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INVITED PAPERS

**THE USE OF GEOSPATIAL DATA FOR FOOD INSECURITY AND
AGRICULTURAL DROUGHT MONITORING AND ASSESSMENT BY THE
FAO GIEWS AND ASIA FIVIMS**

Submitted by FAO Regional Office for Asia and the Pacific **

The Use of Geospatial Data for Food Insecurity and Agricultural Drought Monitoring and Assessment by the FAO GIEWS and Asia FIVIMS[1]

Naoki Minamiguchi
Vulnerability Analysis Coordinator
Asia Food Insecurity and Vulnerability Information and Mapping System
FAO Regional Office for Asia and the Pacific, Bangkok, Thailand

Abstract

The Food and Agriculture Organization (FAO) of the United Nations has been utilizing low-resolution satellite remote sensing data on an operational basis to monitor vegetation and rainfall development over large areas in near real-time through the FAO *Advanced Real Time Environmental Monitoring Information System* (ARTEMIS) since 1988. The FAO *Global Information and Early Warning System* (GIEWS) on Food and Agriculture and the Asia *Food Insecurity and Vulnerability Information and Mapping System* (FIVIMS) are among the main users of the ARTEMIS data in the Asia and Pacific region, while the GIEWS monitors food supply and demand conditions for all countries in the world on a continuous basis and provides timely warnings of imminent food shortages, droughts, and hunger at individual country or sub-regional level. As part of its activities, the GIEWS collects and archives information from many different sources. It makes use of GIS and remote sensing technologies to identify regions experiencing unfavourable crop growing conditions and food supply shortfalls and to determine food insecure areas and/or populations. In particular, the GIEWS makes extensive use of the ARTEMIS near real-time satellite images such as the METEOSAT-derived *Cold Cloud Duration* (CCD) imagery providing a proxy for rainfall over Africa, and *Normalised Difference Vegetation Index* (NDVI) images for all countries, effectively providing the GIEWS with information on drought, crop growing and rangeland conditions. Initially, the focus of the ARTEMIS was on Africa. However, the range of products available through the ARTEMIS has increased steadily over the last 6 years, drawing primarily upon new NDVI products derived from the VEGETATION Instrument aboard the SPOT-4 and 5 satellites, and now include imagery at a resolution of 1 km covering the entire landmass of the globe. The Asia FIVIMS takes full advantage of and extends the experiences gained by the GIEWS and the ARTEMIS to drought and disaster-prone countries in Asia. It has established and maintained own networks of disaster data providers and partners for improved food insecurity and vulnerability analysis as well as provides information on the locations and characteristics of the food insecure and vulnerable in digital maps and other forms. The Asia FIVIMS is also building the capacity of the member countries on short-term drought monitoring and food security analysis.

Key Words: Early Warning, Drought and Crop Monitoring and Assessment, FIVIMS, SPOT-
              VEGETATION, NDVI, CCD

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1. INTRODUCTION

The *Global Information and Early Warning System* (GIEWS) on Food and Agriculture was established in 1975 in response to the request of the 1973 Food and Agriculture Organization (FAO) Conference and the 1974 World Food Conference in the wake of the world food crisis of the early 1970's. The System's principal objective is to provide policy analysts and decision makers with the most up-to-date and accurate information available on all aspects of food supply and demand. The GIEWS warns of any imminent food crises and shortages, droughts and hunger at individual country or sub-regional level so that timely interventions can be planned by relief agencies and donor organisations, and suffering in the affected countries avoided. The System is action oriented and its operations are guided by the need for timeliness. It is recognised as the only comprehensive international source for data and analyses of the current and prospective food supply and demand situations in all countries and regions of the world, and has become a worldwide network including UN and international organizations, regional and national food security and early warning systems, both FAO member and non-member governments, NGOs and numerous trade, research and media organizations.
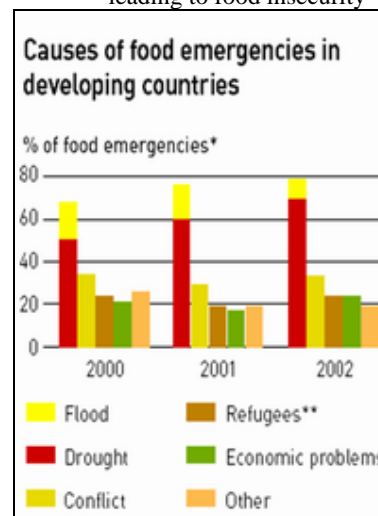
Collection and analysis of the data and information on factors affecting food security situations and/or influencing planted areas and yields is a vital aspect of the monitoring activities by the GIEWS. Such factors include drought, which is a leading cause of food emergencies in the world, followed by civil strife and conflicts. (Figure 1). However, in many drought-prone countries, there is a lack of continuous and reliable information on crop and agro-meteorological conditions, hindering efforts to make effective early warnings and alerts of acute food insecurity. In order to remove the impediment and to complement direct field observations, satellite remote sensing has provided FAO with a low cost alternative for monitoring food crop growing conditions, in particular in large areas in near real-time since the late 1980s.

Figure 1: External and internal shocks leading to food insecurity

* Total exceed 100% because of multiple causes
 cited for many emergencies
** Includes internally displaced people

The satellite images used by the GIEWS are low spatial but high temporal resolution data. Since the late 1980s, the images have been provided by the *Advanced Real Time Environmental Monitoring Information System* (ARTEMIS) of the FAO Environment and Natural Resources Service – formerly the FAO Remote Sensing Centre.

The main reasons for this selection are area coverage, observation frequency and cost. High-resolution satellite systems would provide a more detailed view of agricultural or affected areas concerned, but do not permit weekly or 10-daily monitoring, which is necessary for timely early warning and interventions. Furthermore, in order to cover large areas such as continents, the number of images required would become too high and too costly. For the observations of certain parameters such as clouds as a proxy for rainfall, low-resolution meteorological satellites are rather suitable.

One of the GIEWS's main assets is a database that has been developed over the past 25 years. It contains information on the global food supply and reference information at national and sub-national levels including the satellite images supplied by the ARTEMIS. The GIEWS uses this information to provide up-to-date assessments which are disseminated worldwide in a timely fashion in the form of regular publications as well as by making use of electronic information dissemination technologies including e-mail and the Internet.[2] In addition, the GIEWS sends short-term rapid evaluation missions called *Crop*

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[2] The GIEWS regular publications include *Food Outlook*, *Foodcrops and Shortages*, *Food Supply Situation and Crop Prospects in Sub-Saharan Africa*, and *Sahel Weather and Crop Situation*, downloadable from http://www.fao.org/giews/english

and Food Supply Assessment Missions to the countries experiencing exceptional food emergencies and/or affected by natural or warfare related disasters. These are often the most food insecure countries or sub-regions of the world where accurate and reliable information is often difficult to obtain. Based on the findings and analyses carried out during the crop assessment missions, the GIEWS issues *Special Reports and Alerts*[3], which are concise reports describing food supply and agricultural situations in the affected regions. They are quickly disseminated to the international community and relief organizations for follow-up action.

2. Drought – A Leading Cause of Food Emergencies

Historically many of the drought-induced food emergencies in the world occurred in Africa. Since 1900 to the present, more than half or 57 percent of the world drought events recorded by the Centre for Research on the Epidemiology of Disasters (CRED) in the EM-DAT[4] have occurred in Africa (Figure 2). Yet, in terms of the number of people affected by drought, the impact of the disaster is even greater in Asia. More than 80 percent of the drought affected population of the world reside in Asia.

Figure 2: Distribution of drought events and affected people by region recorded in the CRED EM-DAT from 1900 to 2004 (*Source*: CRED EM-DAT)
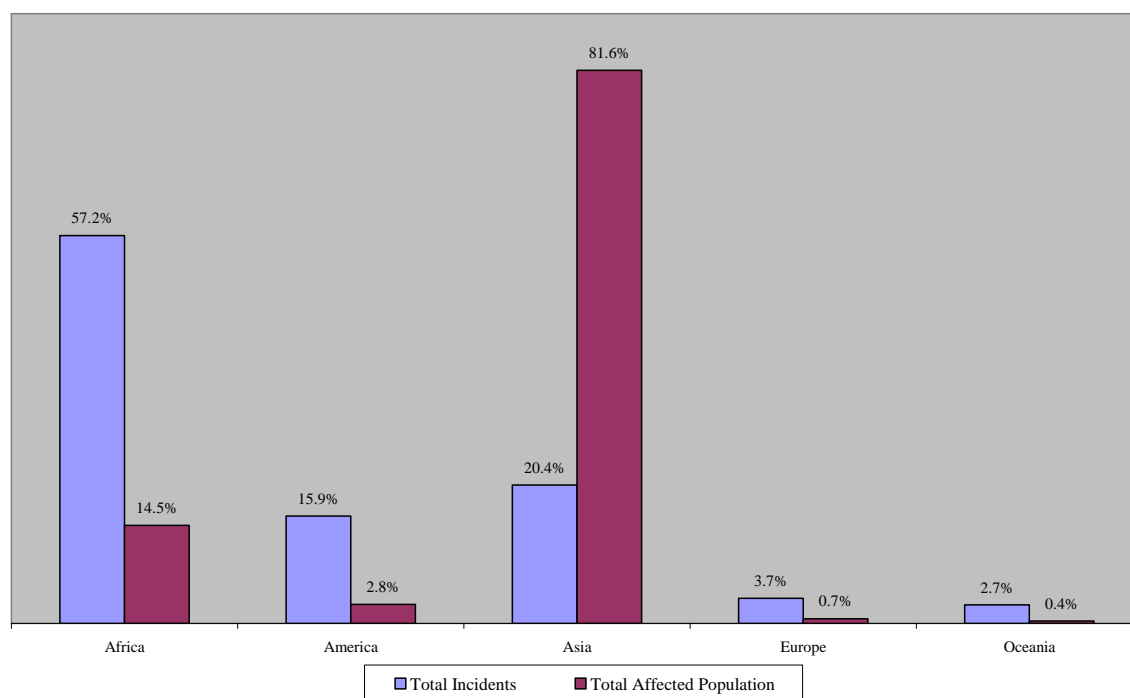

Between 1997 and 2001, the number of drought events in Asia had increased sharply (Figure 3) – including the El Niño related drought in 1998 – which saw a decline in food production in key producing areas such as China and India. However, these countries have been successful in the last two decades in raising food production and hence could effectively deal with the shortfall in food supplies. Moreover, in many countries of the region, progress has been made in reducing the proportion of undernourished people, though their numbers still remain very large. Yet, in Southeast Asia, it is the fact that the 1998 El Niño aggravated the people's welfare already affected by the 1997 financial crisis, which unveiled the socio-economic vulnerability of many households in the region (Santacroce and Minamiguchi 2002).

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[3] http://www.fao.org/giews/english/alert/index.htm

[4] The CRED at the Université Catholique de Louvain in Brussels, maintains the OFDA/CRED International Disaster Database on emergency event, known as the *EM-DAT*, which contains records on disaster events occurred since 1900 to the present.

Figure 3: Drought incidents in Asia from 1976 to 2004 (*Source*: CRED EM-DAT)
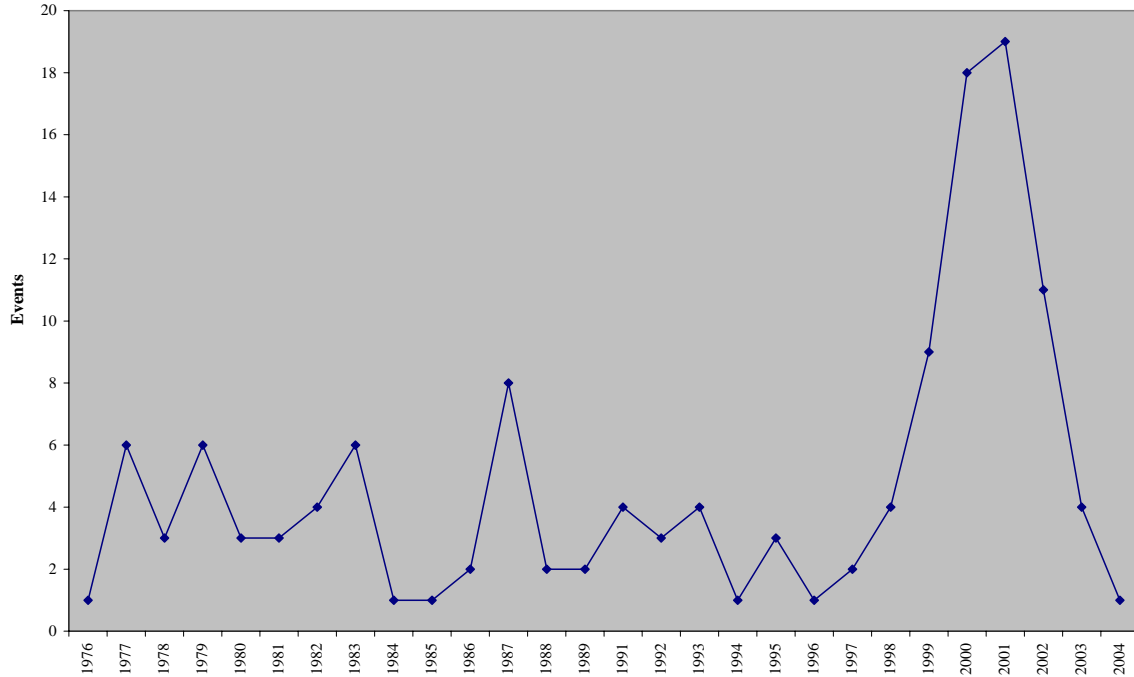
Meanwhile, the profile of food emergencies has gradually changed. Since the 1980s, there has been a significant shift in the major causes of food emergencies or an increase in the number of human-induced food emergencies worldwide (Figure 4). However, drought has accounted for much of the food shortages and food aid relief operations undertaken in the world (See Figure 1 again). This is even more applicable to Asia, which is evidenced by the increased Emergency Operations (EO) for food aid in value terms jointly approved by the FAO and the World Food Programme (WFP) and executed by the WFP. The EO accounts for only a subset of the total disasters and actual food assistance requirements in the world. Nonetheless, it provides important proxy information for the extent and the nature of emergencies. The EO records during the 1994-2000 period reveal that only 18 percent of food aid emergencies operations in Asia were classified as man-made causes such as wars, civil strives and economic crises (Figure 5). By contrast, similar figures for human-induced disasters for the world and Africa were 48 percent and 57 percent, respectively. In Asia, the majority or 53 percent of the emergencies requiring food assistance were due to crop failures – mostly due to droughts – and additional 29 percent were due to sudden natural disasters – mostly floods – during the 1994-2000 period. The proportion of sudden natural disasters in Asia is more or less comparable to such disasters in Africa as well as worldwide.

Figure 4: Main causes of food emergencies - Frequency of occurrence in GIEWS reporting
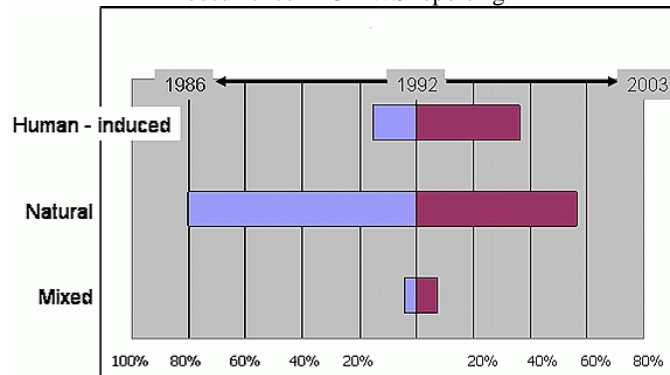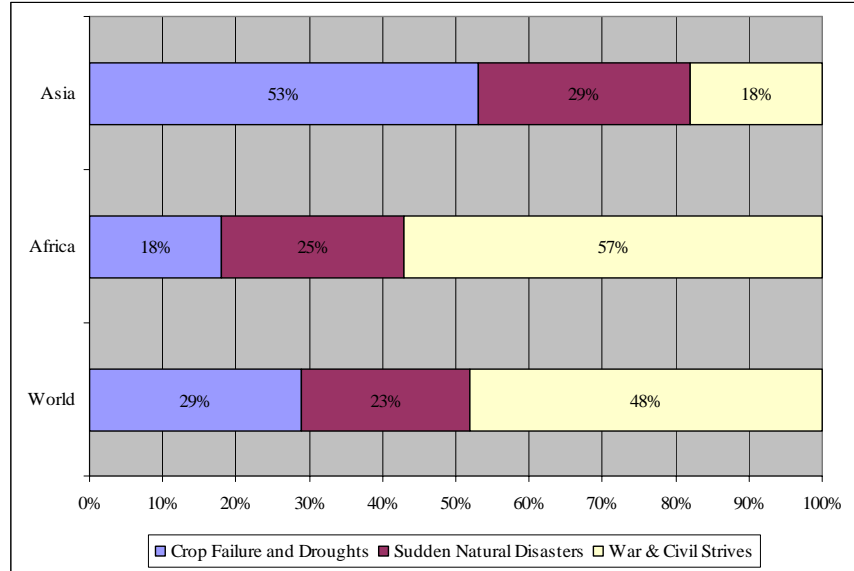
Figure 5: Reasons of emergency operations by region (1994-2000) (*Source*: FAO GIEWS and WFP)

3. Applications of Satellite Remote Sensing Imagery for Drought and Crop Monitoring

3.1. Types and Sources of Remote Sensing Data

The GIEWS makes extensive use of the two types of satellite derived data: *Cold Cloud Duration* (CCD) and *Normalized Difference Vegetation Index* (NDVI) images for agricultural drought and food insecurity monitoring and assessment (Figure 6). Both images are produced and made available on a dekadal – i.e. every 10 days – and monthly basis, providing the GIEWS with the latest information on agro-meteorological and foodcrop growing conditions during the current crop season.

Figure 6: Average Africa CCD and NDVI images for October derived from 1988-2005 (18 years) and 1982-2005 (24 years) time-series monthly composite images
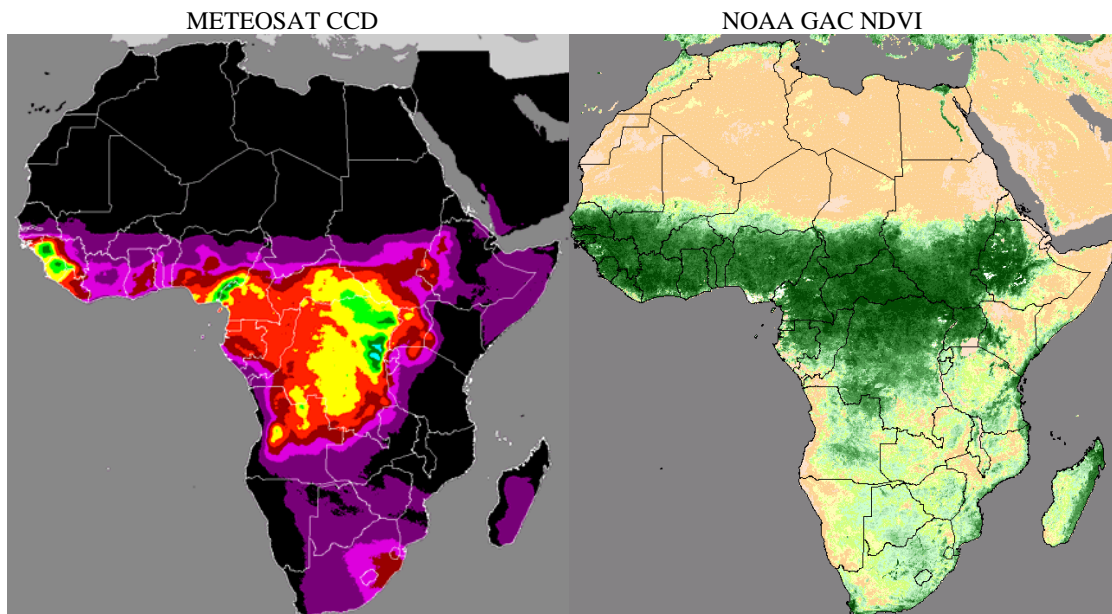
The satellite images are supplied by the ARTEMIS that became operational in August 1988 as the *Africa* Real Time Environmental Monitoring Information System. As the original name of the system reflects, the ARTEMIS was initially established as a centralized system at FAO Headquarters in Rome for the reception and processing of the METEOSAT and NOAA-AVHRR derived satellite data *over Africa*, while responding to the information needs of both the GIEWS and the Emergency Centre for Locust Operations of the FAO Desert Locust Information Service[5] (Snijders and Minamiguchi 1998). The latter has required information on potential breeding grounds over the vast Sahara desert – an environment that is difficult to monitor using ground based techniques.

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Cold Cloud Duration (CCD)	Dekadal and monthly images for Africa indicating rainfall estimates in millimetre, estimated numbers of rainy days, and CCD are processed from the METEOSAT data that the ARTEMIS receives directly and daily from the European satellite through a Primary Data User Station. The processing techniques applied are based on the work of the TAMSAT[6] group of the University of Reading (Milford and Dugdale 1990), which was selected following a study of potential techniques (Snijders 1991). The Dutch Aerospace Laboratory - NLR (Van Ingen Schenau *et al*. 1986) integrated the software components into one, highly automated and operational system. Originally the Government of the Netherlands provided funding for the development of the ARTEMIS.
	CCD images illustrate the amount and spatial extent of cold cloud tops lower than 235°K and are expressed in hours. CCD functions as a surrogate estimate for precipitation, and a long cold cloud duration over an area signifies the likelihood that significant rainfall has occurred. The CCD data are used to trace the evolution of rainy seasons on a 10-day and cumulative basis from the start-of-season through harvest. When combined with rain gauge station data through spatial interpolation techniques, the CCD imagery can be further processed to derive estimated rainfall images as is done for African countries situated below 20 North Latitude (Herman, *et al*. 1997).
	While CCD is effective in the arid and semi-arid areas of Africa, the GIEWS required other methods to adequately describe rainy seasons in the Southeast Asian region. In order to support this need, estimated rainfall images for Southeast Asia generated from the infrared bands aboard the Japanese Geostationary Meteorological Satellite (GMS) have been made available to the GIEWS by the Japan Meteorological Agency on an experimental basis.[7]
Normalized Difference Vegetation Index (NDVI)	The NDVI imagery used by the GIEWS comes from two sources:
	(i) 7.6 km resolution Global Area Coverage (GAC) NDVI images for Africa and Latin America and the Caribbean are produced from the data collected by the Advanced Very High Resolution Radiometers (AVHRR) sensor aboard polar orbiting NOAA satellites. They are processed using a sub-system based on the work of the Global Inventory Monitoring and Modeling Studies group at the NASA Goddard Space Flight Center (Tucker *et al*. 1985). These images are provided to the GIEWS through the FAO ARTEMIS every 10 days.
	(ii) Since 1998, FAO has been acquiring the NDVI data derived from the VEGETATION (VGT) instrument aboard the SPOT-4 and 5 satellites every 10 days

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[5] http://www.fao.org/NEWS/GLOBAL/LOCUSTS/Locuhome.htm
[6] Tropical Applications of Meteorology using SATellite and other data
[7] The GMS derived CCD imagery covering the Southeast Asian region were also received on a daily basis from the University of Hawaii and combined into dekadal and monthly products. However, the use of the CCD from the University was suspended in 1999 since the correlation between actual rainfalls and CCD could not be substantiated empirically.

covering the entire landmass of the globe – i.e. the 4 km imagery covers globally, while the selected windows or regions of NDVI images are at a resolution of 1 km (Figure 7). This effort was originally supported by the Global Vegetation Monitoring Unit of the EC Joint Research Centre's Space Applications Institute. The VGT imagery has a ground resolution of 1 km and is more suitable for national and regional monitoring of major seasonal variations in vegetation patterns, which in turn provides information concerning different phases of plant and crop growth. In 1km images, details are much more visible at subnational level compared to the NOAA GAC imagery (Figure 8).

Figure 7: SPOT VGT NDVI coverage with selected regions of interest for monitoring
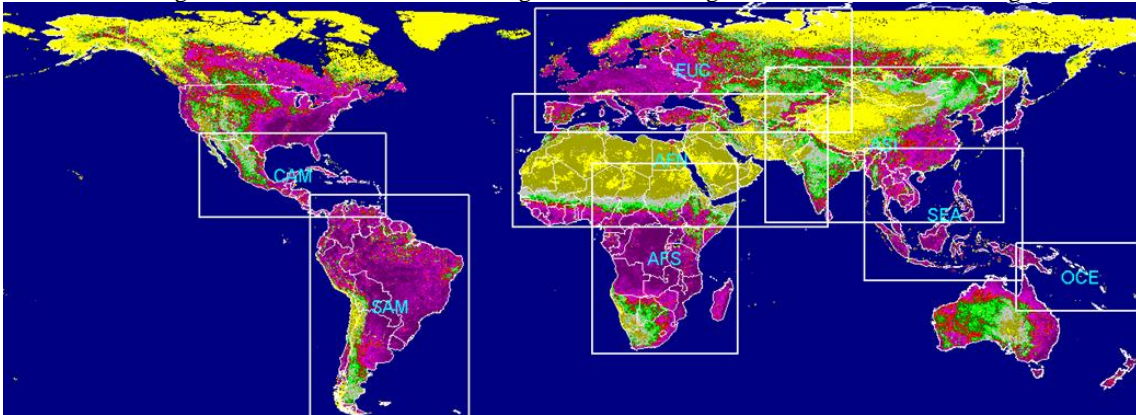
Both CCD and NDVI images have been proven useful for early warning and for drought and crop monitoring over large arid and semi-arid areas such as substantiated in Africa. These are often the only information available in near real-time for many countries and regions where up-to-date and reliable ground-based information on agro-meteorological and crop growing conditions is difficult or impossible to obtain on a regular basis. The satellite images can be used to corroborate field reports, or as a substitute for other sources of agro-meteorological information normally used to estimate crop yields in countries where the required information is weak or incomplete. For many parts of Sub-Saharan Africa, and for developing countries in other regions, the dekadal and monthly composite satellite data have provided a cost-effective and efficient solution for monitoring the current crop season allowing GIEWS crop assessment mission teams to effectively identify areas suffering from low rainfall and drought, and to timely schedule their field missions accordingly.

Hunan Province, China

Figure 8: The area ratio is even more higher: 1 km^2 vs. 64 km^2
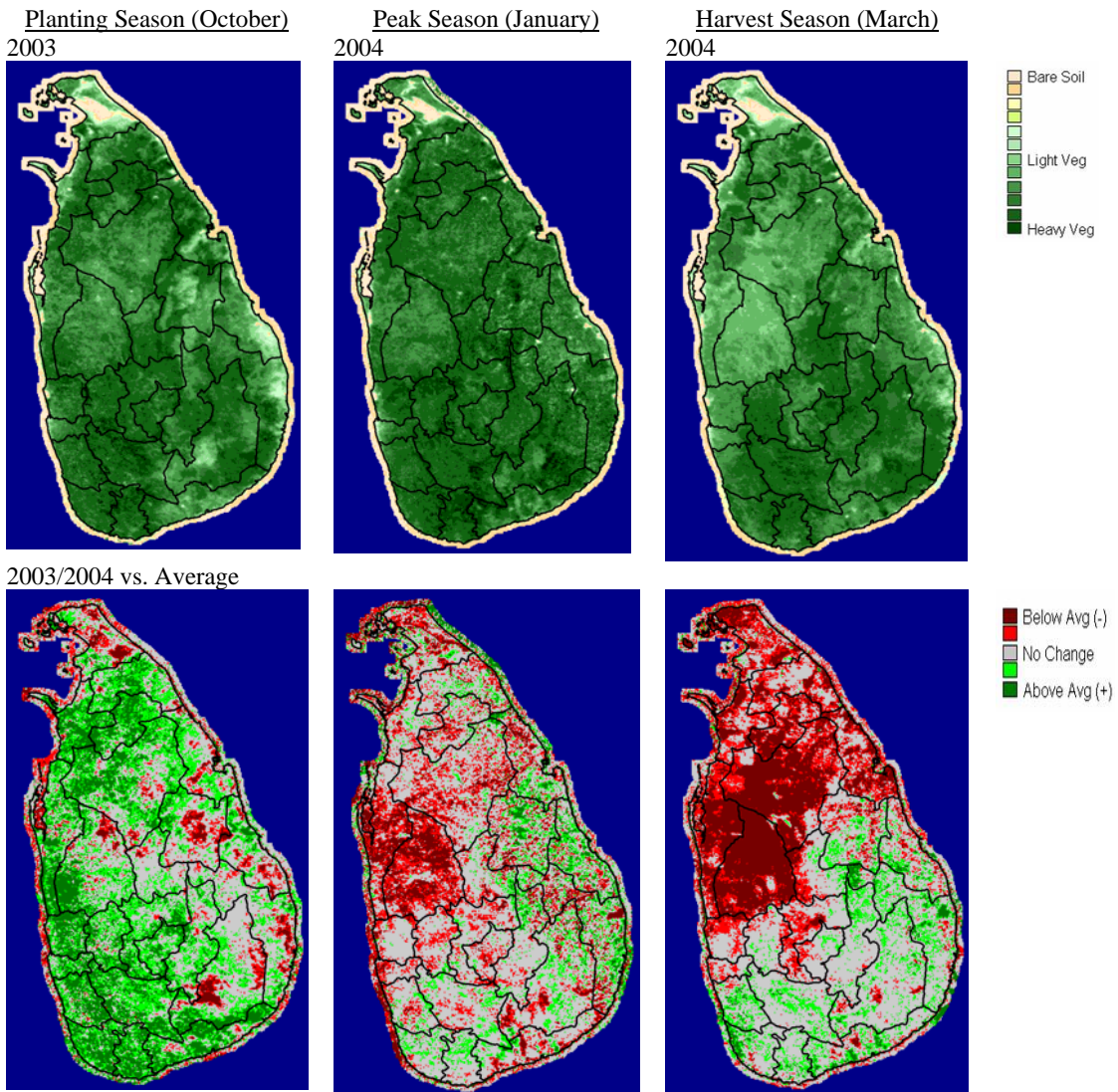(Left) 7.6 km resolution NOAA GAC imagery
(Right) 1 km SPOT VGT NDVI
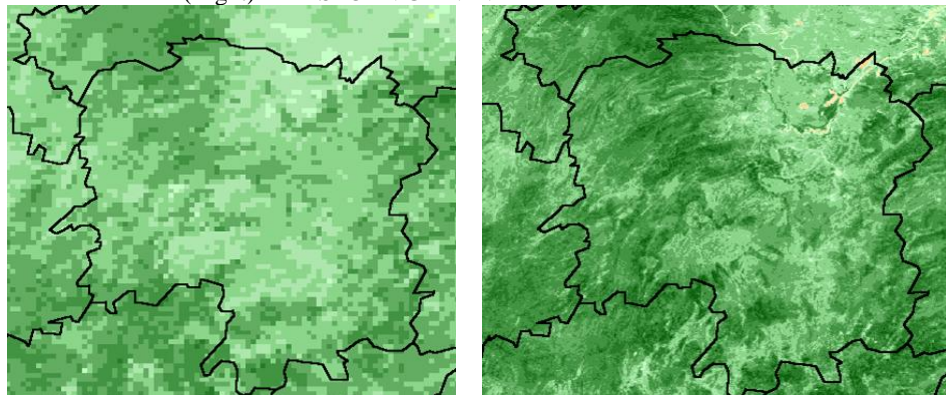
3.2. Crop Monitoring Techniques

FAO has developed various techniques for extracting information on crop growing conditions using the up-to-date CCD and NDVI images available on a dekadal and monthly basis, which provides an indication of yields and crop production expected at the end of a growing season. These include creating simple difference images: a technique which is often used to assess the difference in vegetation vigour at critical periods throughout the growing season such as the start-of-season (planting), and peak and harvest seasons. Figure 9 illustrates an analysis conducted for Sri Lanka in 2003 and 2004. In a similar fashion, with a sequence of current year CCD images, the arrival and retreat of rain clouds can be clearly indicated, providing information on the duration and performance of the crop growing season.

Figure 9: (Left) The 2003/2004 Maha crop season began in September/October with vegetation conditions higher than normal in most parts of the country. (Center) A prolonged drought stemming from reduced rainfall resulted in lower-than average vegetation vigor in the crop growing season. (Right) Failure of the rainfall, characterized as low and erratic during the Maha 2003/04 season resulted in a reduction of paddy production, when compared with the previous year. Kurunegala, Anuradhapura, and Puttalam are the worst affected districts for Maha crops which are clearly shown in the difference images.

Planting Season (October)   Peak Season (January)   Harvest Season (March)
2003   2004   2004

2003/2004 vs. Average

Another example for India is provided in Figure 10. An image from the current growing season was compared with the image computed from the long-term average, or to any image from a previous year, to create a difference image that illustrates critical areas most likely suffering from low rainfall and drought. Crop zone maps can then be overlaid on top of the difference image to further pinpoint affected agricultural regions which are critical to food production and require more attention. Crop calendars are commonly used in conjunction with this technique since an understanding of the cropping season for the different foodcrops in each country monitored by the GIEWS is a prerequisite to the operation.

Figure 10: SPOT-VGT NDVI for September 2002 (drought or bad crop year)
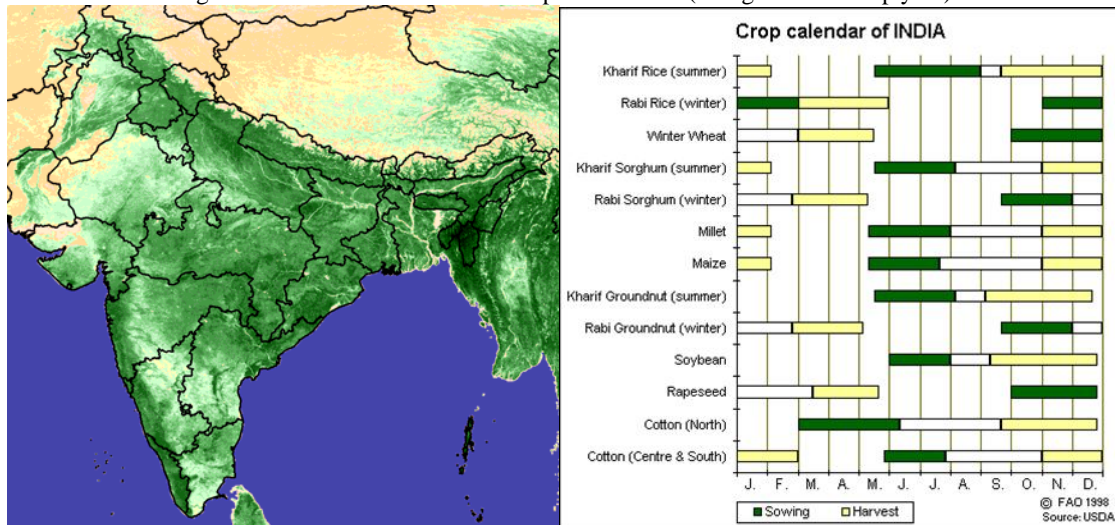
Difference image for September 2002 (drought year) vs.1999 (good crop year) depicting a condition worse-than-a previous year shown in red with the crop zones where maize (yellow) and Kharif rice (blue) are mainly grown.
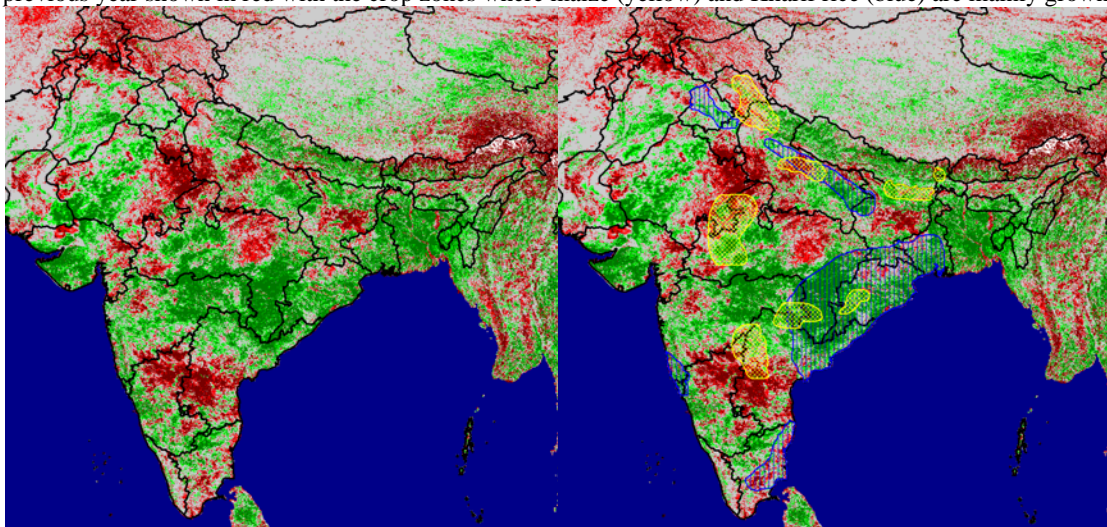
Another effective means of analysing the NDVI and CCD data is to extract average NDVI or CCD values over a known area. The extracted data can then be visualized as a time series and compared with an average trend calculated from the historical archive, or to trends from previous years. The values are often extracted for crop zones or by administrative area. An example is given in Figure 11 where a time series of NDVI for Faryab Province in Afghanistan in 2001 – a drought affected year – is plotted against the long-term average (Figure 11). The sever drought and its impacts on food security in Afghanista and neighbouring countries were reported in a GIEWS' Special Report and Alert issued in October 2001 to seek imperative food assistance from the donor and international communities (Box 1).

More accurate and up-to-date information on crop zones and/or land use/cover maps, if available, can be used to further assist in early detections of cropped areas affected by drought and other agro-meteorological hazards. For instance, monitoring of food insecurity situations in the Democratic People's Republic of Korea has been facilitated by utilizing both the ARTEMIS images and digital land cover and crop use intensity maps produced by the UNEP GRID.
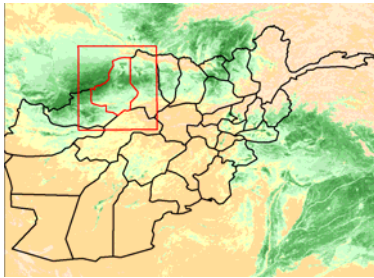
Faryab Province, Afghanistan

Figure 11: The NDVI trend for 2001 (bad crop year) indicates a poor performance of crop production throughout the crop season as compared to the average NDVI trend derived from 1998-2003 time-series images
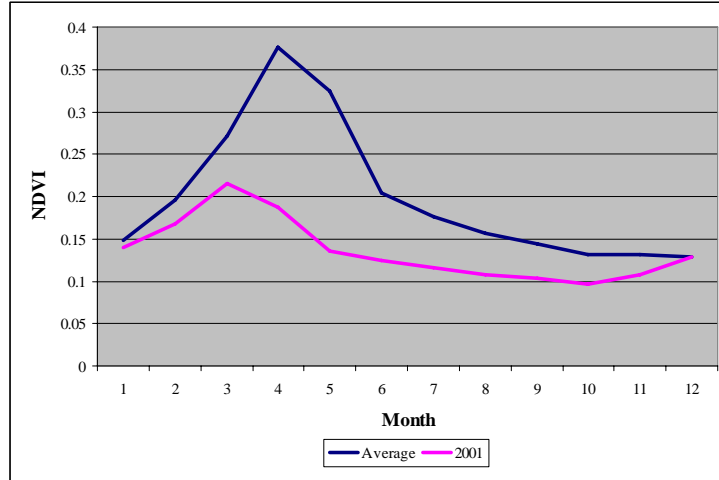
3.3. Data Modelling and Image Analysis

In addition to the time-series analysis and comparison of images, both NDVI and CCD can be used as an input into other models as well. These include agro-meteorological models that make use of the CCD imagery to interpolate rain gauge station data as inputs to the models, and various image clustering methods that analyse temporal profiles of all image pixels for a series of images from the current season, as well as from the historical archive, to create an image depicting areas with similar temporal behaviour (Griguolo and Mazzanti 1996).

Agro-meteorological models developed by the FAO Agrometeorology group utilises station-based information on, among others, observed rainfalls. The ARTEMIS imagery can be typically applied in two different ways: (i) directly – as an input to the model, when there are gaps in the ground-based set of data. For instance, (interpolated) estimated rainfall imagery can be used as a surrogate for observed rainfall; and (ii) indirectly – as an aide to the spatial interpolation of results derived from point-based methods, for instance, by taking into account the spatial information provided by the CCD or NDVI imagery.

These images are also made use of for crop forecasting. The Agrometeorology group has recently developed a tool named *AgroMetShell* and *CM Box* that allow crop water balance calculations and estimate if and when a crop experiences water shortages, eventually leading to reduced crop yields based on rainfall, evapotranspiration and crop data. Crop conditions are further analysed by using satellite imagery, agro-meteorological data and users' knowledge on cropping areas. In Bangladesh, AgrometShell and Satellite Enhanced Data Interpolation (SEDI) techniques were used for modelling crop production together with digital elevation model imagery and agrometeorological data.

Clustering of an image series is a method to integrate both time and space components of the image series through multi-temporal classification. The clustering of the temporal profiles of all image pixels can be done using directly the image values – i.e. "zoning" approach – or by using the difference with a reference data set – "monitoring" approach. A result of such analyses is an image indicating areas with similar temporal behaviour. This approach is mainly applicable towards the end of crop growing seasons concerned.

Statistical methods have been applied by researchers that utilise the NDVI imagery to reveal, for instance, the relation between NDVI behaviours and biomass productivity, in particular for grasslands. Within FAO this technique is not currently used widely since the relation between, for instance, NDVI and crop yields is difficult to establish and often accompanied by a variation that can be higher than the normal year to year variation of the average yield over a country or province.

Box 1: Excerpts from *Special Alert - Famine Threatens Afghanistan While Food Supplies Tighten in Neighbouring Countries* issued on 25 October 2001
(http://www.fao.org/docrep/004/y2234e/y2234e00.htm)

FOOD SITUATION IN AFGHANISTAN

A deepening food crisis in Afghanistan, which poses a serious threat of mass starvation, comes at a time when the food supply position in the neighbouring countries is also seriously undermined by a **prolonged drought**. This year's food production in Pakistan, the Islamic Republic of Iran, Tajikistan, Uzbekistan and Turkmenistan has suffered a significant reduction due to **serious drought**. The unfavourable food supply situation, which has prompted emergency food assistance in some of these countries, therefore gives little comfort to millions of displaced and resident Afghans who in the past could meet part of their food needs with supplies from neighbouring countries. Pakistan and the Islamic Republic of Iran have been supporting millions of refugees from past conflicts but their capacity to cope with the new arrivals is seriously compromised due to insufficient resources.

Even before the events of 11 September, Afghanistan was gripped by a grave food crisis following **three consecutive years of drought** and intensifying economic problems due to continuing civil conflict. An FAO/WFP mission to the country last May found evidence of emerging and widespread famine conditions in many parts of the country, where people had exhausted their coping strategies by selling their assets and migrating in search of food elsewhere within or outside the country. The military operations since 7 October have triggered fresh waves of population displacement, aggravating the already dire humanitarian situation

SITUATION IN NEIGHBOURING COUNTRIES

Islamic Republic of Iran
The disastrous consequences of **three consecutive years of drought** continue to be felt in all sectors of the economy. A UN inter-agency report released in July estimated that about 90 percent of the population (urban, rural, and nomadic) have been severely affected. The shortage of water in rivers and the rapidly falling water tables have resulted in an acute scarcity of drinking water in both rural and urban areas. Large sections of the rural population and their livestock in the affected provinces have started migrating to other areas in search of water. An estimated 200 000 nomadic livestock owners are reported to have lost their only source of livelihood.

Pakistan
Overall cereal supplies will be just sufficient to meet the consumption requirements in the 2001/02 marketing year. Domestic consumption and other utilization requirements are expected to be met from current production and a drawdown of large wheat stocks from last year's good crop. Some exports of wheat due to earlier contracts are also forecast. Rice exports are anticipated to be lower than last year's volume of 2 million tonnes. However, the **prolonged drought** has seriously eroded the food security of a large number of farmers, particularly in Balochistan, parts of Sindh and Cholistan in Punjab.

Uzbekistan
Severe water shortages and **drought two years in succession** have significantly impacted crop production. Water flows in the two main sources of irrigation, the Amu Darya and Syr Darya rivers are reported to be about 40 percent of the average flows, while record hot and dry weather conditions have increased demand for irrigation water. In addition, the available scarce water is reported to be contaminated with high levels of salinity.

3.4. ARTEMIS as a Data Provider and Facilitator

The FAO ARTEMIS maintains an archive of the historical NOAA NDVI images dating back to mid-1981 for Africa and Latin America and the Caribbean, and the METEOSAT CCD images dating back to 1988 for Africa, making it possible to conduct difference image analysis and to utilise other time-series image analysis and processing techniques (Table 1). The ARTEMIS archived images can be viewed online via the METART[8] developed by the ARTEMIS and the Agrometeorology group.

Table 1: Time-series ARTEMIS data covering various regions and new imagery Asia FIVIMS

| Continent/Product:	Source:	Resolution	Coverage	Update	Start
ARTEMIS					
Africa:					
• Cold Cloud Duration	FAO-ARTEMIS	7.6km	Africa	Daily	1988
• Estimated Rainfall	FAO-ARTEMIS	7.6km	W/E Africa	Dekadal	1988
• Interpolated Est. Rainfall	NOAA/FEWS	7.6km	Africa	Dekadal	1995
• NDVI - GAC	NASA-GSFC/FEWS	7.6km	Africa	Dekadal	1981
• NDVI - HRPT	Centre AGRHYMET	1km	W. Africa	Dekadal	1997
• NDVI - HRPT	DMS-Zimbabwe	2km	S. Africa	Dekadal	1997
Asia/Pacific:					
• Cold Cloud Duration	University of Hawaii	5km	Asia/Pacific	Daily / Suspended in	1996 / 1999
South/Central America:					
• Cold Cloud Duration	FAO-ARTEMIS	8km	S/C America	Daily	1998
• NDVI - GAC	NASA-GSFC	8km	S/C America	Dekadal	1981
Global:					
• NDVI - VEGETATION	SPOT	1 & 4km	Global	Dekadal	1998
ASIA FIVIMS					
• NDVI - HRPT	CNEAS	1 km	N/S Korea	Dekadal	2003
• Snow Cover	CNEAS	1 km	Mongolia	Monthly	2004

Apart from the ARTEMIS, the Asia Food Insecurity and Vulnerability Information and Mapping System (FIVIMS) has been receiving from the Center for Northeast Asian Studies at Tohoku University, NOAA AVHRR derived 1-km LAC NDVI data covering the Korean Peninsula as a backup for the SPOT VEGETATION imagery as well as examining the applicability of snow cover images to monitor severe winter conditions in Mongolian – termed *Dzud* in Mongolian (Figure 12). In 1999, Dzud affected large parts of Mongolia following drought in many areas in the summer. As a result, more than 2 million heads of livestock perished, which accounted for almost 8 percent of the entire herd. It is said to be the worst disaster hit in Mongolia in more than 30 years in terms of livestock death.

Overall, the range of imagery available through the ARTEMIS archive can be categorized into two groups: those that give an indication of rainfall – i.e. estimated rainfall and cold cloud duration – and those that give an indication of the effect of rainfall – i.e. vegetation index. However, the ARTEMIS has functioned primarily as a facilitator than a data generator. The suite of data products that are available now, or that may become available in the future on an operational basis – e.g. the TERRA Moderate Resolution Imaging Spectroradiometer (MODIS) data – has increased considerably, and most of the data now originates from outside FAO. In FAO Headquarters in Rome, the ARTEMIS staff assist in the identification of data sources and the establishment of an operational data supply, ensuring that the imagery is acquired, archived, and made available for users both off and on-line. Besides the processing of the raw METEOSAT data, the main processing tasks are currently confined to image format conversions, quality checks and the creation of integrated products. New applications of the ARTEMIS data products – e.g. animal health and Tsetse control – have been explored with the increased variety of

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[8] http://metart.fao.org/default.htm

the imagery and with the increasing size of the archive, not all of which require near real-time satellite imagery such as environmental assessments.

Figure 12. Snow Cover Imagery for Mongolia – February 2004
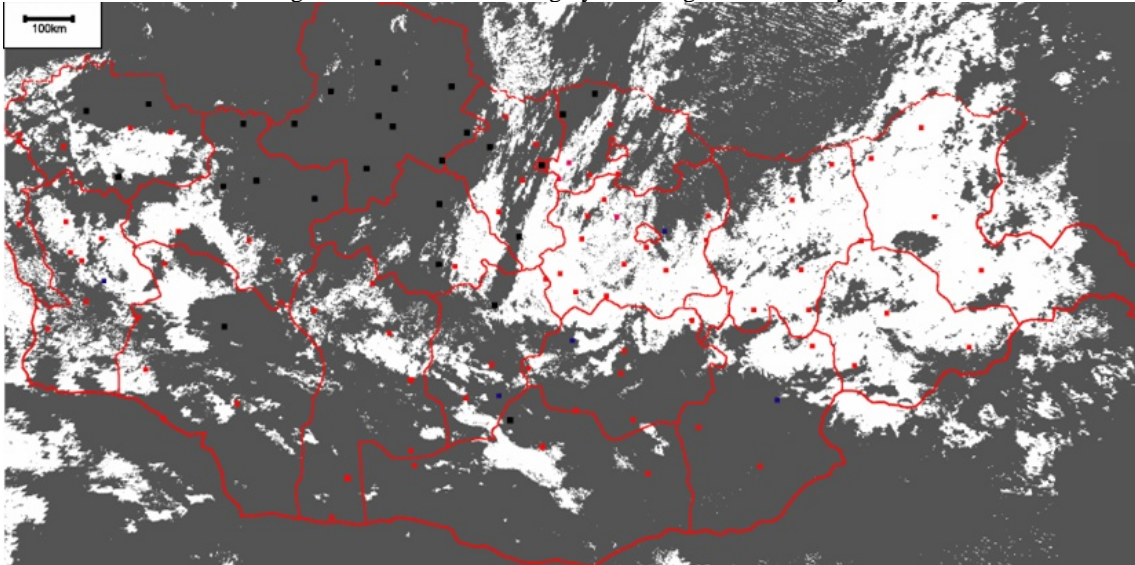
3.5. Known Limitations

CCD images only provide a proxy estimate of actual rainfall and, although methods for the calibration of these data to estimate rainfall are continually being improved, it is not possible to extrapolate too much information from the CCD images alone. The value of the CCD data can be augmented when they are used in conjunction with other agro-meteorological data and NDVI to verify where and when rainfall events have or have not occurred.

Similarly, NDVI provides only a very rough measure of crop growing conditions or vegetation vigour. Low NDVI values between crop germination and maturation could indicate that crops have suffered water stress, whereas high NDVI values do not necessarily reflect the condition of food crops. For example, since the vegetation indices represent the condition of the overall vegetative cover and do not allow for the differentiation of cereal and other food crops, a sudden increase in the vegetation at the beginning of the rainy season does not always signal that crops have been planted.

In a similar fashion, the NDVI images can not be used to determine which crops have reached maturity or have been harvested. In addition, a sharp reduction in NDVI detected towards the end of the crop season (as short as 20 days) could reflect crop wilting as a result of drought, or simply reflect the fact that crop harvesting has taken place reducing the overall NDVI signature of an agricultural area (GIEWS 1996a; Hutchinson 1991). In some cases, the use of the dekadal NDVI images could miss a critical point of decline in crop condition, since it is by nature a 10-day composite produced from the maximum NDVI value recorded for each pixel from the series of daily images. However, such short events are often not critical to the overall crop condition. To properly interpret NDVI, it is essential to know actual planting times using such information as crop calendars and the phenology of local cultivars.

3.6. Tools and Software Available from FAO

Commercially available software packages for the display and analysis of satellite derived images – or even free GIS and image processing software downloadable from the Internet – have been found difficult to use with the images available through the ARTEMIS. The main reason is that these packages serve the "classical" use of satellite data, with multi-band imagery and "false-colour" composite displays. The ARTEMIS imagery, on the contrary, is single-band, like thematic data. This situation led to the development of custom-made software purposely built for use with early warning. They all can be

downloaded from the GIEWS and METART web sites including *WinDisp* that has become a *de-facto* standard for use in the monitoring of food shortages, droughts and food insecurity as well as for early warning exercises.[9]

WinDisp permits the analysis, integration, and overlay of digital map and satellite data in a series of common windows (Figure 13). It is designed specifically for early warning and used extensively within the early warning community for the analysis of low resolution, high temporal frequency satellite imagery in near real-time. The module permits users to compare multiple images; extract and graph trends from a number of satellite images; compute new images from a series of images; build custom products combining images, maps and specialised legends; digitise new maps on screen; to display tabular data in map format; and allow data import and export for major GIS and image processing software. In order to provide varying degrees of automation, WinDisp also supports project files, which can be developed for specific countries and regions allowing users to point and click from various data themes to build composite maps and to do some basic early warning analysis in a series of display windows. The software has extensive batch processing capabilities, which can be utilised to automate routine and tedious tasks. The software can be downloaded from the GIEWS web site with a software manual, sample data and tutorials in English, French and Spanish.[10] 32-bit *WinDisp5* has been developed with new functions and improved usability, which is available from the same GIEWS website for testing.

Figure 13: WinDisp image display and analysis software

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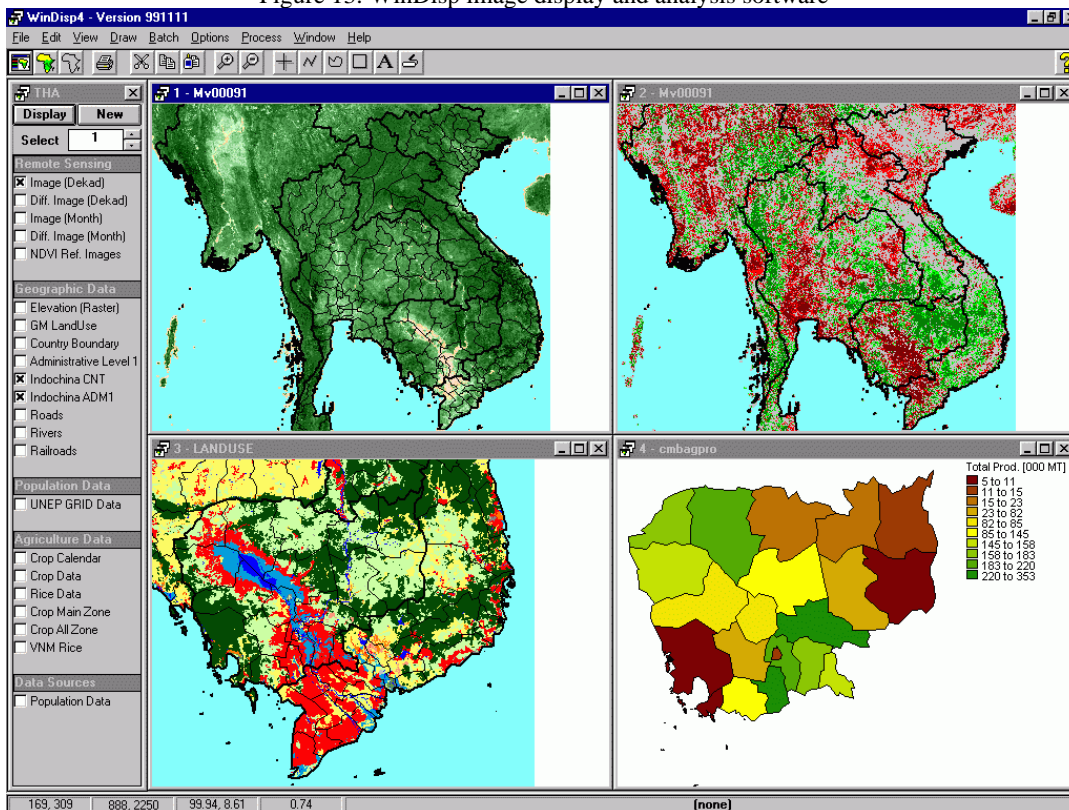
[9] http://metart.fao.org/T_I/GBR/Tools/EToolsMa.htm

[10] http://www.fao.org/giews/english/windisp/windisp.htm

4. Actions for Improved Monitoring and Assessments of Food Insecurity

4.1. Partnership for Effective Responses

It is clear that no system can operate in isolation but needs to be part of an intricate and reciprocal system, of information sharing, at both national and global levels. This linkage is also essential in underpinning the process of warning with response. As these types of linkages have traditionally been weak, and having an effective early warning system is no guarantee that interventions will follow, more concerted efforts by governments, donors and international organisations will be essential to strengthen the linkages between early warning and relief responses to deal with emergencies. In particular, the need for a mechanism to better target and identify vulnerable people is becoming increasingly important.

While there is no way to guarantee that responses will be adequate and appropriate, the GIEWS strives to ensure that the early warning response link is continuously maintained and strengthened. The System has collaborated with Save the Children (UK), WFP's Vulnerability Assessment and Mapping Unit (VAM), FIVIMS, and numerous national and international organisations, in an effort to reach a common understanding of the appropriate tools for localized food security monitoring. The process of developing and harmonising such tools is in its infancy and remains a priority and challenge for the coming years.

4.2. From Transitory to Chronic Food Insecurity Monitoring and Assessments

The assessment of food insecurity situations at sub-national, national, regional and global levels is of paramount importance for development planning and for directing efforts and resources to combat malnutrition and hunger. Similarly, knowledge of the number, nature and exact location of vulnerable populations is required by contingency planners, relief operations, and international aid organizations in times of food emergency and/or civil strife for accurately targeting the beneficiaries of food aid programmes. Food importing developed and developing countries also require vulnerability information since external shocks may disturb the availability of food in the international markets.

In response to this need, the GIEWS, which has traditionally focused more on short-term or transitory food emergencies and crises, has also been actively involved in identifying, monitoring chronic and structural food insecurity and vulnerability situations since the early 1990s. The System hosted two international meetings on *Methodologies for Vulnerability Assessment* as part of an EC-financed *Risk Mapping Project* (GIEWS 1996b and 1997). The meetings brought together international, regional and national organizations involved in food security information and vulnerability assessments, including NGOs, UN agencies, donors, and universities.

The World Food Summit (WFS), hosted by FAO in Rome in November 1996, also recognised the need for an assessment of the extent of hunger and malnutrition, including at local level, and called for the establishment of food insecurity and vulnerability information and mapping systems (FIVIMS) at national and international levels (FAO 1996 and 1998). FIVIMS provides accurate and timely information on the incidence, nature and causes of chronic and acute food insecurity and vulnerability. It assists decision and policy makers to better target limited resources to undernourished and hunger, and is expected to help achieve the WFS goal of halving the more than 800 million undernourished people by 2015. To support the overall FIVIMS effort, FAO has implemented a project entitled *Development of a Vulnerability Information Base, Mapping and Dissemination System for Asia*, or *Asia FIVIMS,* with financial support from the Government of Japan since 1998.

4.3. Asia FIVIMS for Disaster Preparedness

To date, the various elements contributing to food insecurity and vulnerability in Asia have been considered by the Asia FIVIMS. These range from dietary adequacy and food self-sufficiency to disaster and environmental risks. The data used to determine vulnerability factors are being compiled and/or collected in cooperation with Asia FIVIMS partners involved in vulnerability and risk assessments, and then included as part of the Asia FIVIMS database for further assessment. One of the project partners is the CRED. Since the mid 1999, the Asia FIVIMS has collaborated with the CRED in geo-referencing of

the EM-DAT data to produce a time-series, digital geo-referenced data set of natural disasters at subnational level for Asia (Figure 14). These data have been used to investigate causalities between food insecurity and natural disasters including drought, as well as the vulnerability related to such events. (Minamiguchi 2001)

Figure 14: Total number of disasters by province and disaster type reported during the 1975-2000 period – droughts occurred mostly in the South of the Philippines, while the North is more susceptible to wind storms.
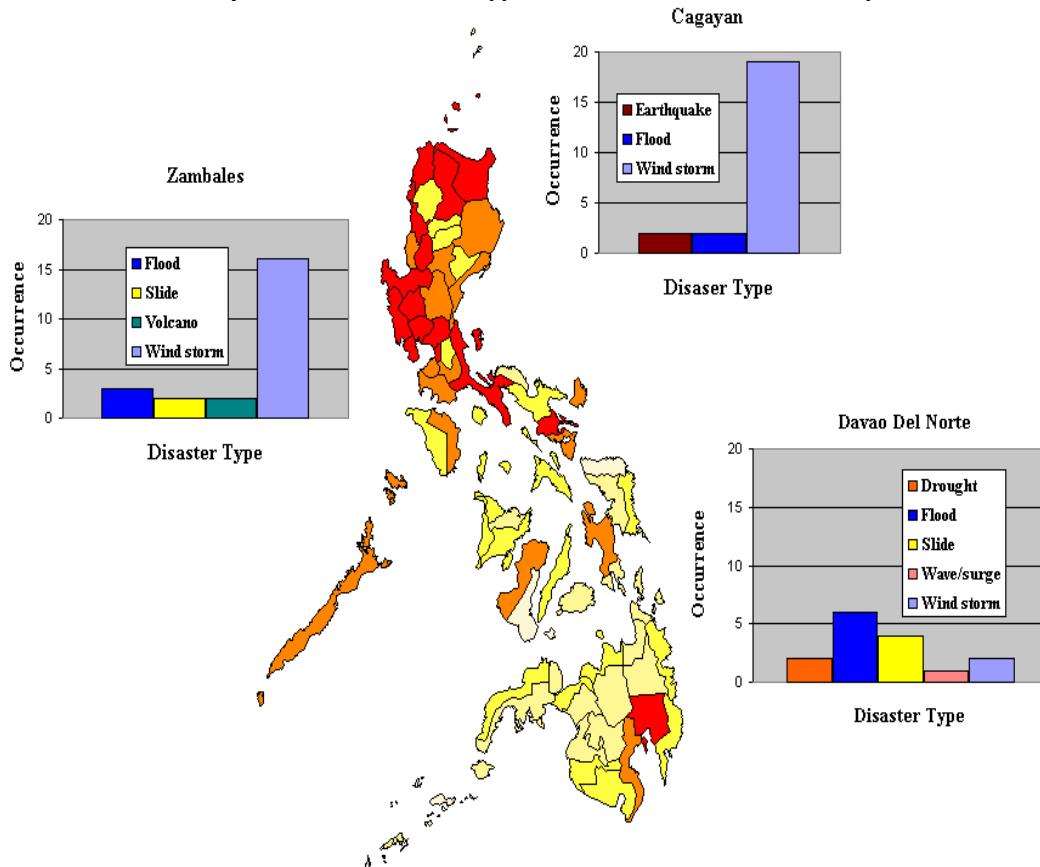
To facilitate improved and timely disaster data dissemination and sharing for effective decision making and relief operations, the Asia FIVIMS has also collaborated with the Asia Disaster Reduction Center (ADRC) to launch the *GLobal IDEntifier Number* (GLIDE) initiative together with other GLIDE partners including the CRED, UN-OCHA/ReliefWeb, USAID/OFDA and the World Bank.[11] All disaster events recorded in the past and new disasters have been assigned a globally common Unique ID code through which any information on disasters published by the GLIDE partners on their websites can be accessed and retrieved instantly as these sites are linked together with the unique GLIDE numbers. Printed documents and reports related to the disasters and published by the partners also carry GLIDE numbers where applicable. For example, the Tsunami disaster that devastated South and Southeast Asian countries in December 2004 is given TS-2004-000147-LKA and TS-2004-000147-IDN for Sri Lanka and Indonesia, respectively. GLIDE numbers are generated automatically and can be obtained from the homepages of the CRED, ReliefWeb and the ADRC. In the Asia FIVIMS, GLIDE numbers are assigned in its web-based dynamic mapping and data dissemination system – *Interactive FIVIMS Data Mapper* – making it possible for system users to rapidly access information associated with disaster events of users' interest. (Figure 15)

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[11] http://www.glidenumber.net

Figure 15. Cambodia Interactive FIVIMS Data Mapper showing the GLIDE number: FL-2000-000438-KHM
assigned to the major flood extent map for 2000 and the percentage of paddy areas affected by drought
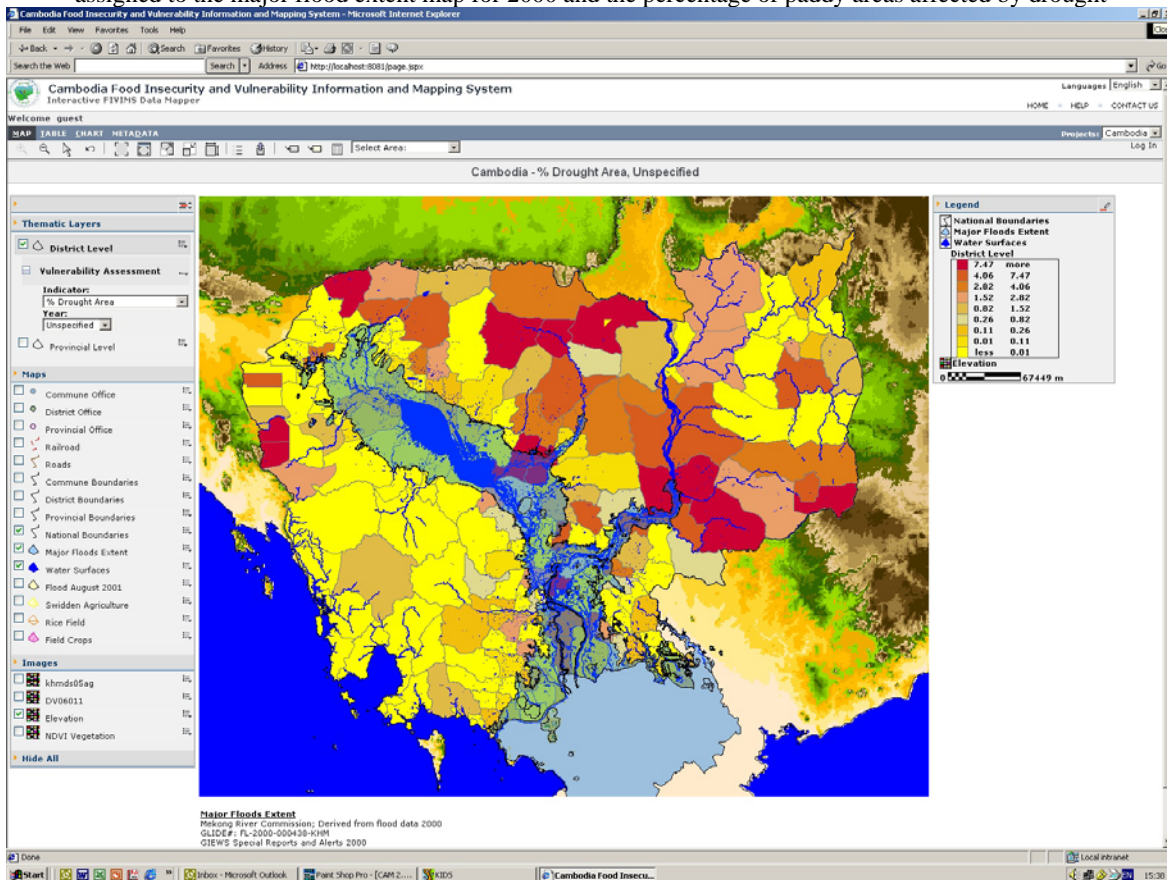
4.4. The Use of the ARTEMIS Data for FIVIMS in Asia

Government agencies involved with disaster management, emergency responses or relief operations, have actively participated in the national FIVIMS Committees and Technical Subcommittees established in most Asia FIVIMS project supported countries. For instance, the National Disaster Coordinating Council at the Department of National Defense in the Philippines has played a vital role in defining the overall framework for the national FIVIMS, whereas the National Committee for Disaster Management in Cambodia has been an integral part of FIVIMS operations. The Asia FIVIMS takes full advantage of and extends the experiences gained by the GIEWS and the ARTEMIS to the national FIVIMS Committees and Subcommittees in disaster-prone – especially drought affected – countries in Asia including Cambodia, Sri Lanka and Thailand. Provision of concrete assistance to the countries began in 2005 with the Office of Agricultural Economics at the Ministry of Agriculture and Cooperatives – FIVIMS Focal Agency in Thailand – and with the national FIVIMS Secretariats in Cambodia and Sri Lanka. The former established the Agricultural Early Warning System (AEWS) in 2004 that has since monitored and provided early earnings of floods, land slides and droughts, as well as estimated disaster impacts on the national economy. With the ARTEMIS near-real time satellite imagery now available through the Asia FIVIMS project every 10 days and monthly, the satellite data have been examined for disaster monitoring in Thailand – in particular, drought – in order to build the capacity of the AEWS, being linked to FIVIMS information already produced by the national FIVIMS Technical Subcommittee. In a similar fashion, the use of near real-time satellite images have been tested by the national FIVIMS Secretariats of the latter two countries and proved to be very useful for building national early warning capacity and for better identifying food insecure and vulnerable areas and populations. In addition, training on *Food Security and Agricultural Drought Monitoring and Assessment Using WinDisp* was

provided to FIVMS Core Analysts and selected Technical Subcommittee members in the respective countries.

5. Conclusions

The Global Information and Early Warning System has five main criteria that must be met in order to accomplish its activities. First, information must be collected and analysed from a wide variety of sources to ensure that all factors related to food security are accounted for. Second, the System must be flexible so that its assessments can be revised quickly as new information becomes available. Third, uniformity is required so that the same types of information and same database structure are maintained for all countries. Fourth, required information management and analysis tools such as the GIEWS Workstation and up-to-date information are in place to assist the GIEWS to undertake crop monitoring and assessments cost-effectively and efficiently, as well as in a timely manner. Fifth, the System's assessments are rapidly disseminated to the international community through both traditional means and electronically. The first and fourth criteria are met through the use of the low spatial but high temporal resolution satellite-derived CCD, NDVI and other agro-meteorological images, which are operationally supplied by the ARTEMIS and utilised by the GIEWS. These images allow the GIEWS to conduct simple but effective spatial and time series analysis techniques, and to meet its need for timeliness and up-to date reporting in support of the Crop and Food Supply Assessment Missions.

It is important to underscore that not all hazard events including droughts result in food emergencies. Disasters and emergencies causing severe food insecurity in developing countries are complex involving multitude of factors – e.g. natural and human induced disasters, political and economical crises, insecurity, etc. – and typically require fairly long time to formulate human response. The nature of emergencies worldwide has changed as we encounter as many human-induced disasters as there are natural ones, although natural disasters still remain a major cause of food emergencies in Asia.

Through the GIEWS and the ARTEMIS, FAO has gained substantial experience in the early warning technology and the applications of remotely sensed images for drought and foodcrop monitoring, emergency responses and relief operations, especially in Africa and Latin America. However, the changing nature of the emergencies requires the GIEWS and the ARTEMIS to change and to evolve in accord with the problems of food insecurity created by disasters and/or crises. Keys to a successful, strong and effective early warning system in this dynamic environment are collaboration, institutional capacity building, state-of-the-art technology, and effective information-response linkages.

Vulnerability analyses being conducted by international and national FIVIMS partner agencies and collaborators have strengthened FAO by providing more accurate and reliable information on the location of food insecure and vulnerable populations and/or areas, and on the causes of their food insecurity and vulnerability. While the GIEWS focuses on short-term, current season food emergencies, FIVIMS draws attention to long-term, chronic food insecurity and vulnerability. Both Systems complement each other thereby augmenting the synergies of the two for more effective drought and food insecurity monitoring and assessments, and facilitating improved decision making and targeted policy and programme formulation. In particular, the Asia FIVIMS is extending the experiences and crop and drought monitoring techniques and knowledge accrued in FAO Headquarters to agricultural disaster-prone countries in Asia where operational early warning systems on food and agriculture have yet to be established. For improved decision making, targeted policy and programme formulation, and timely interventions in crisis situations, national FIVIMSs will increasingly utilise near real-time satellite data together with information generated by the Systems on the food insecure and vulnerable.

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