WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR AGRICULTURAL METEOROLOGY

CAgM Report No. 95

USER REQUIREMENTS FOR SATELLITE AND OTHER REMOTE-SENSING INFORMATION IN THE FIELD OF AGRICULTURAL METEOROLOGY

Prepared by
P. C. Doraiswamy (Co-ordinator), G. B. Diagne, M. Labo, S. K. Shaha, O. Virchenko

Report of the Joint Rapporteurs on User Requirements for Satellite and Other Remote-Sensing Information in the Field of Agricultural Meteorology

WMO/TD No. 1230
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Introduction

This report presents the current remote sensing technology that is applicable to the field of agricultural meteorology. The information presented is applicable for monitoring and assessment of agricultural crops and grasslands and their impact on agricultural production at regional and national levels. The remote sensing technology is accessible to both developed and developing countries and the cost for acquiring the imageries and data from orbiting and geostationary satellite systems have been reduced over the past decade. Some of the imagery is now available without cost to the global user community and they will be identified in this report. However, there is still a great need for training of technical personnel to develop products that are usable to the farmers and managers. The interpretation and timely access to remote sensing products for use in agriculture is lagging behind the development of sensors and the acquisition of data. This report discusses the various types of satellite data that are currently available and examples are provided from different regions of the world that are presently using this technology.

Overviews on the Development and an Update Satellite System Applicable for Agrometerological Studies

The US operated Landsat and French operated SPOT satellites provide high-resolution imagery in a range of visible and infrared bands. They are used extensively for high-resolution studies in natural and agricultural resources.

IRS series: The Indian IRS satellites provide high-resolution imagery in a range of wavebands at visible infrared and microwave bands. Their primary objectives are national mappings of various earth resources.

FY-1: Meteorological satellite program in China consists of two major systems: polar orbiting and geostationary satellites. The main objectives of the programs are to establish, with combination of polar and geostationary orbiters, a comprehensive operational meteorological satellite systems as well as the data application systems, in order to meet the needs on various aspects in China, and enhance the ability to participate international collaboration.

Resurs-O1 series: A series of Russian remote sensing satellites Resurs-O1 is represented by two vehicles: Resurs-O1-3 (launched in October, 1994) and Resurs-O1-4 (July, 1998). Both satellites have polar sun-synchronous orbits, with a mean orbit height of 678 km (Resurs-O1-3) and 835 km (Resurs-O1-4). The spacecrafts are operated by SCR "Planeta". Ground segment of the Resurs-O1 mission includes two large receiving centers at Obninsk and Novosibirsk as well as a net of small regional centers.

Microwave Instruments

ERS series

ERS-1 was launched by ESA in July 1991; ERS-2 was launched in April 1995. This series concentrates on global and regional environmental issues, making use of active microwave techniques that enable a range of measurements to be made of land, sea and ice surfaces independent of cloud cover. In addition, the ATSR instrument on these missions provides images of the surface or cloud top. The GOME instrument on ERS-2 provides atmospheric chemistry measurements.

RADARSAT

RADARSAT is an advanced Earth observation satellite project developed by Canada to monitor environmental change and to support resource sustainability. With RADARSAT's launch in early 1995, Canada and the world will have access to the first radar satellite system capable of large-scale production and timely delivery of data. These data will meet the needs of commercial, government and scientific programs and will provide a new source of reliable and cost-effective data for environmental and resource professionals worldwide.

Large Area Coverage Instruments

NOAA-AVHRR and VEGETATION

These instruments are exhibiting large-scale swath size and a daily revisit capability, which explain their extended use for large-scale land monitoring and vegetation analysis. NOAA polar orbiters: The current series of operational polar orbiting meteorological satellites is provided by NOAA. Two satellites are maintained in polar orbit at any one time, one in a "morning" orbit and one in an "afternoon" orbit. The series provides a wide range of data of interest, including sea surface temperature, cloud cover, data for land studies, temperature and humidity profiles and ozone concentrations. VEGETATION satellite operated by France provides similar bands as SPOT high-resolution data with similar daily coverage and resolution as NOAA-AVHRR.

TERRA: On February 24, 2000, Terra began collecting what will ultimately become a new, 15-year global data set on which to base scientific investigations about our complex home planet. There are three other EOS satellites currently in orbit and fifteen more will follow over the next four years. Together, these spacecraft will help scientists unravel the mysteries of climate and environmental change.

Geostationary Meteorological Satellites

There is a worldwide network of operational geostationary meteorological satellites, which provides visible and infrared images of the Earth's surface and atmosphere. Countries/regions with current geostationary operational meteorological satellites are the USA (GOES series), Europe (METEOSAT series), Japan (GMS series, including the recently launched GMS-5), India (INSAT series) and Russia (GOMS).

Status of Selected Current & Future Commercial Remote Sensing Satellites by Launch Date (last updated 6/24/02)

Operational				
Launch	Satellite (Country)	Distributor:*	Sensor	GSD
1985 – March	Landsat-5 (US)	Space Imaging LLC EDC	MSI	30 m 79 m 120 m
1990 – Jan	SPOT-2 (France)	SPOT Image Corp.	MSI Pan	20 m 10 m
1991 – Aug	IRS-1B (India)	Space Imaging LLC	MSI	36.5 m 72 m
1994 – Oct	IRS-P2 (India)		MSI	36.25 m
1994 – Nov	Resurs-01 (Russia)		MSI	80 m 300 m
1995 – Nov	RADARSAT-1 (Canada)	Space Imaging LLC OrbImage	SAR	8 m
1995 – Dec	IRS-1C (India)	Space Imaging LLC	MSI Pan	23.5 m 70 m 188 m 5.8 m
1997 – Aug	OrbView-2 (US)	OrbImage	MSI	1100 m
1997 – Sept	IRS-1D (India)	Space Imaging LLC	MSI Pan	23.5 m 70 m 188 m 5.8 m
1998 – March	SPOT-4 (France)	SPOT Image Corp.	MSI Pan	20 m 1000 m 10 m
1999 – Jan	ROCSAT-1 (Taiwan)		MSI	800 m
1999 – April	Landsat-7 (US)	USGS	MSI Pan	30 m 60 m 15 m
1999 – Sept	IKONOS (US)	Space Imaging LLC	MSI Pan	3.28 m 0.82 m
1999 – Oct	CBERS-1 (China/Brazil)		MSI Pan	20 m 80 m 160 m 260 m
1999 – Dec	Terra (US)	NASA	MSI	15 m 30 m 90 m 240 m 250 m 500
1999 – Dec	KOMPSAT (Korea)		Pan	6.6 m
2000 – Dec	EROS A1 (International)	ImageSat Intl. Core Software	Pan	1.8 m
2001 – Oct	QuickBird (US)	DigitalGlobe	Pan MSI	61 m, 2.5 m
2001 – Oct	TES (India)		Pan	1 m
2002 – Mar	ENVISAT (ESA)	ESA	SAR	10m
2002 – May	Aqua (US civil)	NASA	MSI	250 m 500 m
2002 – May	SPOT-5 (France)	SPOT Image Corp.	MSI Veg Pan	10 m 1000 m 2.5 m

Status of Selected Current & Future Commercial Civil and Foreign Remote Sensing Satellites continued

Operational and Planned			
Launch	Satellite	Sensor	GSD
2002	IRS-P5 (India)	Pan MSI	2.5 m 10 m
2002	IRS-P6 (India)	Pan MSI	1 m 6 m
2002	OrbView-3 (US)	Pan MSI	1 m 4 m
2003	EROS-B1 (International)	Pan	0.82 m
2003	IRS-2A (India)	MSI	10 m 23 m 125 m
2003	RADARSAT-2 (Canada)	SAR	3 m
2003 or 2004	NEMO-1 (US)	Pan HSI	5 m 30 & 60 m
2004	EROS-B2 (International)	Pan	0.82 m
2004	EROS-B3 (International)	Pan MSI	0.82 m
2004	IRS-2B (India)	Pan MSI	2.5 m 10 m 23 m 125 m
2004	AM-2 (US civil)	MSI	240 m 250 m 500 m
2004	Kompsat-2 (Korea)	Pan MSI	1 m 4 m
2005	Second Generation QuickBird (US)	Pan MSI	TBD 0.5 m TBD 2 m
2005	Second Generation IKONOS (US)	Pan MSI	TBD 0.5 m TBD 2 m
2005	EROS-B4 (International)	Pan MSI	0.82 m
2005	Resource 21 (US)	MSI	10 m 20 m
2005	EROS-B5 (International)	Pan MSI	0.82 m 4 m
2005	Cosmo Pleiades (France/Italy)	Optical Radar	Hi-res Hi-res
2005	SPOT-6 (France)	Pan MSI	5 m 10 m
2006	M5-DigitalGlobe (US)	MSI	5 m
Unknown	EROS-B6 (International)	Pan MSI	0.82 m 4 m

Assessment of the Capabilities of Satellite Systems to Meet the User Requirements in the Field of Agriculture Using an Appropriate Pilot Study

International

FEWS: The Goal of the Famine Early Warning System Network (FEWS NET) is to strengthen the abilities of African countries and regional organizations to manage threats of food security through the provision of timely and analytical early warning and vulnerability information.

Objectives are to determine the geographic extent of ground-derived data, to fill in information for inaccessible areas, and to detect some problems early. Satellite imagery products can be used to get a "bird's eye view" of the situation. One of the greatest strengths of the FEWS project is the ability to combine information gathered on the ground (field observations, market information, and weather station data, etc.) with the "big picture" view provided by the satellite imagery. Over the years, some problems with imagery products used by FEWS have developed, been noted and characterized. This situation creates a challenge to use the imagery products wisely so that accurate conclusions are drawn.

The Normalized Difference Vegetation Index (NDVI) used NDVI to monitor vegetation conditions in the Sahel, where climate conditions are favorable for its use (i.e. no clouds). In recent years, FEWS' mandate has expanded into regions where the seasonal weather conditions are not as favorable for satellite monitoring. NDVI is not as useful in East Africa, the Horn and southern Africa due to long periods of clouds and haze during the most critical parts of the growing season.

Meteosat Rainfall Estimates (RFE) is used to monitor rainfall amounts over most of the African continent. Its strength is that it shows widespread rainfall patterns rather than amounts at one point (ground station data). Every 30 minutes the Meteosat satellite observes and measures the temperature of clouds. A rough relation has been established between the duration of cold (below 235K) cloud tops and the amount of rainfall. The RFE combines the satellite cold cloud duration (CCD) data with ground station data in a sophisticated model that also incorporates other parameters (humidity, wind direction, and topography).

The moister index (CWS) is a third parameter that is generated by FEW is the ratio of water supply to water demand. The “supply” is represented by the sum of the decadal Meteosat RFE and water stored in the soil (excess water stored from previous rainfall events). The demand side is represented by an estimate of potential evapotranspiration derived from data provided by NOAA from a global weather forecast model. The moisture index is computed every 10 days and can be used to monitor the moisture situation throughout the agricultural season. The product relates moisture demand of the atmosphere (estimated by potential evapotranspiration) to the moisture supply available from rainfall to meet this demand. The estimate is based on a moisture “accounting system” calculating the “supply” versus “demand” for moisture.

GIEWS: The Global Information and Early Warning System on Food and Agriculture

Established in the wake of the world food crisis of the early 1970s, GIEWS remains the leading source of information on food production and food security for countries around the world. In the past 25 years, the system has become a worldwide network, which includes 115 governments, 61 Non-Governmental Organizations (NGOs) and numerous trade, research and media organizations. Over the years, a unique database on global, regional, national and sub-national food security has been maintained, refined and continuously updated.

GIEWS has invested in innovative methods for collecting, analyzing, presenting and disseminating information, making full use of the revolution in information technology and the advent of computer communications. The System supports national- and regional-level initiatives to enhance food information and early warning systems.
GIEWS provides policy-makers and relief agencies throughout the world with the most up-to-date and accurate information available. Objective information and early warning will continue to have a crucial role in ensuring that timely and appropriate action can be taken to avoid suffering. In this regard, GIEWS has repeatedly demonstrated its capacity to alert the world to emerging food shortages.

Europe

EC

The European Commission's Joint Research Centre in Ispra, Italy, developed the basic techniques for generating EU Statistics as part of the Monitoring Agriculture by Remote Sensing (MARS) program. The aim of the MARS STAT Project is to improve and harmonize European agricultural statistics using a range of new methods notably remote sensing. The principal objective of this action is to provide early statistical information about European crop surface estimates. This information is integrated into regular crop status bulletins published every month. The results obtained are the evolution percentage at Community level for crop acreage each year with respect to the previous year, as well as indicators of potential yields. The method consists in defining a sample of 60 representative sites for the Community, obtaining and interpreting high-resolution satellite images, primarily SPOT on the different sites and extracting the required information. Service companies, research organizations, and ministries within E.C. Member States, however perform most of the work. The Integrated Agricultural Information System produces regular Crop Status Bulletins. They provide early statistical information about crop surfaces and potential yields to the Directorate General of Agriculture (DG VI) and to Eurostat.

North America

USDA

The Production Estimates and Crop Assessment Division (PECAD) of USDA's Foreign Agricultural Service (FAS) is responsible for global crop condition assessments and estimates of area, yield, and production for grains, oilseeds, and cotton. The primary mission of PECAD is to target, collect, analyze, and disseminate timely, objective, useful, and cost-effective global crop condition and agricultural production information. PECAD brings together remote sensing specialists, agricultural economists, plant pathologists, and hydrology experts to comprise the only operational satellite remote sensing team of its type in the world. Utilizing a variety of geospatial information technologies to analyze global agricultural production and crop conditions.

The mission of the National Agricultural Statistical Service (NASS, USDA) is to improve and advance the services and through research, analysis, and experimentation in statistical methodology and advanced technology and in the development and maintenance of a national area sampling frame and samples. NASS uses satellite imagery to enhance, but not replace, its program of crop acreage estimates and has for the last two decades.

The Spatial Analysis Research Section of NASS develops crop specific digital data layers for selected U.S. Agricultural areas, suitable for use in geographic information systems (GIS) applications. The digital categorized geo-referenced output products use imagery from the Thematic Mapper (TM) instrument on the Landsat 5 and the Enhanced Thematic Mapper of the Landsat 7 satellite. This Program represents a cooperative with several USDA and State agencies. Among the users are other Federal agencies, State and Local governments, Crop Farm Growers Associations, Crop Insurance Companies, Seed and Fertilizer Companies, Farm Chemical Companies, Universities and Value Added Remote Sensing/GIS Companies. The Cropland Data Layer is provided with substantial and the accuracy of crop specific categorization.

Vegetation Condition images based on NDVI are also developed from NOAA AVHRR data. The Vegetation Condition information are developed by two week composite periods. The NDVI measures vegetation vigor caused by chlorophyll activity; this is sometimes called "greenness". These data have proven valuable to USDA policy officials in providing geographic location and monitoring information for vegetation condition in crop areas. Effects of the massive Midwest flood in 1993, the early freeze in 1995, the serious drought in 1996 winter wheat areas, and the late 1996 planting in the eastern corn belt have been monitored using this imagery.

Asia

China

The Center for Agriculture Remote sensing application of the Ministry of Agriculture organized sub-centers all over China to monitor sown area and production of winter wheat, corn and cotton using satellite remote sensing at national scale. The monitoring results are now a part of the official resources of agricultural information system of the Ministry. Technician specialists throughout China work on resources survey, agro-ecological assessment, sown areas, crop condition and disaster monitoring, and yield estimation using remote sensing by Ministry of Agriculture. Its mission is to develop an operational system for agricultural resources, ecology, main crops and disaster monitoring at the national scale for government decision making to support the long-term sustainable development of agriculture in China.

China is also Pioneering in the use of radar for agricultural applications. Scientists and officials of the government in agricultural section pay more and more attention to the radar remote sensing, only does radar serve as all-weathers and whole-day-long monitoring capabilities, but also have many other advantages on the application of agriculture. Conventional visible-near infrared remote sensing is limited during crucial period when clouds occur during rainy season. The spatial resolution many be limiting for operational use from present systems compared to the conventional systems. The cloudy weather, in most eastern part of China, the monsoon weather areas, often happens from May to August, the time when the crops growing and needed to be monitored. It is already the uniform understanding that radar RS has the irreplaceable technological advantage for agriculture. Among the specific applications that are investigate include, land use surveys, monitoring of crop growing conditions, soil moisture measurement and crops classification. Radar remote sensing has specific advantages in some of these applications and can complement conventional remote sensing data.

India

The Indian Space Research Organization (ISRO) has pioneered in launching a series of satellites for various applications that include missions that focus on weather, natural resources assessment, soil moisture and agriculture. The Regional Remote Sensing State Centers (RRSSC) are actively involved in a number of remote sensing applications projects catering to National, Regional, State District and Locale specific needs. With the kind of infrastructure available at the regional centers it is possible to cater to varieties of user requirements. Each center is specialized and well tuned to provide solutions to region-specific problems using remote sensing techniques. Examples of remote sensing applications for agriculture in several key areas are; Crop Acreage and Production Estimation: Remote sensing techniques are used in providing pre-harvest estimates on crop acreage for major crops in various states in the country. Agro-climatic Planning and Information Bank: A pilot project has been on-going for consolidating the large amount of statistical and spatial information generated by various organisations and to create a single-window knowledge base for agricultural development. This provides area specific information on all aspects of farm management that can be implemented by the farmers. This database also a facilitator for providing the users with tools required for preparing developmental plans.

Integrated Mission for Sustainable Development is locale-specific action plans for sustainable development of land and water resources are generated on watershed basis, integrating thematic information generated using satellite data with collateral/conventional information and socioeconomic inputs. The action plans are basically recommendations towards improved soil and water conservation for ensuring enhanced productivity, while maintaining ecological/ environmental integrity of the area/region. The action plans, to illustrate, address identification of sites/areas for surface water harvesting, groundwater recharge, soil conservation measures - through check dams, vegetation bunding; sites/recommendations for improved/diversified farming systems with fodder, fuel wood plantations, agroforestry, agro-horticulture. These action plans are generated by the joint involvement with the respective Governments departments, State Remote Sensing Centers, universities, private entrepreneurs and NGOs.

Collection and Collation of Information on Experience on the Implementation, Operation and Dissemination of Low-Cost Satellite Receiving Stations in the Field of Agrometeorology

The primary source of low cost imagery data available for Agrometeorology over several decades has traditionally been the polar orbiting NOAA AVHRR data. This is a lower resolution data (1 km) and available at almost all regional centers around the world. The low cost of establishing ground station is within the reach of most developing countries at least from regional centers. Since the launch of the Earth Observing System's Terra platform, the MODIS satellite imagery at a relatively higher resolution (250 m) is available through the NASA Data Active Archive Centers (DAAC) in the U.S. The data is free and has to be requested through the Internet Web sites at the various DAAC. Both the NOAA AVHRR and MODIS can be directly acquired through low cost ground stations. The advantage of acquiring these data from regional centers (AVHRR) and NASA (MODIS) is that the data would be preprocessed.

NOAA HRPT Ground Station

The PolarTracker outdoor assembly includes a tracking antenna, pedestal, D-band feed, fully sealed low noise amplifier (LNA) and synthesized down converter. The rugged exterior components of the downlink have been field tested in the searing heat of North Africa, as well as the deep freeze of Antarctica and Alaska. The PolarTacker is a completely automatic earth station. No operators are required. Even orbital element sets are downloaded automatically. System managers control the automatic operation of the system using the Automatic Satellite Acquisition and Processing (ASAP) windows software. ASAP software allows the system manager to specify how many time periods of data to keep for each satellite, which disk drives will be used for data storage, how the data will be processed, and where the processed data will be sent. ASAP software is invaluable when automated over flight scheduling; data acquisition and processing are required.

Terra MODIS Station

The Apex ground station achieved operational status on 14 July 2000. The ground station is used to display to potential clients the systems that will be fully available after the launch of the second satellite Aqua in 2001. Vexcel's basic Apex ground station for EOS uses an antenna with a 3m diameter, receivers and Vexcel's data acquisition and processing sub-systems to provide and process information. Systems upgrades are available allowing customers to receive and process information from additional satellites, the Landsat, ERS and RADARSAT. An antenna system control computer and specially matched RF electronic components are also included. It is designed with economy as a priority, to allow easy, cheap access to the scientific information gathered by the satellites. The information is broadcast free and nearly continuously from the satellites and is available to all ground stations and to spacecraft via a MODIS instrument.

Techniques for Integration Information Coming From Different Satellite Sensors With Ground-Based Meteorological and Agronomic Data Using Gis Technology for Inclusion in Agrometerological Models

Remotely sensed data is a valuable tool to apply in crop models within a GIS environment. Properly and adequately processed remote sensing data can serve as an aid in the definition of management zones to independently simulate in GIS grids of study areas. Biophysical parameters such as leaf area index, crop development, canopy density, and evapotranspiration can be directly input to crop simulation models.

Research on integration of remotely sensed optical and thermal data has been applied in process models (Maas et al., 1992; Maas 1998; Moran et al., 1996). Barnes et al., (1997) applied this method of integrating optical and thermal data for wheat crop yields in plot level studies. Moulin et al., (1995), successfully used this approach, simulating LAI for wheat crop from temporal variation of spectral reflectance at field and local scales. The simulated LAI from SPOT satellite was directly linked to a model to predict crop yields.

In all these field and watershed level research the remotely sensed data from ground, aircraft and satellites, were used to retrieve crop physiological condition/parameter and compare with the simulation results. Assuming that the remotely sensed data is the true representation of the crop condition, model parameters are modified to similar values retrieved from remotely sensed data.

Doraiswamy et al. (2000), went further with this approach of integrating remotely sensed data in crop simulation models in application for spring wheat yield assessment at regional scales. Crop condition and physiological parameters were retrieved from NOAA AVHRR data to adjust the crop yield simulation model. The input data is developed on a GIS grid and simulation conducted at the desired grid level. This was successfully tested over a five-year study in the U.S. spring wheat areas. Further evaluation of this approach was tested with field level verification and yields simulated using the MODIS data for assessment of county level yields of corn and soybeans (Doraiswamy et al., 2001). This integration technique has the potential for operation assessment of crop yields at regional scales.

Requirements for Satellite and Other Remote Sensing Data and Information Including Automated Weather Station Data for Use in Agriculture

There is a need for timely access of satellite based imagery and surface climatic data acquired from polar orbiting and geostationery systems. There is global coverage of data but limitations exit in the availability of adequate number of data downlinks in developing countries. There are National and Regional Centers (International and intergovernmental programs) that have the necessary ground station technology to acquire this data, however the infrastructure to disseminate the data in a regular and timely manner for operational programs may not exist. These are countries that need more attention in developing internet-based dissemination of local and country level information regarding current crop and vegetation conditions. Some the products developed from weekly remotely sensed data such as crop condition and biomass may be monitored through to season and final results such as crop yields may be assessed at the end of the season.

There is a critical need to increase and improve the weather station data network for use in agricultural meteorology programs. The current level of data available at near-real time or at a weekly and monthly frequency is inadequate for timely assessment of management decisions especially during catastrophic events such as drought and floods. There have been advancements in automated data acquisition systems that require little maintenance and can store data in microchips over extended periods of time. These low cost systems require low power and can be solar-charged. A major effort has to be made to develop these data acquisition systems and setup to standards acceptable to WMO. Retrieval and electronic processing of the data is easier than manual weather station data but resources have to be dedicated for the training and set up of and operational system.

Capabilities of Satellite Systems Meet the User Requirements

The user needs to access satellite data and information products are based on dedicating resources for such programs. Training of technical personnel to acquire, process and interpret the satellite imagery is a major task that has to be recognized by management in the Agricultural Ministries. In developed and developing countries the training of technical personnel in the areas mentioned had not been given a serious consideration. The acquisition of satellite data is a much easier than the interpretation of data for specific applications that are critical for assessment and management of natural and agricultural resources. The application areas and the required resources dedicated can vary greatly between the tropic and temperate regions of the world.

Long-term planning and training of technical personnel is a key ingredients to success in the use of current and future remote sensing technologies to benefit the national goals in agricultural development of sustained and improvement for agricultural needs of the twenty first century.

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