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http://www.eohandbook.com/eohb2012/case_studies_global_food_security.html

Global Food Security

Overview

Many already see food insecurity as the single biggest threat facing humanity in the 21st century. There are many reasons for this. The world population has just reached 7 billion, increasing at a rate of about 100 million per year, and is expected to reach about 9.1 billion by 2050 according to United Nations projections. In addition, per capita demand for nutritional intake is constantly increasing, especially in developing countries, and it is estimated that agricultural production will have to almost double over the next 50 years relative to 2010 levels to keep pace with population growth and increasing nutritional demands. On top of this, Intergovernmental Panel for Climate Change (IPCC) climate models predict future rises in atmospheric temperatures and significant fluctuations in precipitation over space and time, which is expected to severely stress water resources, causing further difficulties in feeding the world.

The reality is that the 'green revolution' era (growing more food per unit of land) has ended. After swift agriculture expansion in last 300 years (Figure 1), global cropland areas have stagnated at approximately 1.5 billion hectares, of which roughly 1.1 billion hectares are rain-fed, and 400 million hectares are irrigated (Figure 2). Cropland areas have begun to decrease in some key agricultural producing countries (e.g. USA) due to increasing demand for fertile arable lands for alternative uses such as bio-fuels, encroachment from urbanization and industrialization. Furthermore, ecological and environmental imperatives such as biodiversity conservation and atmospheric carbon sequestration have put a cap on the possible expansion of cropland areas to other lands such as forests and rangelands. On top of all this, irrigated areas that were at the heart of the green revolution era through rapid increases in their areas and productivity have virtually come to a standstill as a result of limited water resources.

In combination, these issues raise some fundamental questions for today's decision-makers and society at large. How do we ensure food security for the rapidly growing human population, without increasing cropland area or water use (or with reduced cropland area and water use)? The challenges highlight the critical need to have a comprehensive understanding of global croplands and their water use that help ensure global food security.

G20 Action Plan

In June 2011, G20 Agriculture Ministers, met to address the issue of food price volatility with the ultimate objective of improving food security prospects. They agreed on an Action Plan on food price volatility and agriculture, stressing the need to increase agricultural production and productivity on a sustainable basis. They noted this will require "improvements in land and water management, improved agricultural technologies, an appropriate and enabling environment which could lead to increased investments notably from the private sector, well-functioning markets and means to mitigate and manage risks associated with excessive price volatility of agricultural commodities".

The G20 Action Plan has five main objectives:

1. Improve agricultural production and productivity both in the short- and long-term in order to respond to a growing demand for agricultural commodities.
2. Increase market information and transparency in order to better anchor expectations from governments and economic operators.

3. Strengthen international policy coordination in order to enhance confidence in international markets and to prevent and respond to food market crises more efficiently.
4. Improve and develop risk management tools for governments, firms and farmers in order to build capacity to manage and mitigate the risks associated with food price volatility, in particular in the poorest countries.
5. Improve the functioning of agricultural commodities' derivatives markets.

Recognising the importance of timely, accurate and transparent information in helping to address food price volatility, and the need to improve the quality, reliability, accuracy, timeliness and comparability of data on agricultural markets, the G20 Action Plan aims to develop an Agricultural Market Information System (AMIS). The AMIS seeks to encourage major players on the agri-food markets to share data, enhance existing information systems, promote greater shared understanding of food price developments, and further policy dialogue and cooperation. The AMIS will involve G20 countries in the early stage, inviting other main grain and oilseeds producing, exporting and importing countries, representatives from major commodity exchange markets, and the private sector to participate. Early efforts will focus on those market players accounting for the greatest part of world food production, consumption and trade. The AMIS will be housed at the Food and Agriculture Organization (FAO) of the UN with a secretariat including other international organizations.

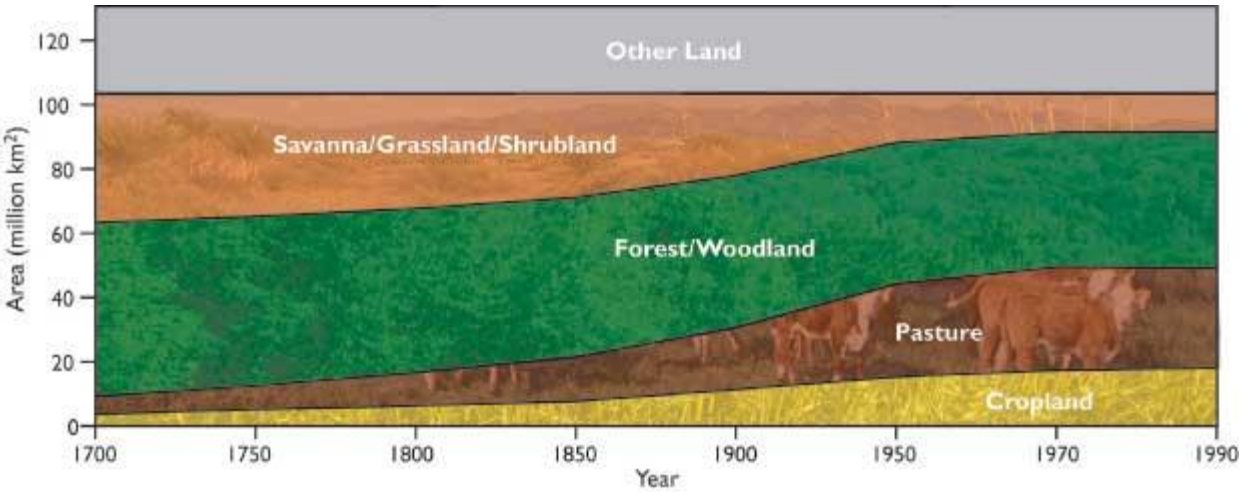

Figure 1. Changes in land cover during the last 300 years due to agricultural expansion.
During the last 300 years there has been a large increase in the amount of land devoted to agriculture (croplands and pastures) coming at the expense of natural ecosystems. As human population and material consumption continue to increase, the pressure on our finite land base will also continue to increase. (Data from the Center for Sustainability and the Global Environment, University of Wisconsin)

The Role for Satellite Earth Observations

A diverse array of information is needed in support of the kind of ambitions being pursued by the G20 to contribute to global food security, including (e.g., Figure 3): crop types, precise location of crops, cropping intensities, cropping calendar, crop health/vigour, watering methods (e.g., irrigated, supplemental irrigated, rain-fed), flood security and drought information including early warning and damage assessments, water use assessments, crop productivity, water productivity (productivity per unit of water), agro-meteorological information (e.g. precipitation, solar radiation, land surface temperature, snow cover and heat/cold wave), and terrain data (slope or aspect of land). Advanced geospatial information systems are needed to manage this data and to develop a global view of croplands, their productivity, and their water use in support of effective food security and market pricing analyses. Data must be consistent across nations and regions and must be updated at a frequency consistent with the derivation of information relevant to different cropping cycles.

The global scale of this endeavour, and the need for it to be a sustained and operational undertaking in support of our on-going food security challenges, is daunting, and would simply be unachievable without the capabilities provided by satellite Earth observations. These observations are fundamental in making complex agricultural monitoring systems (such as AMIS) globally consistent, repeatable and scalable. Important advances and features of the data in this context include:

- synoptic, wide area coverage with global reach;
- frequent temporal coverage and repeat for coarse resolution sensors, complemented by high resolution data available less frequently;
- well calibrated and stable measurements allowing reproducibility of data across different national and regional information systems;
- free online access to key sensors, such as Landsat and MODIS.

Achieving the necessary coverage and repeat frequency of global croplands and the multiple parameters of interest is an extremely significant undertaking, and will require a fusion of data from multiple satellites and coordination of satellite assets of all countries – including those operated by industry. Noting the scale and complexity of the challenge, the Group on Earth Observations (GEO) has identified agriculture as one of the societal benefit areas which serve to focus its coordination activities.

The recent political emphasis on food security and food price volatility has put the essential role of satellite Earth observations firmly into the spotlight. However, satellite Earth observation data has long been used in this capacity and is the basis for many existing crop estimation systems. These include the United States Department of Agriculture Foreign Agricultural Service (FAS-USDA), and the European Commission's Monitoring Agriculture with Remote Sensing (EC-MARS), which combine weather data, in situ information and satellite data to estimate production and yield.

Several important global datasets and time series have been employed to develop a cropland history of the world going back to 1970s. These include: AVHRR GIMMS (1981-2006), MODIS time-series (2000-present), and Landsat Global Land Survey (GLS) 30m mosaics for the 1970s, 1980s, 1990s, 2000s, 2005s, and 2010s. Satellite datasets such as these are the starting point for important global cropland assessments, however current best estimates still feature significant uncertainties. Sources of this uncertainty include differences in national definitions, the use of coarse resolution imagery that fails to pick fragments of croplands, uncertainties in sub-pixel estimates of areas, lack of coordinated and systematic global ground data collection, and a host of other issues. In addition, intensity of cropping (e.g., single, double, triple, continuous cropping) add to areas' uncertainties of which are substantial. Global analyses rely on a multitude of information inputs, including many satellite-based sensors, which means that significant coordination efforts are required.

GEO-GLAM

Recognising the fundamental role for Earth observations as the building blocks of AMIS, the G20 GEO Global Agricultural Geo-Monitoring Initiative (GEO-GLAM) was launched in 2011. The initiative will be coordinated by GEO through its Agriculture Community of Practice. GEO-GLAM will focus on ensuring availability of the necessary observations, notably from satellite systems, and will aim to reinforce the international community's capacity to produce and disseminate relevant, timely and accurate forecasts of agricultural production at national, regional and global scales.

The first planning meeting of GEO-GLAM was held in Geneva in September 2011 to start the process of developing a detailed implementation plan with core partners. There were 13 G20 members represented, along with CEOS, FAO and WMO. Three actions have been identified as the focus for the development of GEO-GLAM in 2012 and beyond:

Action 1 - National capacities for agricultural monitoring: strengthening, capacity building, experience sharing, research, and a focus on countries at risk.

Action 2 - Global and regional agricultural monitoring systems: harmonising, connecting and strengthening existing systems, inter-comparing and disseminating their information.

Action 3 - Global Earth observation system for agricultural monitoring: developing an operational system, coordinating satellite and in-situ Earth Observation and weather forecasting.

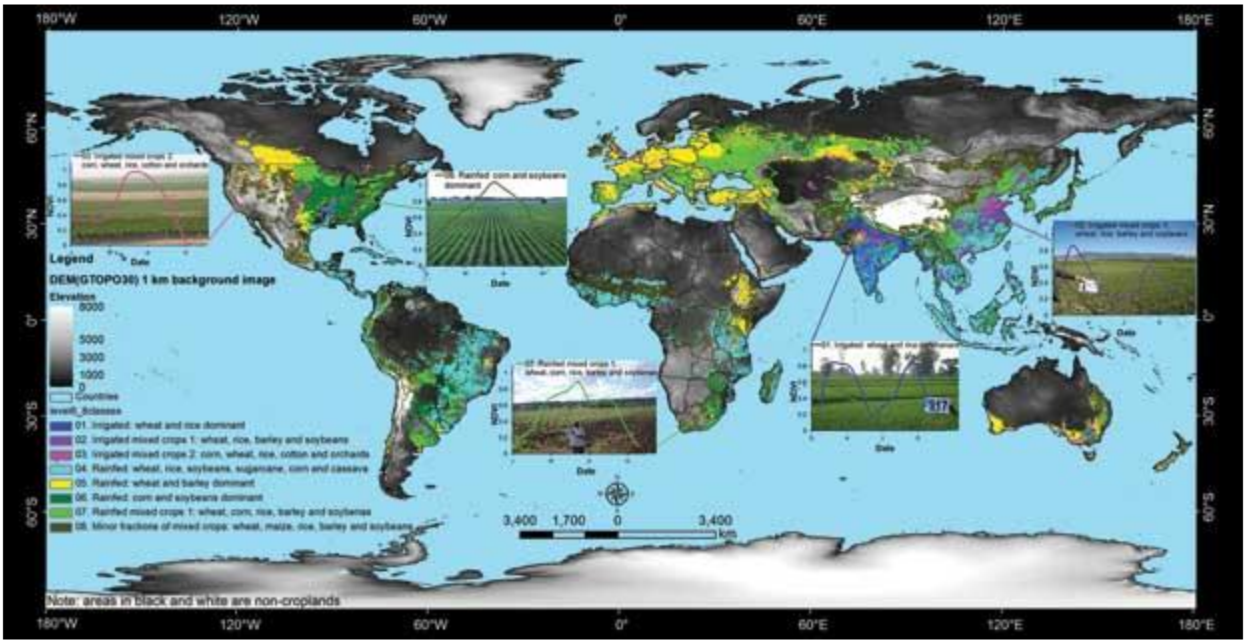

Figure 2. Spatial distribution of global cropland areas of about 1.5 billion hectares along with 5 dominant crops which occupy 60% of this area.
(Thenkabail and Gumma, 2012).

The Way Forward

The GEO-GLAM initiative will focus community attention on agricultural monitoring, seeking to ensure that politicians and decision-makers recognize the link between sustained satellite observations and the availability of the fundamental information required to support food security strategies, including ambitious programmes such as the G20's proposed AMIS system. The sheer volume of satellite data involved will require extensive coordination by all of the world's civil space agencies, probably supplemented with data from key commercial systems. A number of CEOS member agencies are working to develop an understanding of the issues involved with this coordination, and considering implementation options.

It is also recognised that a number of technical advances will be needed to meet future needs:

- higher spatial (30m or better) and temporal resolutions will be needed to support needs of market information systems;
- data fusion techniques must successfully blend inputs from multiple sources, to increase the richness of data and to better characterize crops;
- accurate automated cropland classification algorithms are needed to scale up, and routinely and rapidly produce cropland area statistics and crop productivity estimates.

Improved understanding of the biophysical and biochemical properties of crops and their productivity is anticipated from the use of sensors with fine spectral resolutions. Hyperspectral sensors will be used to develop detailed spectral libraries of crops throughout the growing season, and in different agricultural regions around the world. This in turn will lead to improved satellite-derived crop classification and classification accuracy. These improvements will increase confidence in models of various crop biophysical and biochemical parameters such as biomass, leaf area index, yield, plant water content and so on.

The study of plant life cycle events and how they are influenced by seasonal and inter-annual variations in climate (cropland phenology), cropping intensity, and crop calendars require time-series datasets sustained over long periods. For example, MODIS time-series have been combined with detailed field plot data to help build the history of agricultural development. Continuing to build these datasets will provided valuable information on changes in land and water use.

Improved information on crop area and type will help inform improved cropland and water use, contributing to food security. Globally, humans use about 4000 km3 of freshwater annually. Approximately 70% of this is used for agriculture, with more than half used by just four countries: India 684 km3; China 364 km3; USA 197 km3; and Pakistan 172 km3. Agricultural water use varies based on many factors, including the extent of cultivated and irrigated areas, intensity of cropping, climate, efficiency of water use, crop types and evapotranspiration of crops. In order to better understand and optimise agricultural water use, accurate global croplands data and water use information products are required, contributing to strategies to produce more food sustainably.

Agro-meteorological factors such as precipitation, solar radiation, land-surface temperature and soil moisture heavily influence vegetation growth, and are imperative to predict crop yields (Figure 4). Global agricultural information systems will require these parameters on multiple scales, and with global coverage. Many of the key data sources are provided by operational meteorological satellite programmes, coordinated under the auspices of WMO. These satellite sensors enable measurements of agro-meteorological variables globally and uniformly with a consistent revisit time. Meteorological parameters are essential in forecasts of future crop yields, and historical records are also useful in determining relationships between climatic factors and annual crop yields. This kind of information will be required for modelling the impact of anticipated climatic changes on the yields of different crop types and in support of adaptation strategies in different countries and regions.

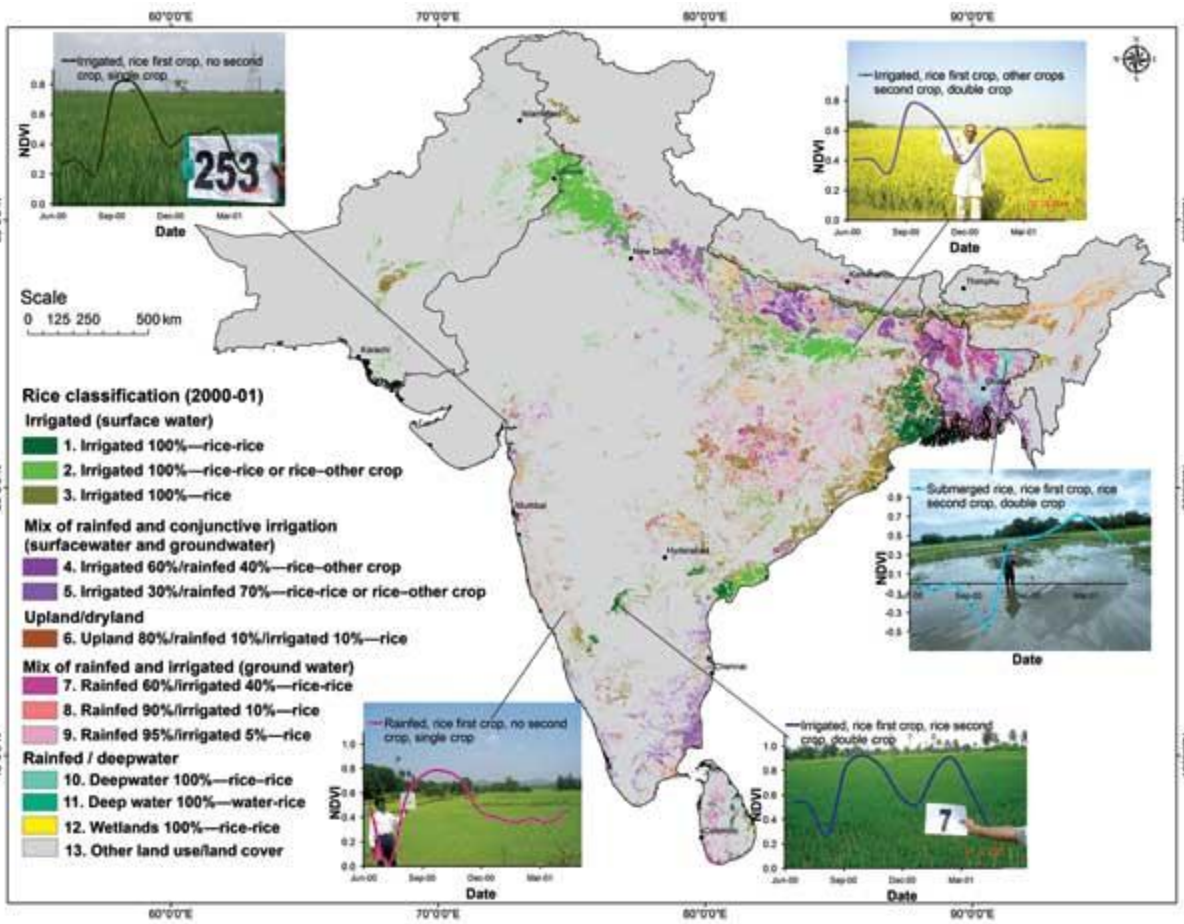

Figure 3. Crop phenologies and intensities studied using time-series remotely sensed data illustrated for rice crop in South Asia. A clear and deep understanding of phenologies and intensities will require us to develop a temporal and

spectral knowledge base of each crop in different agro-ecosystems of the world leading to mapping of distinct classes within a crop which in turn will lead to accurate assessments of green water use (rain-fed croplands) and blue water use (irrigated croplands). [adopted from Gumma et al., 2011].

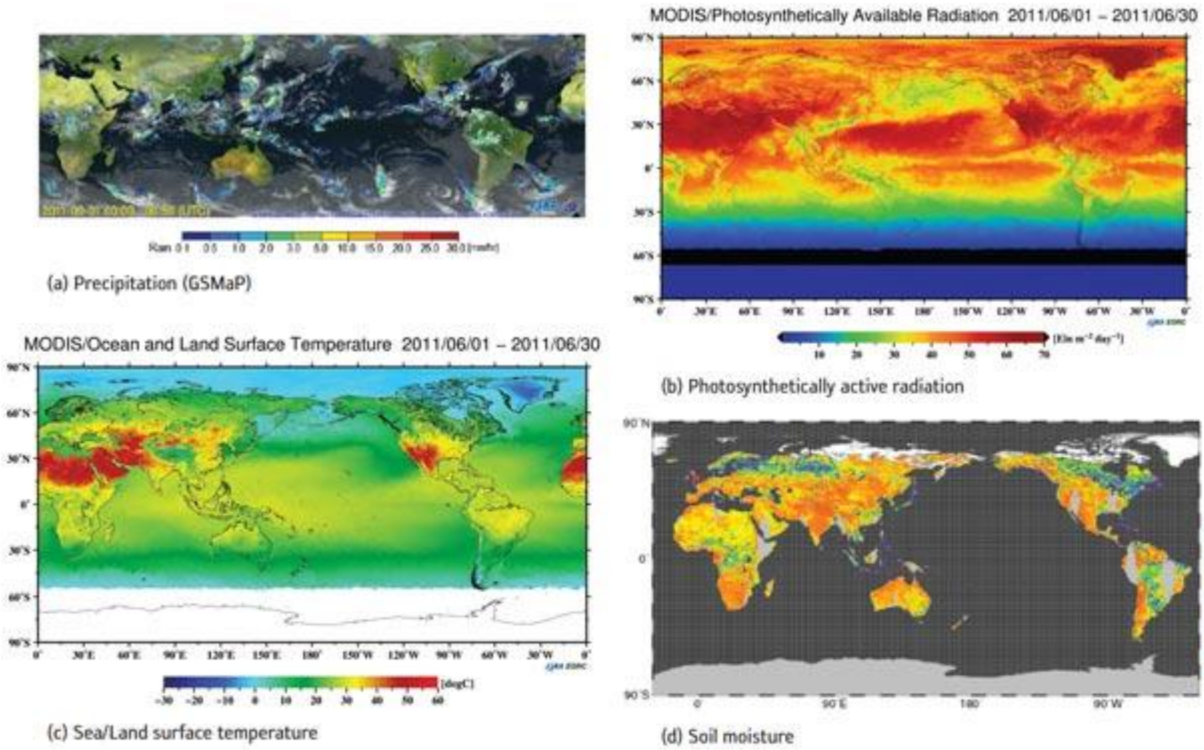

Figure 4 illustrates the examples of satellite-based global agro-meteorological products showing global hourly precipitation product (Fig.4-a), namely Global Satellite Mapping of Precipitation (GSMaP), derived from multiple Microwave and RADAR systems including TRMM PR/TMI, Aqua AMSR-E, DMSP SSM/I (Kubota et al, 2007). Photosynthetically Active Radiation (Fig.4-b) and Sea/Land Surface Temperature (Fig.4-c) are estimated from Terra/Aqua MODIS (Frouin et al., 2007, Saigusa et al., 2010), and soil moisture (Fig.4-d) is estimated from AMSR-E (Fujii et al. 2009).

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Further Information

Food Security Portal: www.foodsecurityportal.org
International Water Management Institute: www.iwmigiam.org
Land Use and Global Environment Lab: www.geog.mcgill.ca/~nramankutty/Datasets/Datasets.html
FAO Irrigation maps: www.fao.org/nr/water/aquastat/irrigationmap/index.stm
USDA Statistics Service: www.nass.usda.gov/research/Cropland/SARS1a.htm
GEO Agriculture: www.earthobservations.org/cop_ag_gams.shtml
Case Study contributors:
USGS: P.S. Thenkabail
JAXA: S. Sobue
International Rice Research Institute: M. Gumma