



Country-Level ASIS: an agriculture drought monitoring system

Background

The Food and Agriculture Organization of United Nations (FAO) has developed an agricultural drought monitoring system to support individual countries to monitor and manage agricultural drought and the risks it entails. The tool uses satellite data to detect agricultural areas (farmland) in which crops might be affected by drought. The country-level version is based on the general methodological principles used in the Agriculture Stress Index System (ASIS), which is globally operational at FAO-Rome as a form of technical support to the Global Information and Early Warning System (GIEWS) <http://www.fao.org/giews/earthobservation>.

The country-level ASIS purpose is to simulate the analysis that an expert in remote sensing would undertake, and simplify the results displaying them as maps.

Country-level ASIS was created with the purpose of assisting countries to strengthen their agricultural drought monitoring and early warning systems. Once the tool is calibrated with field information (current land use maps, sowing dates, length of the crop cycle and crop coefficients), it offers more precise results regarding the water stress periods for different crops than the global tool. The surveillance of agricultural drought is a continuous activity along the year. It is ba-



sed on satellite information received from FAO every 10-day, which is an ideal time period for monitoring annual crops because it takes into account the water contribution made by soil water holding capacity. The final results are then summed up in maps that are easily interpreted by decision-makers that can implement the drought mitigation activities on time. As Country-level ASIS identifies administrative units that are most likely to be affected by drought, the tool is also useful to guide public investments such as harvesting rainwater, irrigation and establishing or preserving water reserves.

► Innovations at country-level ASIS

- Country-level ASIS brings together in a single index the three dimensions that characterize a drought event: **intensity** (the different values of the vegetation health index (VHI) are classified due to their intensity), **temporal** (VHI values are averaged out during the crop growing period), and **spatial** (VHI values classified as affected by drought are spatially averaged at administrative unit level). ASIS evaluates the severity (intensity, duration and spatial extent) of the agricultural drought and presents the final results by administrative unit, thereby allowing for comparison with the country's agricultural statistics.
- Country-level ASIS improves crop-specific analysis. It is the first system based on satellite information that multiplies the anomaly found on the vegetation index by the crop coefficient. It introduces the sensitivity to water stress of each phenological phase. For cereals the most sensitive phases are flowering and grain-filling.
- At country level, the tool allows the user to define several levels of drought categories: extreme, severe, moderate and slight. The global tool only considers severe drought conditions.
- At global level the agricultural area is represented by the sum of ten crops, all of them cereals. However, in the country-level version, the national institutions decide which crops they want to monitor. This allows to improve the calibration of the tool by introducing sowing dates collected directly from the field. This also replaces the theoretical approach used by the global level system. Further, country-level ASIS allows to simulate more than two crop seasons in countries where climate conditions allow to have more than two crop seasons in a single calendar year.
- The basic analytic units can be changed by the user, who may decide to use either administrative or agro-ecological units.
- The tool enables the user to calculate, midway through the crop cycle, the probability that a specific pixel will be classified as drought-affected at the end of the cycle. The probability at the start of the cycle is based on the pixel's historical probability of being drought-affected, obtained from the 30-year historical series. As the agricultural season proceeds, every ten days new information on the evolution of the vegetation at pixel level becomes available, making it possible to adjust the historical probability on the basis of recent data. Once at least half the crop cycle has elapsed, the omission error is reduced and the probability of correctly classifying the pixel as drought-affected increases.
- Countries which are interested in strengthening their agricultural climate information systems by using country-level ASIS will receive a historical archive with over thirty years of satellite information records from FAO. This 30-year record means it is certain that the series will contain an extreme drought event, which is not necessarily the case for shorter series.
- In order to extend the satellite data series an "inter-calibration" study took place using data generated by the NOAA-AVRRH satellite (available since 1984 and 16 km resolution) and METOP-AVRRH (available since 2007 and 1 km resolution). This "simulation" between the two satellites makes it possible to recover long-term pixel memory, thereby guaranteeing that the pixel has suffered at least one extreme event over the 30 years on record. In the absence of long term data series, there is a risk of underestimating the drought phenomenon.

Methodology

► Detecting Agricultural Drought

The agricultural drought monitoring system is based on the basic principles of absorption, transmission and reflection of solar energy. For photosynthesis, in the visible solar spectrum, plants use the wavelength that corresponds to red. Under conditions of water stress, the stomata close so as to protect the plant from dehydration. However, plants absorb carbon dioxide through the same stomata, as this is necessary for photosynthesis. The result is a reduction in biomass production. Water stress will have a higher effect on yield reduction if it occurs during a phenological phase that is particularly sensitive to water scarcity, such as flowering and grain-filling. This process is shown in figure 1.

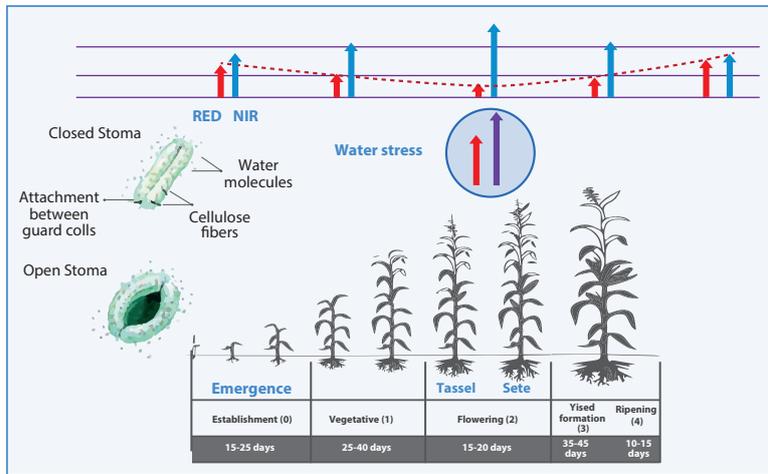


Figure 1

Illustration of how energy is captured by satellite (red arrows indicate red wavelength; blue arrows indicate the near infrared wavelength). Whenever there is water stress, the satellite captures a higher proportion of the red wavelength. This basic principle allows for detecting drought in agriculture.

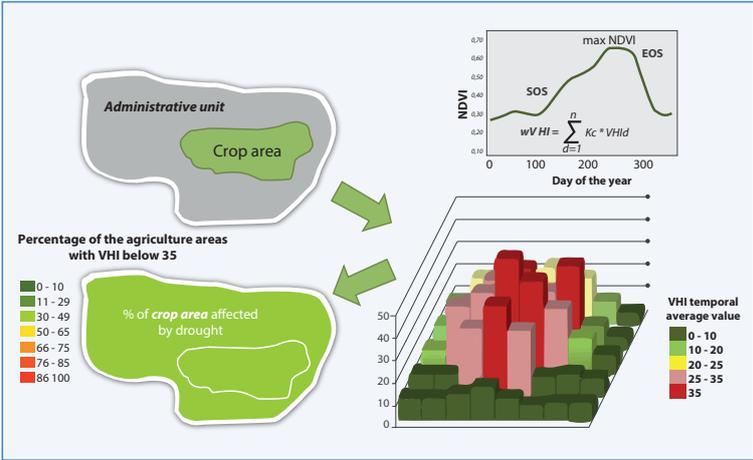
Source: FAO

ASIS uses the Vegetation Health Index (VHI) derived from the Normalized Difference Vegetation Index (NDVI), which indirectly measures primary production through its relationship with photosynthetically active radiation. VHI was developed at the United States National Environmental Satellite, Data and Information Service (NESDIS), and has been successfully applied in many different environmental conditions around the globe,

including in Asia, Africa, Europe and the Americas.

A first step in ASIS is to calculate the average VHI as crop development proceeds (timescale), which makes it possible to assess the intensity and duration of dry periods during the crop cycle at pixel level. ASIS is based on data on climatic conditions necessary for crop development (temperature of vegetation coverage and biomass production) from the METOP-AVHRR sensor at 1 km resolution. **The second step** is the calculation of the percentage of agricultural area affected by drought (pixels with $VHI < 35$ – a value identified as critical in previous studies) to assess the spatial extent of the drought. Finally, the whole administrative area is classified according to the percentage of affected area. For agriculture, it is important to focus on the periods most

sensitive to water stress, such as the flowering and grain filling phases. ASIS evaluates the severity (intensity, duration and spatial extent) of the agricultural drought and presents the final results by administrative unit, thereby allowing for comparison with the country's agricultural statistics.



► Institutional implementation of country-level ASIS

- To establish the tool at country level, it is recommended to create an interinstitutional group including staff from the Ministry of Agriculture, the Meteorological Institute, the Ministry of the Environment and other potential users, such as emergency commissions and agricultural insurance companies.
- FAO will provide technical assistance to calibrate the tool, training people in the use of country-level ASIS and for the interpretation of the different vegetation indexes. During the training process the interinstitutional group will be given the historical archive (1984-to the present). Every 10-day FAO will supply new satellite images through the file transfer protocol (FTP).
- The country must have a computer with a 4TB hard drive as minimum and it should be just dedicated to monitoring agricultural drought. The only software requirement is to have Java.
- An advantage of country-level ASIS is that it analyses satellite data and generates early warning maps automatically. This ensures the sustainability of the system and reduces to one or two the number of people needed to run the system. However, it is recommended, that interpretations are done by the entire interinstitutional group, to enrich contributions and warning messages.

Figure 2

Illustration describing the process used to calculate the percentage of crop area affected by drought and its agricultural stress index (ASI) at administrative unit level. The graph on the upper right-hand shows the VHI temporal average values, while the graph on the lower right-hand displays their VHI spatial values. Droughts are ranked at four levels: extreme (red), severe (pink), moderate (yellow) and slight (light green). The dark-green pixels reflect normal vegetative growth.

Source: FAO

► Potential Country-level ASIS Applications

Until today it has been identified that country-level ASIS can be used as:

- a monitoring and early warning system for agricultural droughts;
- a trigger for implementation of mitigation activities, to be included in national drought plans;
- a trigger for payment of indexed agricultural insurance;
- an independent variable to build yield forecast models;
- a tool for the probabilistic prediction of areas to be affected by drought;
- a tool for carrying out specific studies regarding the El Niño phenomenon, or to guide public investments in infrastructure intended to mitigate the impact that droughts may have on agriculture.

Find below more detailed description of the potential uses of country-level ASIS:

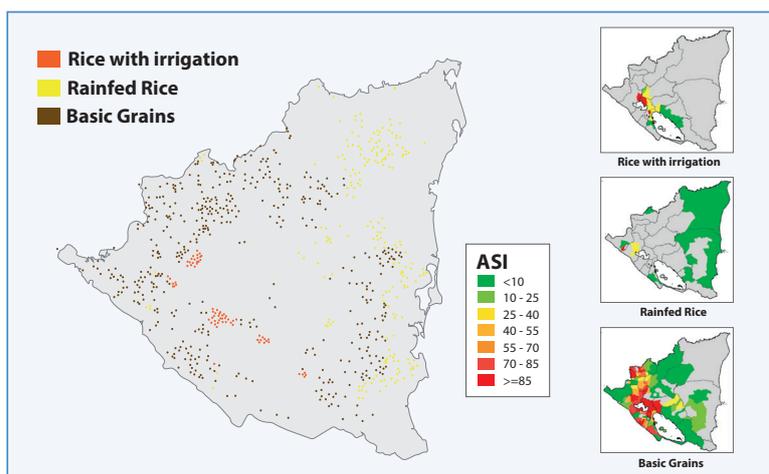
► Monitoring droughts in agriculture (every ten days)

Country-level ASIS allows to monitor drought events on agriculture by specific crop (figure 3), taking into account the water needs of each type of crop. For instance, the water needs of sorghum are introduced by using its coefficients (K_c)¹, which are inferior to those of rice or maize. The graph on the upper-right hand in figure 2 shows how the anomaly of the vegetation health index (VHI) is multiplied by the K_c ; this will lend more weight on the temporal integration of the water deficits which may have taken place during the crucial flowering and grain-filling periods.

Figure 3.

The map on the left displays areas with irrigated rice, rain-fed rice and staple foods (beans and maize) in Nicaragua. For their part, the maps on the right show the percentage of farmland under each of these crops which were affected by drought during the first crop season of 2014. The drought took place while an El Niño event seemed to be taking shape, although it ultimately did not materialize.

Source: FAO



► Probabilistic forecast of agricultural droughts

Country-level ASIS will enable the user to calculate, midway through the crop cycle, the probability that a specific pixel will be classified as drought-affected at the end of the cycle. The tool will have this predictive application with statistical significance. The probability at the start of the cycle is based on the pixel's historical probability of being drought-affected, obtained from the 30-year historical series. As the agricultural season proceeds, every ten days new information on the

¹ The crop coefficient (K_c) describes variations in the amount of water which plants extract from the soil as they grow, from sowing to harvest time.

evolution of the vegetation at pixel level becomes available, making it possible to adjust the historical probability on the basis of recent data. Once at least half the crop cycle has elapsed, the omission error is reduced and the probability of correctly classifying the pixel as drought-affected increases. This probability is calculated at pixel level, making it possible to produce maps with information at 1 km resolution. Statistics relating to the calculated probability are also expressed in the form of maps to help the user to visually check the statistical validity of the probability. (figure 4).

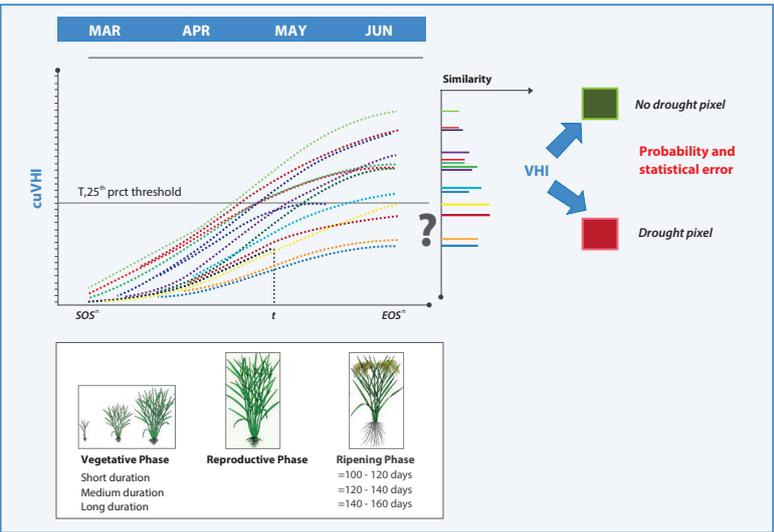


Figure 4. Country-level ASIS calculates the probability that a pixel located within a particular agricultural area will be affected by drought. The degree of error is reduced as the crop season advances. In operational terms, an acceptable level of risk is reached at mid-season.

Source: FAO

Triggering mitigation activities

A drought warning produced by the monitoring system should lead to take action by national institutions involved on mitigating the effects upon rural dwellers which droughts have on crop yields. The percentage of farmland affected by drought can trigger

the mitigation activities set forth on national drought plans (figure 5).

Triggering payments of agricultural insurance

ASI values can be used as a trigger for geospatial index-based insurance policies. For this purpose, the ASI histori-

cal values series is extracted from the 30-year series, and the empirical probability that it exceeds a certain value "x" is calculated, as the threshold for defining a catastrophic event which it is to insure against. The premium of the insurance contract is calculated for the number of catastrophic events to be insured. Insurance based on geospatial data

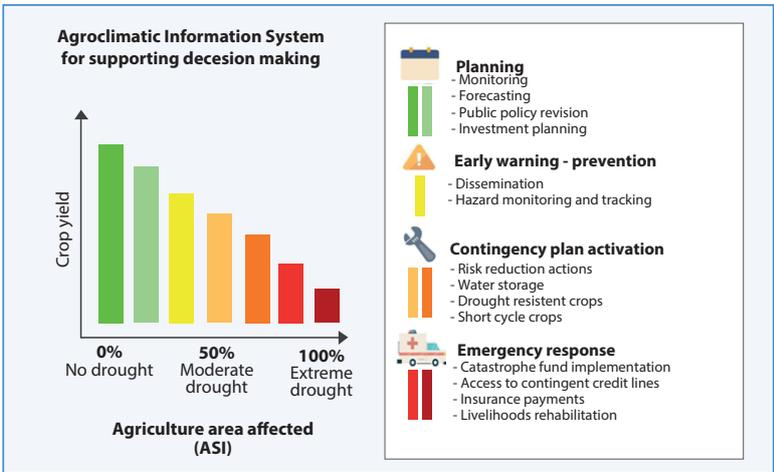


Figure 5. The percentage of agricultural area affected by drought can be used to trigger implementation of mitigation activities set forth on national drought plans.

Source: FAO

is preferable to contracts indexed to data from the meteorological network. Indeed, geospatial data have a higher resolution and are more reliable for insurance companies,

since they eliminate the risk of data manipulation (moral hazard).

On the other hand, they are harder to explain to farmers,

and insurance policies must therefore be targeted to agricultural associations or cooperatives, which may better understand data from remote sensors (Figure 6).

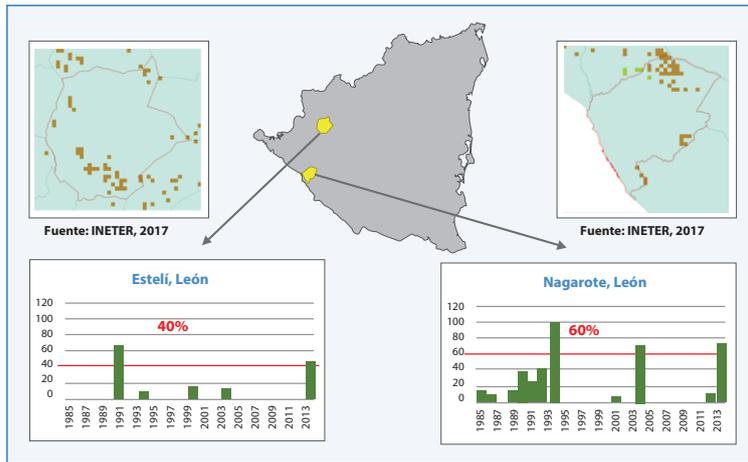


Figure 6.

Two examples of insurance payment triggers when the insurance acquired is indexed by remote sensors. The information is culled from an updated land use map for two municipalities in Nicaragua (Estelí and Nagarote). In the case of Estelí, the threshold for payment is when the affected area is equal to or higher than 40% and covers two extreme events. As for Nagarote, the trigger is unleashed at 60% and three extreme events are covered. The latter municipality would therefore have an agricultural insurance premium higher than that for Estelí.

Source: FAO

► Yield forecast model

The results produced by the system can be used as independent variable in order to generate yield forecast models using the regression technique. To do so, it is necessary to have yield data over a series of years for the crop to be studied.

Figure 7 shows an example of the crop yield forecast model as used in Syria.

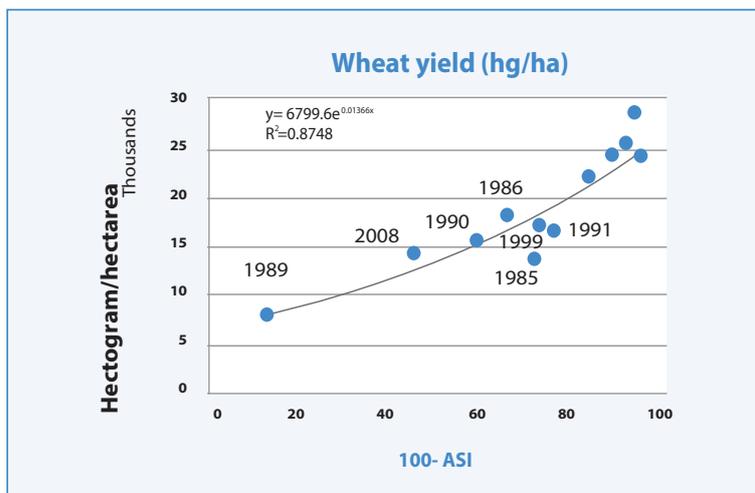


Figure 7

Relation between the ASI index and wheat yields in Syria.

Source: FAO

► **The ASI historical series (1984-2016) allow to understand the impact of events such as El Niño on agriculture**

Historical series for agricultural areas affected by drought allow for relating its impacts to adverse climate events such as El Niño. Figure 8 shows that in the case of rice, the first crop season is affected during the first year of an EL Niño event, while for the second and third seasons the impact occurs during the second year of the event.

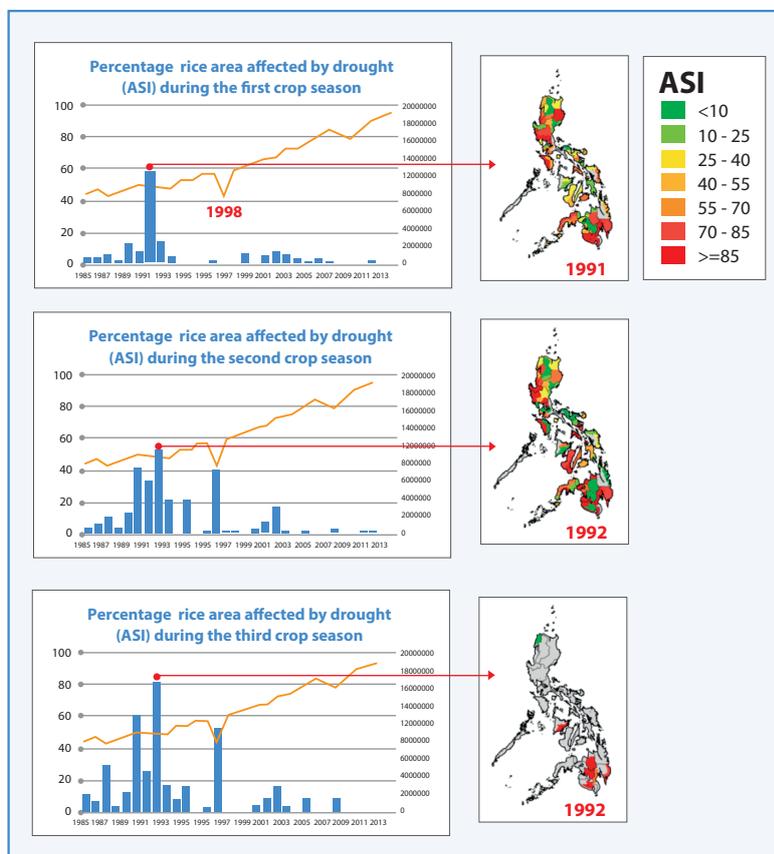


Figura e.

A historical series of rice area affected by drought in the Philippines (1984-2014). Shown is the influence of the 1991/92 El Niño event, which severely affected the country. The most severe El Niño event during the past thirty (30) years took place in 1997/98 and while it had little effect on the first crop season, it severely affected the second and third seasons.

Source: FAO

Contact Information

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