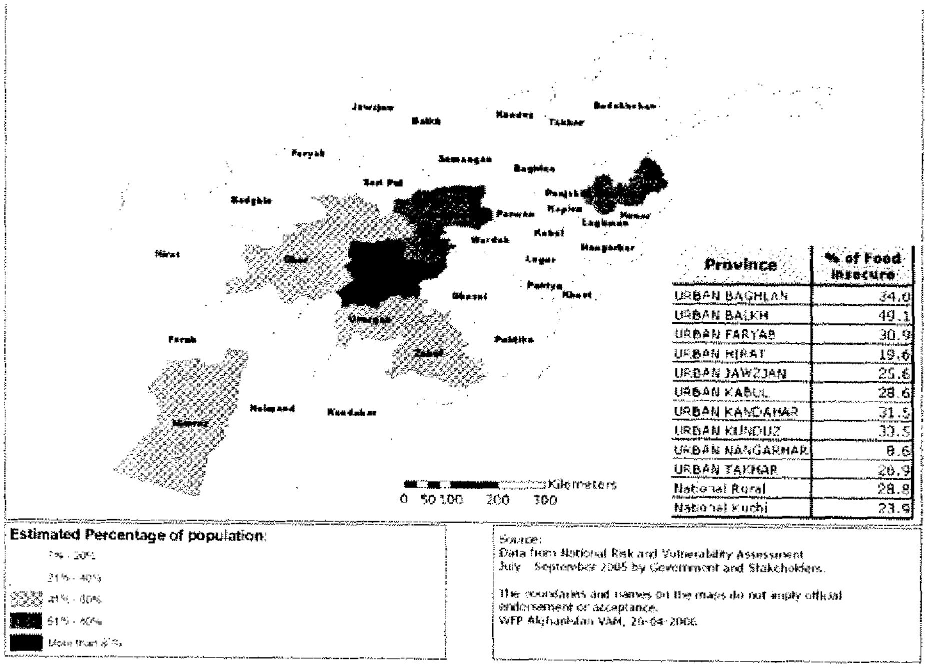

Figure 6.

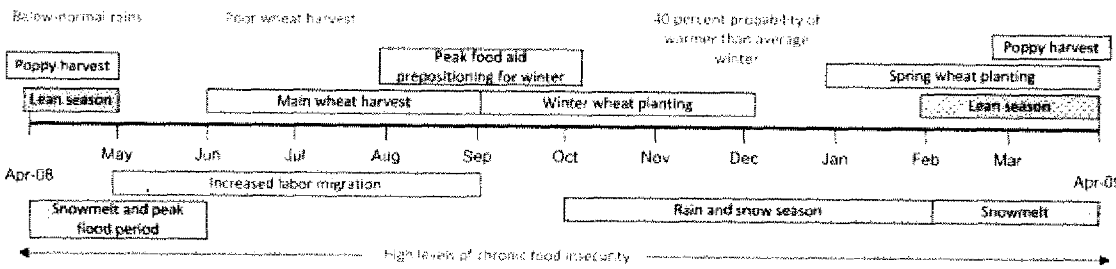

Figure 7

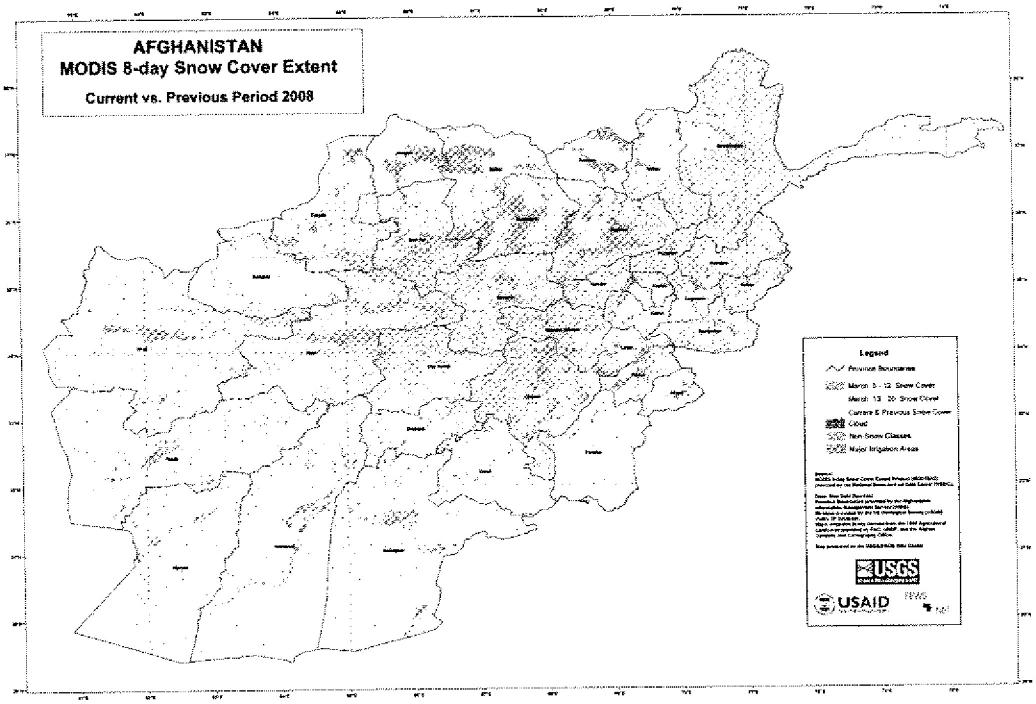
AFGHANISTAN
MODIS 8-day Snow Cover Extent
Current vs. Previous Period 2008
Legend
Province Boundaries
March 5 - 12 Snow Cover
Current & Previous Snow Cover
Cloud
Non Snow Classes
Major Irrigation Areas
USGS
USAID

Figure 8.

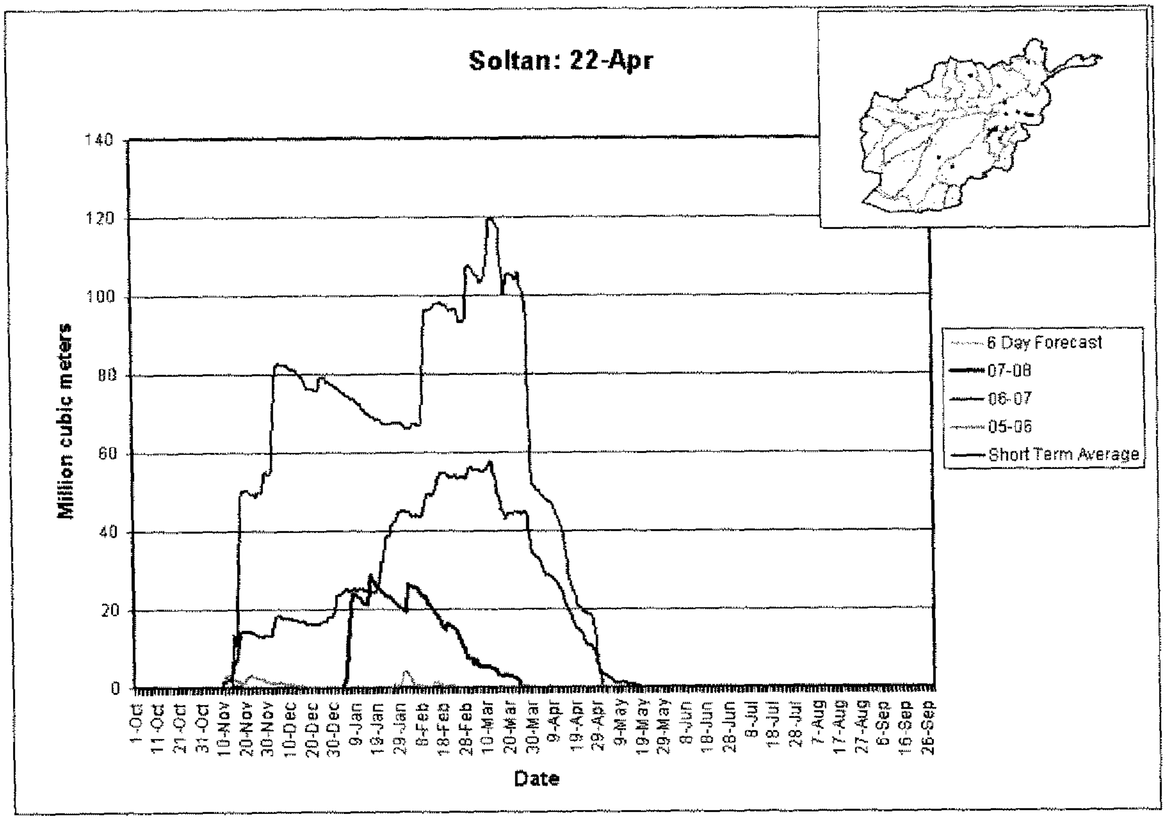
Soltan: 22-Apr
Million cubic meters
0
20
40
60
80
100
120
140
1-Oct
11-Oct
21-Oct
31-Oct
10-Nov
20-Nov
30-Nov
10-Dec
20-Dec
30-Dec
9-Jan
19-Jan
29-Jan
8-Feb
18-Feb
28-Feb
10-Mar
20-Mar
30-Mar
9-Apr
19-Apr
29-Apr
9-May
19-May
29-May
8-Jun
18-Jun
28-Jun
8-Jul
18-Jul
28-Jul
7-Aug
17-Aug
27-Aug
6-Sep
16-Sep
26-Sep
Date
6 Day Forecast
07-08
06-07
05-06
Short Term Average

Figure 9.

Table 1.

	Local	National	Regional	International
Community	Individuals with access			
Civil Society	Local NGOs	National NGOs	Regional NGOs	International NGOS (Save the Children, Oxfam)
Government or intra-governmental	Municipal or departmental government	Ministry of Agriculture, Health Parliament	ECOWAS SADC African Union	United Nations General Assembly
Private Sector	Local shop owner or trader	National Companies	Regional Companies	Transnational Corporations
International organizations			CILSS	FAO WFP
Donors		National Government Private sector	African Development Bank	USAID DFID EU

Table 2. Current FEWS NET data products and descriptions.

Category	Type	Product	Description	Spatial Extent	Spatial Resolution	Time Step	Source (see acronym list for definitions)
Biophysical Monitoring	Precipitation	RFE - Rainfall Estimate	multi-sensor and gauge merged model	Africa, SE Asia, SW Asia	0.1 deg	daily	NOAA CPC
		Unbiased RFE	RFE with post processing unbiasing procedure that tunes imagery to historical rainfall	Africa	0.1 deg	Daily	USGS
		TRMM - Tropical Rainfall Monitoring Mission 3b42RT	multi-sensor and gauge merged model	global	0.25 deg	daily	NASA GSFC
		GTS Station Data - Global Telecommunication System	station data, daily	global	point	daily	United Nations (WMO)
		CMORPH - NOAA CPC Morphing Technique	multi-sensor and guage merged model (NO gauge data in CMORPH)	global	0.1, 0.25 deg	daily	NOAA CPC
		Projected Rainfall	1-3 month predicted rainfall data	Africa	0.1 deg	Daily	USGS, UCSB
	Derived Precipitation Products	SPI - Standardized Precipitation Index	18-yr mean standardized anomaly (30-yr mean for Africa SPI, not familiar with the SW Asia product)	Africa, SW Asia	0.1 deg	10 day, 1, 2, 3, 6 and 12 mon	UCSB, USGS
		SOS - Start of Season	determines beginning of growing season	Regional (Africa, C.America, Haiti)	0.1 deg	daily, seasonal	USGS
		ITCZ – Inter-Tropical Convergence Zone	estimates onset of rains appro. week before	Regional (Africa)	vector coverage	daily, seasonal	NOAA CPC
		WRSI - water requirement satisfaction index	estimates crop yields by crop type	Africa, SW Asia, C.America, Haiti	0.1 deg	daily, seasonal	USGS
		Rangeland WRSI	estimates rangeland grass condition	Africa,	0.1 deg	10-day, seasonal	USGS

Table 2. Current FEWS NET data products and descriptions.

Category	Type	Product	Description	Spatial Extent	Spatial Resolution	Time Step	Source (see acronym list for definitions)
	Clouds	OLR - Outgoing long wave radiation	precipitation proxy	global	8km	hourly	NOAA CIRES Climate Diagnostics Center
		IR - Infrared Temperature	precipitation proxy	global	25 km	hourly	NASA GSFC Global Change Master Directory
		Water Vapor - MODIS	precipitation proxy	global	1 km	daily	NASA GSFC
Biophysical Monitoring	Global Climate Indicators	MJO IR - Madden Julian Oscillation/ 200 h/PA velocity potential	upper level convergence, precip predictor	global	25 km	hourly	NOAA CPC
		GFS Vorticity	upper level convergence, precip predictor	global	0.5 and 1.0 deg	4x daily	NOAA
		ENSO phase - Sea Surface Temp Anomalies	related to seasonal precipitation in some regions	global	25 km	daily	IRI and NOAA CPC
	Precipitation Forecast	GFS model - Global Forecast System	precipitation forecast – 24-168 hour	global	0.5 and 1.0 deg	4x daily	NOAA
		NCEP/Eta model	precipitation forecast – 24- 72 hour	regional models	22 km	3-hourly	NOAA CPC
	Vegetation	AVHRR GIMMS NDVI (normalized difference vegetation index)	vegetation density and health	global	8km	10 and 15 day composites	NASA GSFC
		AVHRR NOAA Vegetation Health	vegetation plus temperature	global	16 km	Weekly (7 day)	NOAA
		SPOT Vegetation NDVI	vegetation density and health	global	1km	10 day composites	VITO, FAS-USDA, NASA GSFC
		MODIS NDVI Projections based on CMG product	Projections of vegetation density 1, 2 and 3 months into the future	Africa	5000 m	Monthly	NASA, UCSB, USGS
		MODIS NDVI - MOD13	vegetation density and health	global - limited availability	250 m	16 day composites	NASA GSFC

Table 2. Current FEWS NET data products and descriptions.

Category	Type	Product	Description	Spatial Extent	Spatial Resolution	Time Step	Source (see acronym list for definitions)
		MODIS NDVI – MOD09 one day latency prod	Vegetation data created from MOD09 data with 9 hour latency	Global	250m, 500m	8 day and daily	NASA GSFC
	Soil Moisture	SSM/I Soil Moisture	soil moisture, vegetation proxy	global	30km	weekly, monthly	NOAA
		CPC Leaky Bucket model	soil moisture, vegetation proxy	global	25km	monthly	NOAA CPC
		MI - Moisture Index	estimates available water for crops/vegetation (supply/demand ratio)	Africa, SW Asia	0.1 deg	daily, 10-day	USGS
		SWI – Soil Water Index	Estimates amount of water available for crops/vegetation	Global, Africa	deg, 25 km	10-day, monthly	USGS

Table 2. Current FEWS NET data products and descriptions.

Category	Type	Product	Description	Spatial Extent	Spatial Resolution	Time Step	Source (see acronym list for definitions)
Biophysical Monitoring	Fires	MODIS Rapid Response	fire locations mapped onto true color MODIS imagery	global - limited availability	250 m	daily	NASA GSFC
	Snow	Snow station data	precipitation, snow fall and temperatures	Asia	point	daily	AFWA
		Snow depth grid	Modeled data using SSM/I surface temps + climatology	Asia	48km	daily	AFWA
		Snow cover	AMSU Microwave from NOAA-satellites 15 and 16	Asia	24km	daily	NOAA NESDIS
		Snow Water Equivalent	Spatial implementation of the Utah Energy Balance model	Afghanistan	0.1 deg	daily	USGS
	Hydrology	BERM - Basin excess rainfall model - flooding	basin flood potential driven by NOAA RFE Precipitation	Africa	by basin	daily	USGS
		Reservoir levels	global reservoir and lake elevation from radar	Globe, selected	by water body	monthly	FAS-USDA, NASA
		Cyclone Monitoring	image of cyclone track from Navy	E.Africa	-	daily	JTWC-NOAA CPC
	Seasonal Forecasts	IRI SSTA + COLA AGCM temp and precip predictions	guidance for upcoming agricultural season	global	1-5 degree	3-month	NOAA-CPC, Columbia IRI
Socio-Economic Monitoring	Agricultural Production	production figures for various commodities	production statistics from selected countries	Africa	-	Seasonal	FEWS/ UN (FAO)
	Market Prices	market prices for various commodities	commodity prices from markets in selected countries	Africa	-	Monthly and/or weekly	FEWS

Table 2. Current FEWS NET data products and descriptions.

Category	Type	Product	Description	Spatial Extent	Spatial Resolution	Time Step	Source (see acronym list for definitions)
Socio-Economic Monitoring	Food Economy Zones	Livelihood Zone Maps	map shows division of country into uniform zones	Global	-	static - periodic update	FEWS
		Livelihood Zone Profiles	describes cash income and food production sources	Global	-	static - periodic update	FEWS
		Scenario modeling baselines	describes impact of different shocks	Global	-	static - periodic update	FEWS
	Employment	Monitoring of labor markets	Wage-earning is a critical piece of the local economy in many places	Africa	-	Ongoing	NGOs, local government through FEWS Representatives
	Population	Monitoring of migrant vs permanent population levels	Large movements of populations can signal a food crises	Africa	-	Ongoing	NGOs, local government through FEWS Representatives
	School Attendance	Local Representatives monitor attendance rates	To determine if food crisis is occurring	Africa	-	Ongoing	NGOs, local government through FEWS Representatives
	Infra-structure Maps	Roads, administrative maps, infrastructure maps	enables rapid response in event of emergency	Global	-	static - periodic update	UN WFP/FEWS

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