

ASAP - Anomaly hot Spots of Agricultural Production, a new early warning decision support system developed by the Joint Research Centre

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Abstract— Monitoring food security requires near real time information on crop growing conditions for early detection of possible production deficits. Anomaly maps and time profiles of remote sensing derived indicators related to crop and vegetation conditions can be accessed online thanks to a rapidly growing number of web based portals. However, timely and systematic global analysis and coherent interpretation of such information, remains challenging. With the ASAP system (Anomaly hot Spots of Agricultural Production) we propose a two-step analysis to provide timely warning of production deficits in water-limited agricultural systems worldwide every month. The first step is fully automated and aims at classifying each sub-national administrative unit (Gaul 1 level, i.e. first sub-national level) into a number of possible warning levels, ranging from “none” to level 4 and depending on the nature and number of anomalies taken into consideration. Warnings are triggered only during the crop growing season, as derived from a remote sensing based phenology. The classification takes into consideration the fraction of the agricultural area for each Gaul 1 unit that is affected by a severe anomaly of two rainfall-based indicators and one biophysical indicator, and the timing during the growing cycle at which the anomaly occurs. Maps and summary information are published on a web GIS. The second step involves the verification of the automatic warnings by agricultural analysts to identify the countries (national level) with potentially critical conditions that are marked as “hotspots”. In their evaluation, the analysts are assisted by graphs and maps automatically generated in the previous step, agriculture and food security-tailored media analysis, and the automatic detection of active crop area using high resolution imagery (e.g. Landsat 8, Sentinel 1 and 2) processed in Google Earth Engine. Maps and statistics, accompanied by short narratives are then made available on the main webpage and can be used directly by food security analysts with no specific expertise in the use of geo-spatial data, or can contribute to global early warning platforms such as the GEOGLAM Early Warning Crop Monitor, which perform monthly multi-institutional analysis of early warning information.

Keywords—agriculture; early warning; drought, decision support system

I. INTRODUCTION

Agricultural drought, with its negative effects on agricultural production, is one of the main causes of food insecurity worldwide. Extreme droughts like those that hit the Sahel region in the 70's and 80's, the Ethiopian drought in 1984 and the recent Horn of Africa drought in 2010/2011 have received extensive media attention because they directly caused hunger and death of hundreds of thousands of people [1]. With the recent trend of persistently high food prices and a continuously increasing demand for agricultural production to satisfy the food needs and dietary preferences of an increasing world population, drought is one of the climate events with the highest potential of negative impact on food availability and societal development. Droughts aggravate the competition and conflicts for natural resources in those areas where water is already a limiting factor for agriculture, pastoralism and human health. Climate change may further deteriorate this picture by increasing drought frequency and extent in many regions of the world due to the projected increased aridity in the next decades [2].

One way to mitigate drought impacts relies on the provision of timely information by early warning and monitoring systems that can be used to ensure an appropriate response [3]. Obviously, even if the impact of a drought can be timely assessed, having an operational early warning systems in place is only a first step towards ensuring rapid and efficient response [4].

In order to fulfil the information needs of the Directorate General for International Cooperation and Development (DG DEVCO) of the European Commission for programming their food security related assistance and the growing need of the international community for global agricultural monitoring information consolidated among different agencies (such as in the case of GEOGLAM, Global Agriculture Monitoring Initiative, products), the Joint Research Centre (JRC) is developing an information system called ASAP (Anomaly hot Spots of Agricultural Production). ASAP addresses users with no expertise in processing remote sensing and weather data for crop monitoring and aims at directly providing them with

timely and short decision support messages about agricultural drought dependent production anomalies. The expert assessment at country level is supported by a newly developed automatic warning classification scheme at the first subnational administrative level (GAUL1) mainly based on the Flemish Institute for Technological Research (VITO) and JRC developed time series analysis software SPIRITS (Software for Processing and Interpreting Remote sensing Image Time Series; [5]). In this contribution we describe the main features of the ASAP system version 1, currently at the operational test level.

II. ASAP SYSTEM OVERVIEW

A. Geographic coverage

Most of the datasets used by ASAP are available at the global scale. The automatic classification of drought warnings at the sub-national administrative level is therefore available globally. However, the main added value of ASAP system lies in the analysis and short warning messages produced by JRC analysts, and this information will be made available only for ca. 80 target countries. These countries were selected in accordance with the need of contributing to the GEOGLAM Crop Monitor for Early Warning and the need of food availability information of the European Commissions (EC) for countries where food security is a priority sector for the European Development Fund programming. Target countries are depicted in Figure 1 and include most of the African countries and selected ones in Central America, Caribbean region, and Central and South East Asia.

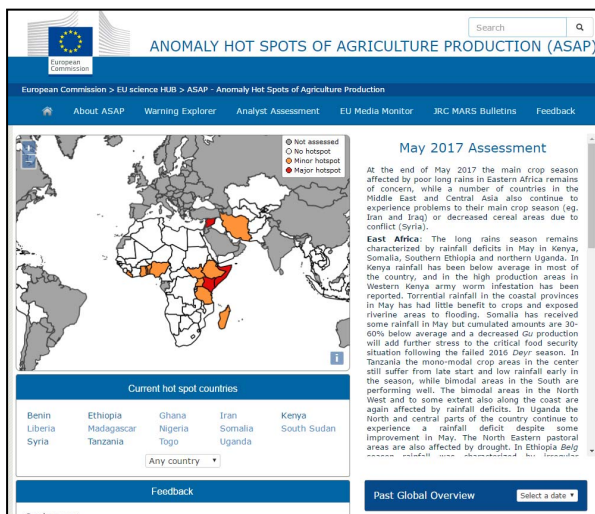


Fig. 1. ASAP main page. GEOGLAM crop monitor for early warning countries and a selection of 11th EDF food security priority countries are shown in white. Agricultural hot spots in May 2017 are shown in orange and red.

B. System components

The ASAP system aims to detect hotspot countries potentially experiencing agricultural production problems and disseminate the results at different levels targeting both users with technical background in remote sensing and agronomy and non-technical users (e.g. decision makers, socio-economist,

nutritionists). The ASAP web platform is structured in three main modules: the Analyst Assessment, the Analyst Dashboard, and the Warning Explorer Tool.

The Analyst Assessment page (<https://mars.jrc.ec.europa.eu/asap/>) is the main entry of the web platform and shows the results of the analyst assessment, with hot spot countries listed and mapped. The user can then navigate to the page of the country of interest, where the analyst' assessment is published together with a set of basic information describing agricultural conditions as maps of indicators, graphs and statistics. For each country, a more extended report is available as pdf document with detailed information at national and sub national level. The goal of this interface is to provide users with no technical skills with a summary picture of ongoing agricultural production problems.

The Analyst Dashboard is a restricted access interface where JRC analysts can revise country by country the results of the automated warning classification systems together with additional remote sensing derived information. In the same dashboard, the analyst can visualize information coming from the JRC European Media Monitor semantic search engine (EMM). Additional information based on high resolution images (Landsat 8, Sentinel 1 and 2) and processed with Google Earth Engine is also made available to give a better insight into the local conditions of crops and rangeland. Based on the analysis of the available information, the analysts decide which countries should be labelled as hotspots and write a short text summarizing the situation. Once the assessment of all the countries for which a warning was issued by the automatic warning system is completed, the results are published in the Analyst Assessment page. While automated data processing is performed every 10 days, the analyst assessment is taking place every month and updated .

Finally, the ASAP Warning Explorer (<https://mars.jrc.ec.europa.eu/asap/hsds/>) is a WebGIS where the warnings at sub-national level are visualized for any past to current 10-day period. A panel with the summary of all relevant information calculated automatically by the system is made available dynamically when a spatial unit is selected, including: phenological stage, progress of the season, rainfall and Normalized Difference Vegetation Index (NDVI) profiles, active area, areas affected by critical conditions according to each indicator used by the warning classification system. This tool can be used to analyse the crop or rangelands conditions by technical users with some background of GIS and remote sensing for agricultural monitoring.

The ASAP software platform was developed using a combination of a large set of open tools, mainly PostgreSQL, PostGIS, SPIRITS, Python, R, Geoserver, and OpenLayers.

III. AUTOMATIC WARNING CLASSIFICATION

The goal of the warning classification algorithm is to automatically perform a standard analysis of rainfall estimates and remotely sensed biophysical status of vegetation. The result is summarised into a warning level ranging from none to 4. Gaul 1 administrative units for which a warning was triggered are then inspected by experts for further analysis and the identification of the hot spots at national level.

A. Data

The automatic warning classification of ASAP v.1 is based on 10-day rainfall estimate (RFE) products of the European Centre for Medium-Range Weather Forecasts (ECMWF) at 0.25° spatial resolution and observations of the NDVI from the MetOp mission at 1 km spatial resolution. Both sources are acquired with a 10-day frequency. ECMWF and MetOp time series are available from years 1989 and 2008, respectively. Satellite-based phenology is computed over a 16-year time series (1999-2014) of NDVI observations from the SPOT-VEGETATION (VGT) mission (same spatial and temporal resolution of MetOp). Both VGT and MetOp NDVI products are temporally smoothed with the SWETS algorithm [6].

Croplands and rangelands are identified using masks generated from the harmonized land cover/land use dataset of [7] and the FAO GLC-SHARE global land cover [8], respectively. The masks, derived from an original resolution of 250 m, are expressed at the lower spatial resolution of RFE and NDVI data as Area Fraction Image (AFI, i.e. the percentage of the pixel occupied by the given target).

B. Methods

Warnings are based on the analysis of anomalies of RFE and NDVI products and are automatically generated at the Gaul 1 administrative level by extracting relevant information over the cropland and rangeland area, according to the above described masks. Anomalies occurring in other land covers are ignored. We focus on drought-related production deficit and we thus use both indicators (RFE and NDVI) in countries where the annual climatic water balance (i.e. precipitation – potential evapotranspiration) is negative. Elsewhere, we only consider NDVI.

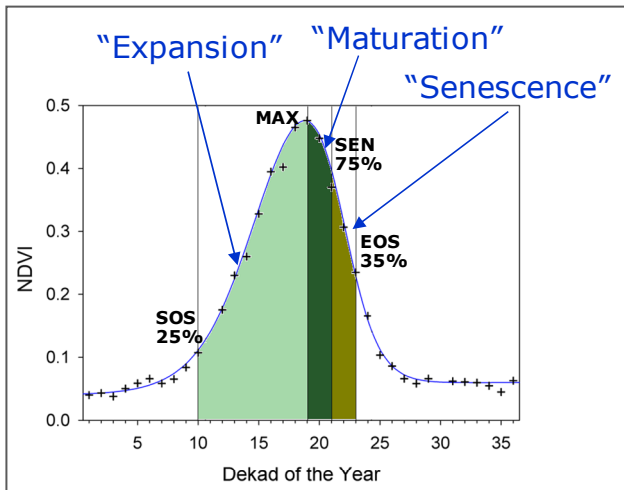


Fig. 2. Graphical representation of the phenological events as derived by satellite data. Dekad stand for 10-day period. The period between SOS and MAX is referred to as “expansion”, the one between MAX and SEN as “maturity”, and the one between SEN and EOS as “senescence”.

The warning classification is updated whenever new observations become available (i.e. every 10-days) and produced separately for the cropland and rangeland layers. For simplicity and conciseness, in the following description we will refer to the cropland layer only. For a given Gaul 1 and time T of analysis, the classification is started only when the time T is

within the growing season for at least 15% of the total crop area. This rule excludes that anomalies occurring outside the growing season are considered to be relevant. To define the mean growing season period we rely on satellite derived phenology computed with the SPIRITS software using the long term average of SPOT-VEGETATION NDVI time series.

As a result of the phenological analysis, the following key parameters are defined for each land pixel: number of growing season per year (i.e. one or two); start of season (SOS, occurring at the time at which NDVI grows above the 25% the amplitude between SOS and maximum NDVI); time of maximum NDVI; start of senescence period (SEN, when NDVI drops below 75% of the amplitude between maximum NDVI and EOS); and end of the season (EOS, when NDVI drops below 35%). Fig. 2 provides a graphical representation of the phenological events.

Pixel-level analysis

Rainfall and biophysical indicators are computed per pixel. RFE data are used to compute the Standardized Precipitation Index (SPI, [9]), an index widely used to characterise meteorological drought at a range of timescales. SPI1 and 3 (i.e. using 1 and 3 months accumulation period) are considered to account for a short and prolonged meteorological water shortage, respectively.

Vegetation status is characterised by the standard score of the cumulative NDVI over the time window ranging from SOS to time of analysis (zNDVIc). The mean difference of NDVI (mNDVI_d) over the same period is also computed to discard poorly vegetated pixels where an anomalous zNDVI_c may not represent a problem.

Once the images the various indicators are computed, we produce three boolean masks indicating per pixel if the indicator value is considered to be “critical”. As the three indicators (SPI1, SPI3, and zNDVI_c) are all standardized variables, we use a threshold of -1 (i.e. values smaller than this threshold are considered critical), corresponding the lowest 16% of observations (under assumption of normal distribution). In this way, each pixel in a given Gaul 1 is classified as critical (or not) for SPI1, SPI3 and zNDVI_c. Note that zNDVI_c is flagged as critical only if also mNDVI_d < -0.05.

Gaul 1 level analysis

The final warning level is computed for the Gaul 1 level and is based on the fraction of the area (of pixels having an ongoing growing season) being subjected to the different critical anomalies (SPI1, SPI3, and zNDVI_c). In this way we aim at detecting unfavourable growing conditions that may represent a food security problem. We thus trigger a warning only if two conditions on the anomaly are met: 1) the interested area is subjected to a severe negative anomaly in one or more indicators and 2) the area concerned by the anomaly is relevant. For this purpose we compute the critical area fraction (CAF) as the number of pixels flagged as critical over the total number with an active growing season at time of analysis:

$$CAF_x = \text{critical_area}_x / \text{active_area} \quad (1)$$

The subscript x refers to the indicator considered ($x = \text{SPI1}, \text{SPI3}, \text{zNDVIc}$). Note that all calculation are made taking AFI into account. Therefore, the extent of the area exceeding a given threshold is not simply the total number of the pixel but the weighted sum of their AFIs.

Any $\text{CAF}_x > 25\%$ (i.e. one quarter of the active area) will trigger a warning for that admin level. The level of the final warning depends on which indicators have a CAF exceeding the threshold and the median phenological timing of the crop. We consider the median progress of the season of the administrative unit and the modal phenological stage (expansion, maturity and senescence). So, albeit two seasons with different modality may be present at the same time and with different progress (e.g. the mono-modal in maturity and the bi-modal in expansion), we will report the median progress (in %) and modal phenological stage. This timing will be thus related to the more abundant of the two (in terms of area of active pixels).

To establish the final warning level, in our classification scheme we put emphasis on the relative importance of the various indicators and on their agreement. We acknowledge that rainfall is the main driver of crop and rangeland growth and that NDVI is the result of such a driver (plus other perils other than drought), so we rank the RFE and NDVI anomaly events with increasing warning levels (Table I).

TABLE I. ASAP WARNING LEVELS

Warning source (Indicator with CAF > 25%)	Warning level by warning source and pheno- phase	
	Expansion OR maturation	Senescence
	Favourable conditions	Favourable conditions
zNDVIc* +	-	-
none	-	-
SPI1 U SPI3 U zNDVIc*	1-	-
SPI1	1	-
SPI3	1+	-
SPI3 & SPI1	1++	-
zNDVIc*	2	4
zNDVIc* & SPI1	3	-
zNDVIc* & SPI3	3+	-
zNDVIc* & SPI3 & SPI1	3++	-

The phenological stage is also related to the warning level. In fact, during senescence, rainfall based indicators do not trigger warnings while NDVI still does, since rainfall has limited importance on crops during this phenological stage (except for rainfall excess which could cause high moisture in harvested grains).

IV. CONCLUSIONS AND WAYS FORWARD

ASAP has been officially launched at the European Development Days in Brussels on the 8th of June 2017 and includes a preliminary version of the high resolution imagery visualization environment. Numerous improvements are currently being implemented to both the automatic warning classification system and to the web platform including:

- i) the update of the current cropland and rangeland masks using an optimal region-specific selection of available global and regional land cover products;
- ii) replacement of the SPI1 indicator with the Global Water Requirement Satisfaction Index (a soil water balance models aligned with the ASAP phenology);
- iii) replacement of MetOp NDVI time series with MODIS NDVI filtered for optimal noise removal in near-real time applications [10].
- iv) Improvements of the Analyst Assessment and Warning Explorer pages including adaptations of both layout and content and improvement of the high resolution visualization platform.

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