Coordinating Role of the Food and Agriculture Organization in Developing Tools and Methods to Support Food-Security Activities in National Agrometeorological Services

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Abstract

The first part of the paper presents a short description on the activities of the Food and Agriculture Organization (FAO) in the field of food security information and early warning systems (FSIEWS) with particular reference to their agrometeorological component. Starting in 1978, FAO has provided technical assistance with multilateral and bilateral financing to more than 50 projects for the establishment of regional and national FSIEWS around the world, to monitor all aspects of food availability, stability of supply, accessibility, and biological utilization. Focusing on the present and future availability of food, the agrometeorological component looks mainly at crop monitoring and yield forecasting, embracing an activity usually carried out by Agricultural Extension Services and National Agrometeorological Services. The second part of the paper concentrates on FAO's approach in the development of methods and tools (e.g., software, databases, training, publications, and advisory services to farmers) for the agrometeorological user community of FSIEWS.

Introduction

The FAO of the United Nations was founded in 1945 with a mandate to raise levels of nutrition and standards of living, to improve agricultural productivity, and to better the condition of rural populations in the world. At present, FAO is one of the largest specialized agencies in the United Nations system and the lead agency for crop and livestock agriculture, forestry, fisheries, and rural development. Since its foundation, FAO has operated to alleviate poverty and hunger by promoting agricultural development and improved nutrition. While food production has increased at an unprecedented rate since FAO was founded in 1945, the world's population grew almost three times over the same period. A specific priority of the organization is encouraging sustainable agriculture and rural development, a long-term strategy for increasing food production and food security while conserving and managing natural resources.

As pointed out earlier, FAO's activities aim to reduce food insecurity in the world, especially in developing countries. This commitment was further reiterated at the World Food Summit (FAO, 1996) where a Plan of Action was adopted aiming at reducing the number of the world's hungry people in half by 2015. The commitment was renewed at the World Food Summit: Five Years Later (Rome, 2002b). This approach targets the increase of food production and improved access to food, but there is also a need to monitor the current food supply and demand situation, so that timely interventions can be planned whenever the possibility of famine, starvation, and malnutrition exists. With an imminent food crisis, actions need to be taken as early as possible to mobilize resources and because logistic operations are often hampered by adverse natural or manmade conditions, including war and civil strife. The availability of objective and timely information is, therefore, crucial and can be achieved by setting up an operational FSIEWS.

This paper stresses the importance of timely and reliable agrometeorological information and describes how FAO has, in the last 20 years, supported the enhancement of its quality and quantity. This was done through the development of appropriate tools and methods in line with the technological progress of software, hardware, and communication facilities but also by the availability of a large choice of geo-referenced data. The development of tools and methods always proceeded in a total and continuous synergy with field projects, where FAO's main investment is represented by capacity building.

Definition of Food Security

At the World Food Summit (Rome, 1996), food security was defined as the situation "[…] when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life." This definition links the four aspects of food security: availability of staple foods, stability of supplies, access for all to these supplies, and the biological utilization of food (FAO, 2001b). Since the 1970s, FAO has been active in supporting the establishment, improvement, and reinforcement of national food information systems, which are the main structure of food security monitoring.

Needs for Timely and Reliable Food Security Information

Forecasting is the basic element of all warning systems, and it must be applied to the four aspects of food security (availability, stability, access, and biological utilization), giving decision makers enough time to react to the warning, with as high-as-possible a degree of reliability (the more long-term the forecasts, the less reliable they are). Very often, the most urgent needs for food information in a country relate to, first, the early identification of food crises among specific vulnerable population groups and their needs for relief assistance, and, second, domestic food production and the annual quantification of national cereal import requirements. The lack of systematic information is a serious constraint to effective planning of commercial and non-commercial food imports, and monitoring relief operations, including targeting of beneficiaries and matching types, quantities, timing, and duration of relief to actual requirements. For this purpose, there is a need for timely crop forecasts, plus information on cross-border or internal flows of people and food; livestock, grazing conditions, and herd sizes; market prices of agricultural inputs, basic foods, and livestock; and other major determinants and indicators of the food security status and risks of acutely and chronically vulnerable groups. Behavioral responses of population groups subjected to acute food shocks caused by armed conflict or drought must be continually monitored to provide indications of the depth of local food crises. The identification of vulnerable groups and using rapid and qualitative methods to complement available data are also needed to plan a timely and appropriate response.

Structure of a Food Security Information and Early Warning System

Most of the existing food-security monitoring systems are organized around the following four main pillars:

- Agricultural production monitoring (APM), normally combined with monitoring products of livestock farming;
- Market information system (MIS) that usually monitors domestic trade and sometimes international trade (import/export);

- Social monitoring of the most vulnerable populations or monitoring of groups at risk (MGR) that focus on monitoring poverty; and,
- Food and nutritional surveillance system (also called food and nutrition monitoring) (FNSS), which generally, depending on the situation, monitors the health and nutritional status of populations.

These four pillars are generally countrywide and linked to the technical services of each of the ministries concerned. They have specific aims and set up their own means and organization, but it is fundamental that all of them set up an integrated system. Thus, the monitoring of food availability (production + imports - exports - losses) should be supported by monitoring information on both production and foreign trade supplied by the Market Information System; the monitoring of the stability of supplies, which uses data from the Market Information System as well as data on the status of infrastructure and stocks; the monitoring of access to these supplies, which should take into account mainly social indicators (poverty, unemployment, migrations, etc.); and the monitoring of biological utilization, which should use data acquired from health and nutritional monitoring. Figure 1 shows the conceptual framework of the FSIEWS (FAO, 2001b).

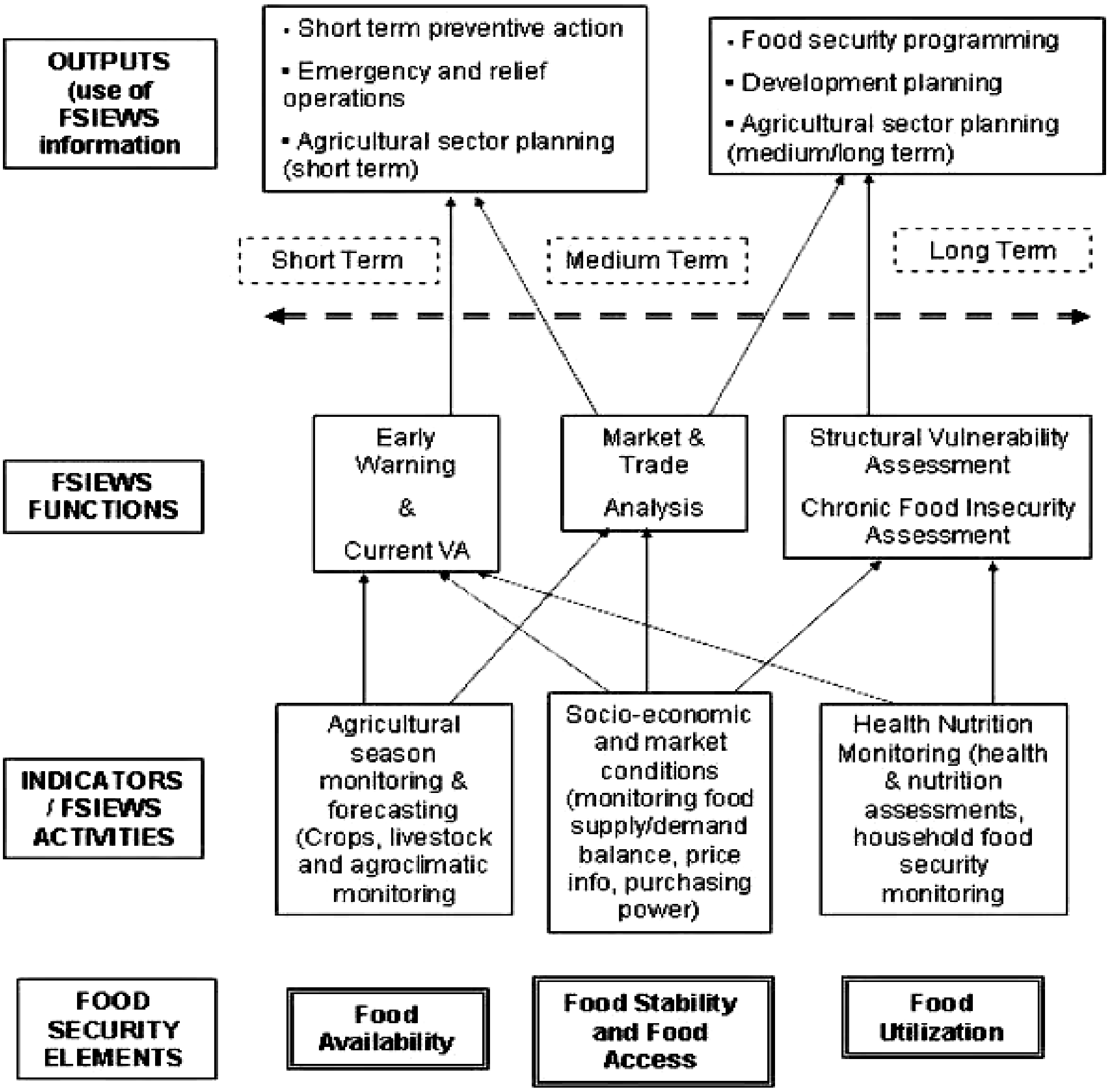

Figure 1. Conceptual framework of the FSIEWS.

The Agrometeorological Component of FSIEWS

The agrometeorological component of the FSIEWS is integrated into the agricultural production monitoring, particularly, concerning cereal crops and pasture. Most of the crop monitoring and forecasting methods are developed around the water balance calculated during the growing season and take into account the phenological development of the plant. The agrometeorological approach produces better results in semi-arid areas where the water deficit is the main factor limiting crop productivity. This approach gives less satisfying results in regions (even semi-arid ones) where: 1) farming does not follow a homogeneous pattern, 2) area is not well represented by the neighbor weather stations; and, 3) excess of water, sunshine amounts, incidence of pests, and diseases tend to be the main limiting factor(s). Simple statistical (trend) models perform very poorly in semi-arid countries, where the inter-annual variability of yields reaches very high values.

The monitoring of rainfed crops is based on the following principal tools:

- Use of real-time meteorological data;
- Use of crop-specific water balance models;
- Processing of real-time satellite images (mainly by NOAA, SPOT – Vegetation and Meteosat satellites);
- Use of spatial interpolation tools;
- Use of gridded surfaces of crop-related parameters derived, or not, from satellite images (e.g., soil water holding capacity, soil type, land cover, land use, crop area sample, etc.);
- Use of seasonal forecasts;
- Field sample surveys, mainly for harvest estimates.

These tools can be used for rapid qualitative evaluations of crop status (development, stage in the cycle, condition, etc.), which can become quantitative depending on the availability of additional information (agronomic data, statistics on yields, long-term time series, etc.) and providing the information is validated.

The National Oceanic & Atmospheric Administration (NOAA) satellite produces digital images from which a Normalized Difference Vegetation Index (NDVI) is obtained. NDVI provides a measure of the amount and vigor of vegetation at the land surface. The magnitude of NDVI is related to the level of photosynthetic activity in the observed vegetation. In general, higher values of NDVI indicate greater vigor and amounts of vegetation. NDVI is derived from data collected by National Oceanic and Atmospheric Administration (NOAA) satellites, and processed by the Global Inventory Monitoring and Modeling Studies (GIMMS) at the National Aeronautics and Space Administration (NASA). NDVI is a nonlinear function that varies between -1 and +1. Values of NDVI for vegetated land generally range from about 0.1 to 0.7, with values greater than 0.5 indicating dense vegetation. This satellite index is largely correlated with the volume of living vegetation. In arid and semi-arid conditions, the state of crops and the surrounding vegetation are closely linked.

The SPOT-Vegetation satellite produces digital images from which an NDVI is also obtained. The geostationary Meteosat satellite produces infrared temperature images every half-hour. In tropical regions, it can be assumed that areas with temperatures lower than about –40°C are covered with rain clouds. The cumulated number of hours in a given period (i.e., 10-day) with this low temperature is defined as Cold Cloud Duration (CCD) and it can be represented as a digital image. The relationship between rainfall and CCD is positive, in other words, high rainfall values generally coincide with high CCD values. As a result, a geo-referenced image is produced to provide decadal amount of rainfall over Africa, namely Rain Fall Estimate (RFE).

The Agrometeorology Unit of FAO

The Agrometeorology Unit is part of the Environment and Natural Resources Service (SDRN) in the Department for Sustainable Development. SDRN is the FAO focal point for environmental data. The Agrometeorology Unit collects near real-time meteorological data (mainly precipitation) from various sources for several hundred stations around the world to be used for the agrometeorological crop monitoring and yield forecasting. Reference data, covering almost 30,000 weather stations worldwide, including normals (30-year averages) as well as time series, come from various published and unpublished sources, mainly National Meteorological Services and international research centres.

Since 1978, FSIEWS have been established in almost 50 countries and the agrometeorological component is an integral part of the structure of the FSIEWS. In conceiving and implementing field projects aiming at the creation of the FSIEWS, great attention (also in terms of budget) has always been devoted to capacity building. To achieve this goal, three axes are followed: 1) Direct and permanent link with national agrometeorological services and regional institutions to avoid building a new structure but rather to strengthen the existing one with particular attention to internal and external staff training; 2) Technical partnership with international organizations; and, 3) Continuous development of agrometeorological software for crop monitoring and yield forecasting, mainly database management and applications.

Starting in 1974, the Agrometeorology Unit has developed and continuously improved a crop-forecasting methodology with the aim of supplying updated information on crop conditions in sub-Saharan countries to FAO's Global Information and Early Warning System (GIEWS), and also to provide tools to the agrometeorological component of the various national Food Security Information and Early Warning Systems. In the early days, a qualitative (manual) methodology was elaborated, based on the relationship between the Water Requirements Satisfaction Index (WRSI), as produced by a crop-specific water balance, and the crop condition (Frère and Popov, 1986). Today, the methodology aims to predict crop yields (tons/hectare) and production before the harvest actually takes place, typically a couple of months in advance (May or June for the Northern Hemisphere).

This approach is characterized by the integration of the various tools as described in section 5 and the data-flow shown in Figure 2. The left-hand side of the figure (elliptic boxes) lists the sources of the data: the meteorological network, satellites, field observers (mostly agricultural extension staff), and national services dealing with soils (e.g., soil survey), crops (services of the ministry of agriculture), and national agricultural statistics. The number of partners and the diversity of data types create some difficulty, as well as interesting problems, which were described elsewhere (Gommes et al., 1996). Each of the sources may contribute one or more types of data (second column, rectangles). For instance, meteorological data can be provided, in addition to the ad hoc national network, by remotely sensed sources. Several methods are now available that are used to derive or interpolate rainfall or sunshine data from satellite information. The same applies to some crop data such as planting dates, which may be derived from NDVI time series. Based on the meteorological and agronomic data, several indices are derived which are deemed to be relevant variables in determining crop yield, for instance crop-water satisfaction, surplus and excess moisture, average soil moisture, etc. The indices (variables) then enter an equation (the yield function) to estimate station yield. At this stage, the data are still station-based since most input is by station. Station yields are then area-averaged using, for instance, NDVI as a background variable, possibly adjusted with other yield estimated provided by national statistical services, multiplied by planted area to obtain a district production estimate.

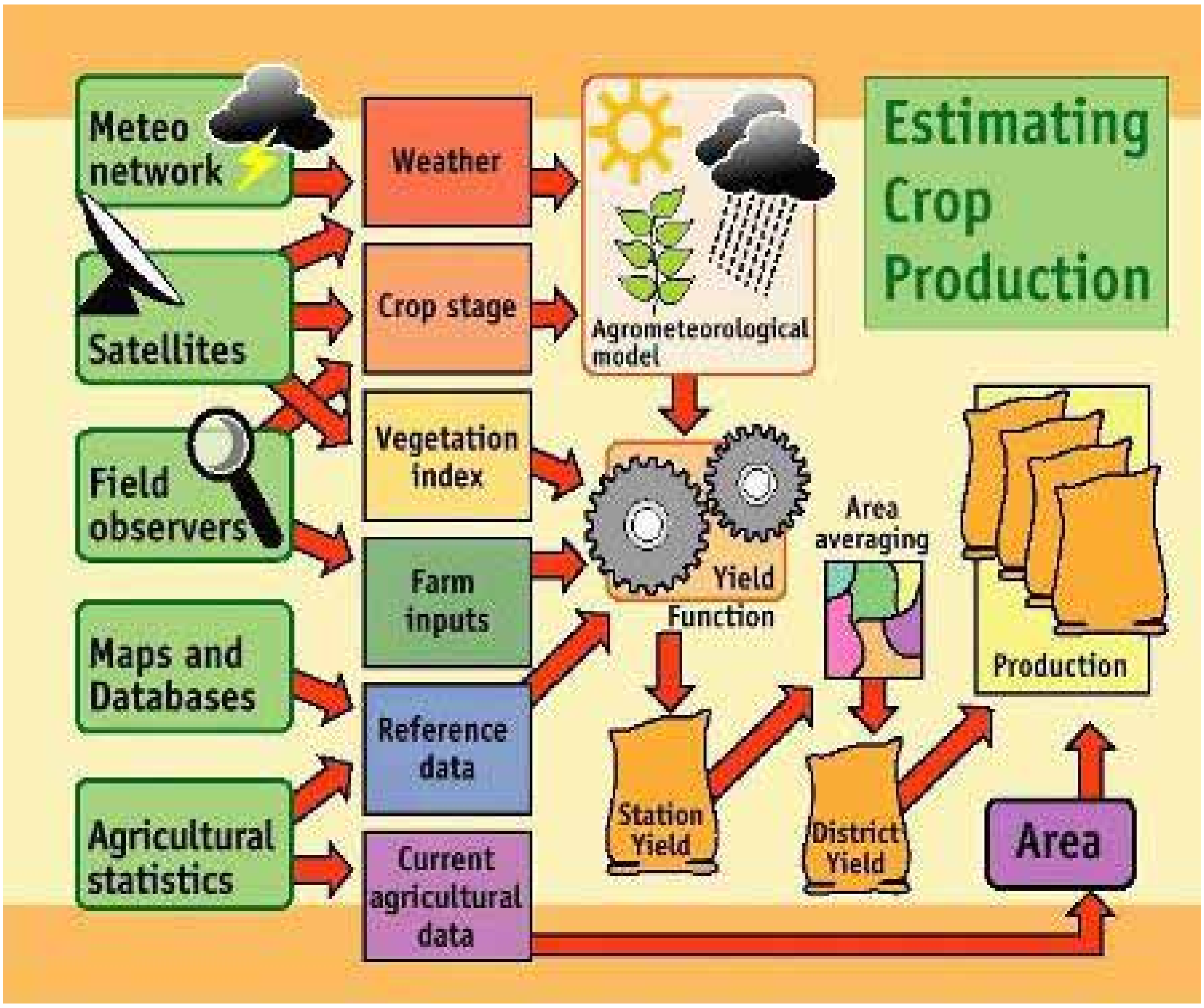

Figure 2. Estimating crop production.

Institutional Situation of the Agrometeorological Component of FSIEWS

From an institutional point of view, the agricultural production and harvest forecast monitoring systems are usually established in two stages: establishment of an operational monitoring structure, and gradual fine-tuning of the system as it becomes a forecasting system, upon inclusion of further inputs such as information on nutrition and markets. The systems can be situated within two different institutions: a technical directorate under the ministry of agriculture, and the national meteorological services. The latter can be placed under the ministry of agriculture or, very often, under the ministry of transport. In principle, all the FSIEWS's institutions provide information in their particular areas but, often, their data management and their analyses capacities are main weaknesses. Furthermore, data and information exchange among various FSIEWS's institutions and external partners must often be authorized by specific agreements or by governmental decrees, creating large delays in implementing it.

During recent years, FSIEWS' concept has evolved in line with many governments' decentralization policy, at the district level there is a need to synthesize and analyze data and information to monitor emergency conditions and vulnerable groups and plan timely relief responses. However, the needed capacities at the district level are weak and human resources need to be adequately trained to assume these responsibilities.

Technical Situation of the Agrometeorological Component of FSIEWS

Two of the reasons for the weak or non-existent data flow into FSIEWS from partner institutions are the weak institutional support structures and the lack of effective networking. A very important structure for an efficient data flow is represented by the agrometeorological networks, from the simple rainfall station to data transmission, collection, archiving, and analysis. Furthermore, the links between FSIEWS and its partners and among FSIEWS's institutions are crucial. At the same time, vertical institutional links between national and sub-national levels, as well as clearly identified and strong structures that support FSIEWS activities at sub-national levels, will require institutional capacity building through training and institutional organization of existing structures. This is reflected in a joint training effort between FAO and the national institutions. It can be estimated that about half of the FSIEWS in Africa have reached the situation where they are able to issue quantitative forecasts, while the other half are still in a situation of a simple crop monitoring. It is usually not the poor quality of data that prevents countries from going from qualitative to quantitative. The limiting factor tends to be the lack of properly trained agrometeorologists. Training and reduced staff turnover are two of the solutions to this situation. It is essential that users receive only products that are stable in time and space and are (tools and data) low-cost/free-ware. This is not only because financial resources of many national services are limited, but also because of the bureaucratic difficulties for the national services to spend money abroad. One of the ways to solve this problem is to have the tools developed and made available by FAO or other non-profit organizations.

At the end of the data processing, information is generated and must be disseminated, but the main limitation to the dissemination of information is the interaction between agrometeorologists and the extension workers, from basic understanding to practical applications. This is the reason why information and communication technologies must be a component of the training of agrometeorologists in order to provide the best possible advice to the decision makers and the farming community (Weiss et al., 2000).

FSIEWS and Agrometeorological Component Users' Needs

The potential users of the FSIEWS and their needs could fill several pages. Referring to the agrometeorological component, it is relevant to quote the aims of agrometeorology by Austin Bourke (1968) and cited by Monteith (2000): "The task of the agrometeorologist is to apply every relevant meteorological skill to help the farmer make the most efficient use of his physical environment, with the prime aim of improving agricultural production; both in quantity and quality. The agricultural meteorologist can be helpful only in so far as inspiring the farmer to organize and activate their own resources in order to benefit from technical advice."

In order to play an efficient role for the improvement of the agricultural production, the agrometeorological service should implement the recommendations as clearly stated by Stigter, et al., (2000) at the International Workshop on Agricultural Meteorology in the 21st

Century held in Accra, Ghana. As far as the FSIEWS users' needs are concerned, the agrometeorological component has a major responsibility before and during the cropping season because the major factor affecting yields and production in developing countries is the inter-seasonal weather variation. It becomes more and more important to supply seasonal climate forecasts, in particular, before the start of the cropping season in order to adapt the agricultural system to increased weather variability (Archer, et al., 2003). Lessons learned from local initiatives show main constraints and corrective measures to improve communication between agrometeorologists and farming communities about seasonal climate forecasts (Patta and Gwatab, 2002). It must be stressed that agricultural production and food security in developing countries can be improved by more efficient agrometeorological advisory services to farmers, in order to stabilize their yields through management of agroclimatic resources as well as other inputs such as fertilizer and pesticides (Gommes, 1997).

Databases and Applications Software Development Support

Most of the existing FAO agrometeorological tools were and are developed in pursuing the three axes listed in section 5 and in direct response to local requirements of the FSIEWS, but also taking into account the technological progress, particularly software and hardware. Concerning data, such as background information on field inputs and satellite indices, FAO has often been a precursor by testing the potential of new data types, in particular, remotely sensed data. The result is a near-optimal integration of meteorological, remotely sensed, and other geo-referenced data for the application of various agrometeorological tools in combination with GIS's routines.

The Y2K represents an important milestone for the FAO Agrometeorology Unit as, since then, most of the application's programs have evolved for a better response to users' needs (FSIEWS in particular), performance, and integration. The evolution looks at four objectives along the same viewpoint (from station value to gridded data): 1) Better meteorological data quality and accessibility to a larger audience; 2) integrated agrometeorological tools, mainly for crop monitoring and yield forecasting; 3) spatial interpolation tools, to create climate "surfaces" and to estimate local climate; and 4) GIS tools for agrometeorology, mainly for analysis of remotely sensed data.

Concerning the first objective, the Agrometeorology Unit has taken some initiatives to overcome the impasse caused by the end of support of the existing software operating under the DOS environment and to migrate the global climatic database into the FAO Oracle Data Warehouse. Climatic and real-time meteorological data from different sources are collected under various forms and, depending on the various input formats, data are either manually entered and stored digitally or processed by the Data Management Module of CLICOM (Climate Computing) software developed by the World Meteorological Organization (WMO, 2001), or by the Automated Climate Data Management (ACDAM) software developed by FAO (Verelst, 2000). The new system will allow you to incorporate data into a modular database running under a Relational Data Base Management System and link to an interface under MS-Access.

Another important objective is the development of AgroMetShell (AMS) which is an integrated toolbox used to assess the impact of weather conditions on crops, using statistical and crop-modeling approaches. It is a collection of tools for the integrated analysis of ground data and low-resolution satellite information, which have been brought together under a common interface. AMS is built around a database of crop, weather, and climate data that are used to compute a crop-specific soil water balance and to derive some agronomic/agrometeorological value-added variables (indicators) used to assess crop conditions (FAO, 2004). The software integrates data analysis and Image Data Analysis (IDA) functions. The main functions of AMS include the following:

- Database functions (configure, input, output, and manage data);
- Daily of 10 total crop-specific soil-water balance measurements to monitor crops and carry-out risk analyses;
- Several methods of spatial interpolation of agroclimatic variables and other indicators and their output in gridded format; and,
- A number of calculations commonly carried-out by the operational agrometeorologist of the FSIEWS, such as calculation of crop-water consumption (potential evapotranspiration), rainfall probabilities, growing season characteristics, statistical analyses, etc.

The third objective is represented by LOCCLIM 1.0 (Local Climate Estimator), which is a computer program that estimates the climate for any location on Earth. It is based on the worldwide climatic database FAOCLIM2 (FAO, 2001a) developed and programmed by Dr. Jürgen Grieser of the German Meteorological Service (FAO, 2002a). Using the Inverse Distance Weighted Average (IDWA) approach, LOCCLIM 1.0 offers:

- Estimate of the climate (expectation values of eight variables) at any location specified either by coordinates or by a mouse click on a map;
- Estimate of the uncertainty of the given results with respect to regional variability;
- Estimate of the altitude dependency of the variables and of the horizontal gradient of the variables;
- Estimates of monthly as well as decadal and daily expectation values;
- Calendar day on which the variables have their maximum and minimum;
- Number of days with expectation values above a threshold;
- Calculation of the length of the "growing period" or "growing season" which is the period (in days) during a year when precipitation exceeds half the potential evapotranspiration.

The “NEW_LOCCLIM” will be issued shortly. Next to other improvements, it will include eight different interpolation techniques next to IDWA and the possibility to operate on user-provided data.

WINDISP is multi-donor software developed for the display and analysis of satellite derived images of low-resolution, high-frequency satellite imagery available in near real-time through FAO-ARTEMIS (Advanced Real Time Environmental Monitoring Information System) such as from NOAA, Meteosat, and SPOT-Vegetation. The current version (WinDisp version 5.1, FAO, 1998) allows the user to:

- Display and analyze satellite images;
- Compare two images and analyze trends in a time-series of images;
- Extract and graph trends from a number of satellite images such as during the growing season for comparison with other years;
- Compute new images from a series of images, and extract statistics from a series of images;

- Display tabular data in map format;
- Build custom products combining images, maps and specialized legends;
- Write and execute batch files to automate routine and tedious tasks; and,
- Build a customized project interface for providing users with detailed menus of available data for a country or a specific area.

Conclusions

Agrometeorology is an important component of the "food security information and early warning systems" that monitor the availability of food by evaluating the impact of weather and climate on crop development. A sizeable part of the staff and financial resources of the FAO Agrometeorology Unit is devoted to the technical support of FSIEWS around the world. The main activities of the Unit include the development of tools and methods for crop monitoring and yield forecasting, starting with the re-habilitation and/or strengthening of the agrometeorological networks, and all aspects linked to the data transmission, collection, archiving, analysis, and dissemination. The basic philosophy is a total synergy with national and regional institutions and the development of integrated toolboxes, such as AgroMetShell, involving agrometeorology, remote sensing, and GIS tools for data collection, spatialization, and analysis.

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