Agrometeorological Services Required Under Emergency Situations: An Example from Afghanistan

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Abstract

In this paper, the requirements under emergency situations for a fully operational Agrometeorological Services in Afghanistan are presented. The requirements include: installation of meteorological stations, data transmission, data archiving, data control, data processing, analysis, results, and products issued. Important consideration has been given to the development of agrometeorological database, information systems, and statistical analyses. The paper also describes the process of capacity-building through intensive on-the-job training courses in Kabul and the use of advanced agrometeorological tools. All of these tools are necessary to respond to any question emanating from the Ministry of Agriculture and Animal Husbandry (MAAHH), as well as from the decision-makers in the country such as: the Food and Agriculture Organization (FAO), the Famine Early Warning System Information Network (FEWS-NET), the Ministry of Rural Rehabilitation & Development (MRRD), the World Food Program (WFP), the Ministry of Irrigation, Water Resources and Environment (MIWRE), and food security audience, in general. All these tools, equipment, and means are presently being used in Afghanistan.

Introduction

An FAO project supporting the Food, Agriculture and Animal Husbandry Information Management and Policy (FAAHM) Unit gathers all available information regarding:

- Agro-economic and statistical data/information for food crops;
- Historical meteorological data (time-series) from the Afghan Meteorological Authority (AMA); and,
- Historical crop yields/production (time-series emanate from the Central Statistics Office [CSO]).

The project supports the establishment of an agrometeorological unit located under the FAAHM Unit within MAAHH. A fully operational agrometeorological service in Afghanistan will still require the remainder of 2004 for a full-time team of well-trained agrometeorologists (International Expert + five local specialists + logistics support) to implement the program. To build such a system, the agrometeorological project of the Food Security and Early Warning System of the FAO Emergency Programme, includes the following steps:

- Establishing a wide-rainfall stations network, (at least 205 reliable stations for this preliminary period), combined with a crop-monitoring network (80 reporting fortnightly stations: crop stages/pasture and condition;
- Installing 26 complete agrometeorological stations (including 6 automatic complete stations with solar panel) over all the country;

- Designating focal persons at the regional agrometeorological office levels (Hirat, Mazar-I-Sharif, Kunduz, Kandahar, Fayzabad, Jalalabad, and Ghazni);
- Defining efficient scheme of circulation of the meteorological and agrometeorological information (modern transmission tools);
- Installing appropriate computer programs for data entry, management, and analysis of agrometeorological data;
- Preparing required meteorological reporting forms such as Microsoft (MS) Excel worksheets, mailing list for users of agrometeorological bulletins, and checklist for an agrometeorological spreadsheet bulletin, etc.;
- Defining the layout and contents of the decadal, monthly, and yearly agrometeorological bulletins;
- Setting up an agrometeorological data management system, including Crop Water Requirement Satisfaction Index and utilization of remote sensing products (for staple and pasture);
- Setting up an integrated database for data collection, analysis, and reporting on early warning and food security;
- Setting up an operational methodology (crop-yield forecasting model) for the conduct of crop assessment and food production;
- Setting up an operational methodology for the conduct of pasture assessment (Livestock Early Warning System [LEWS]); not yet established;
- Improving and standardizing permanent agrometeorological early warning information system methodologies, tools, and techniques;
- Organizing workshops and on-the-job training at different levels and matters regarding agrometeorological techniques, methodologies, and computer science to raise the level for the local staff; and,
- Setting up an operational website and information system.

Inputs

This part of the paper explains the meteorological situations in Afghanistan. Afghanistan is an arid to semi-arid country whose agricultural production depends on the availability of water, either as direct rainfall or in the form of irrigation. In Afghanistan, rainfall data is difficult to access due to the fact that most of the old time-series was stopped in 1977 or, in some cases, in 1992. Meteorological stations have been damaged and no rainfall data are being collected (except from four agrometeorological stations: Kabul, Jalalabad, Mazar-I-Sharif, and Herat installed in 1999 under the FAO project). The Meteorological Department and the Institute of Meteorology are not functioning regarding field observation.

Due to this particular situation, agrometeorological observations have become a very important task for the country. Due to the area of the country (646,000 km²) and the very erratic spatial distribution of rainfall for mountainous regions, data from a large network of rain gauges are required. In addition to rainfall, other parameters are highly important and needed in Afghanistan. They are: snowfall and snow cover, upon which most of the country's irrigated sector depends; and frost and low temperature. Accurate and timely information on agrometeorological observations, including all weather parameters, actual planting time, areas planted, harvested crop, and crop conditions and pasture are highly needed for each agro-ecological zone and each district in Afghanistan. In other words, the agrometeorological approach to helping agriculture can only be effective if reliable, real-time, and timely data are available.

The timely collection and the proper utilization of agrometeorological information help promote increased farm profits under favorable weather conditions or decreased farm losses under unfavorable conditions. In this sense, a fortnightly form of crop and pasture monitoring is used for 80 sites that cover the most important agricultural areas in Afghanistan. The field observations come through pre-printed forms from**:** agriculture services, some non-government organizations (NGOs), and meteorological department staff.

To be accurate and reliable, the forms are filled out with care regarding the quality of the data recorded, the representation of each site of observation, and the timetables of summaries of all observations according to the international norms in force emanated by the WMO.

Crop and Pasture Monitoring Forms

Rules were followed regarding:

- Levels of measures (heights of sensors): same for all selected stations;
- Time and numbers of daily observation, to be standardized for the whole country;
- Use of standard and same type of instruments compliant with the official network that we installed with the agrometeorological FAO project; and,
- Respect of standard for representation of the sites of measures (security problems and some fund limitations have hampered the best choices concerning the site's representation).
- Regular reporting procedures regarding: Timely data transmission; Data collection and archiving using software such as FAO-AgroMetShell, MS-Excel, and MS-Access; Data calculation and analyses of weather impact on crop production (several agrometeorological tools are used presently in the FAO project).

The need for observation requirements for Afghanistan regards essentially the biological information with fortnightly frequency for all administrative areas for wheat, maize, rice, and barley. The observations are carried out on crops and rangeland conditions in the neighborhood of each installed rain gauge station or complete meteorological station (in general, less than 5 km radius from the meteorological station). The goal and objectives of biological observation is to assess crop status, pests, and diseases incidence; pasture availability, plus livestock movement route and transhumance. These observations concern, at a glance: crop stages, crop growth and condition, adverse effects, forecasted crop harvest for the current year in comparison to previous year's harvest.

Field crops and pasture reporting actually practiced in Afghanistan are:

- Phenological: main stages (easy to observe) for three staple crops;
- Crop condition;
- Pasture condition: agrometeorological support services for livestock (relation between water, grazing, and livestock condition) in conjunction with the LEWS**.** However, this work is not implemented yet. The cattle breeding nomads are the Kuchi in Afghanistan. The Kuchi comprise an estimated 7 percent to 10 percent of the Afghan population. They also form the Peulh (Foula) in all of West Africa.
- Phytosanitary conditions: the status of phytosanitary conditions concerns insect infestations. For instance, Moroccan locust attacks in areas infested and treated (as well as other insects) depend on the agroecological zone areas and incidence of plant diseases.

All of their apparitions are strongly linked to: a) essentially the climatic conditions that are harmful, especially for the critical phenological period; b) plant species/varieties; and c) farming practices in the production area. Observations, in cooperation with the Plant Protection Department, concern frequency, incidence, and recognition of the danger in the fields. The information collected is very useful for Plant Protection Services.

- Phyotosanitary treatments: eradication of weeds and frequency and use of any chemical products;
- Planting and replanting times (including delays) and average length of season by agricultural area;
- Input used: fertilizer [Urea, Diammonium Phosphate (DAP)], manure, phytosanitary products, or shortage of inputs.

Meteorological Information

This section provides details of the information that is collected and summarized into the decadal agrometeorological bulletin, along with the type and frequency of observations at each agrometeorological station. In this matter, each parameter is recorded daily along with the values accumulated and/or calculated for each current decade, which are sent using a timely transmission tool to the respective FAO sub-offices in Afghanistan.

The goal of physical observations is to know more about the biotope surrounding the field of cultivation. In other words, to know more about the weather conditions that regularizes the life of the plants. For our purpose, meteorological data are recorded at various types of stations (traditional rainfall and automatic agrometeorological stations). All the agrometeorological stations are situated in agricultural areas where instruments are exposed to atmospheric conditions similar to those of the surrounding crops. At these complete stations, air temperature, humidity, wind speed, and sunshine duration are typically measured at 2 meters (m) above ground level. Climatic data for selected stations are regularly collected in addition to the respective coordinates (latitude, longitude) and elevation. To maintain the accuracy and representation, the instruments are installed inside radiation shelters having natural ventilation except for rain/snow gauges.

The weather variables collected in Afghanistan are:

- Total daily rainfall in millimeters (mm);
- Intensity/frequency/duration of the rain (rain recorder);
- Snowfall: snow depth and water equivalent in mm;
- Decadal rainy days;
- Air temperatures (mean, maximum, minimum);
- Daily temperature feature (thermograph);
- Relative humidity in percent (hygrograph);
- Wind speed at 2 m level;
- Sunshine duration in hours;
- Evaporation (pan A evaporometer) in mm and wind speed at 0.5m, plus water temperature; and,
- Dew point temperature.

On the other hand, information about rivers' flow discharge and hydrometeorology information in general can be added, in relation with the importance of winter snow (in collaboration with Afghan Water Resources and Irrigation Departments).

Determination of Some Derived Parameters

The list of the derived outputs follows:

- Decadal Potential Evapotranspiration (PET): calculated according to Penman–Monteith method, (decadal step);
- Or, estimated by Pan Evaporation class A or, estimated by satellite Aqua/MODIS method (daily step);
- Decadal Water Requirements Satisfaction Index (WRSI): Crop Water Balance Model (decadal step) using FAO AgroMetShell program;
- Soil water stored at each end of the decadal;
- Water deficits and/or surplus; and, actual evapotranspiration (the use of such a water balance model to analyze the impact of agrometeorological conditions, essentially water, extends the scope and abilities of agrometeorological methodology).
- Historical WRSI for wheat, rice, and maize to determine minimum, maximum, and standard deviation WRSI values for the available time-series (1942 to 1977) in Afghanistan (useful as a predictor for the future crop-yield forecasting model);
- Mean water requirements (in mm) for different planting dates (wheat, barley, rice) and different crop coefficients by decade and each selected site (we change the planting date to see the variation of water requirement);
- Simulation and determination of the best planting dates;
- Accumulated degree days for different thresholds (0° and 10° C);
- Global radiation estimated from sunshine duration in mm water equivalent (not yet implemented);
- Soil moisture (for Agricultural Research Station only) in percent of the soil volume;
- Satellite files and pictures (remotely sensed data: Normalized Difference Vegetation Index (NDVI), snow cover and depth, estimated rain (RFE) and actual daily evapotranspiration);
- Snow-cover surveillance, ground observation, and expected potential water availability (water supply) during the summer for irrigation**.**

Livestock Transhumance and Pasture Availability

This section refers to the LEWS. In the future it will be included in the workplan of the FAO Agrometeorological Project due to the importance of livestock in Afghanistan. The assessment will be done by using the following:

- Biomass estimated by NDVI, and water balance model used for grazing and forage (rangeland index: 100 days cycle length and Kc=1);
- Transhumance and livestock movement routes and date's observations;
- Hydrological information **(**in collaboration with irrigation world bank project);
- Level of water table in the wells;
- Rivers stage and discharges, spring stream, and river flows and,
- Satellite imagery (to be received through Rome FAO Headquarters and United States Geological Survey (USGS), Afghanistan, MS Windows product)**.**

The NDVI assesses covert vegetation according to the total biomass (reflecting biomass levels) and freshness (water stress in crop or grass result in lower NDVI values). The trend in NDVI from decade to decade for specific areas is a good indicator for onset of rain, dry spells, and the quality of the season. Comparisons with previous decade and previous years or average values provide useful information.

Decadal files of NDVI are received at decadal steps via e-mail through the Artemis system at FAO headquarters in Rome, Italy, and from which numeric values are extracted and analyzed, summarized, and can be used as a predictor in the future into the Crop Yield Forecasting Model. The staff of the agrometeorological project are summarizing and analyzing the overall NDVI time-series (several years, since 1998) for Afghanistan.

Aqua/MODIS Estimated Evapotranspiration PET

National Aeronautics and Space Administration (NASAs) Earth Observing System (EOS)

The evapotranspiration will be retrieved at 500 m spatial resolution and composite on an 8-day basis using the Aqua/MODIS satellite instruments. Evapotranspiration is described as a fractional value called "Evaporation Fraction (EF)," which is a fraction of latent heat energy to available energy. This value represents not only the "dryness" of the land surface, but also the characteristics of the land surface in terms of energy partitioning, which have a large influence on the local and regional climate and environment.

Professional staff have been trained to analyze these images and in the use of the appropriate hardware and software equipment. Satellite images are widely used in semi-arid areas. Decadal digital files are obtained through the sensors installed onboard National Oceanic & Atmospheric Administration (NOAA) and other satellites. A full-system process for entering and processing the data and summarizing results in MS-Excel files have been put into operation in Afghanistan this year.

Processing and Analysis

Calculation requirements refer to the statistical analysis of weather data sets and data acquisition and processing. Technical outputs for each agroecological zone or agricultural area are produced but preliminary control must be performed. The procedure for the statistical correction and completion of partial or missing weather data are*:*

- Data quality checking (data error);
- Approximate (estimating), formatting, and replacement of missing data;
- Completing data sheet by data interpolation;
- Analysis of the statistical homogeneity of data series;
- Determination of statistical laws that govern decadal, monthly, and yearly rain distribution for the Afghanistan weather conditions;
- Data entry (worksheets and databases);
- Second data checking on the entered data.

Preliminary Processing and Analyzing of Meteorological Data

This section discusses the preparation of agroclimatic studies. Many methods and tools are used regarding several climatic parameters. As preliminaries studies, an agroclimatology analysis includes:

- Calculation of decadal rain from monthly values of rain;
- Calculation of derived parameters such as solar radiation (sunshine duration), daylight duration, potential evaporation (PET), etc.;
- Calculation and maps for the mean meteorological conditions and for the actual observed values in addition to the departures from the agroclimatic normal conditions (rainfall, temperatures, frost, snow days, rainy days, starting of the rainfall season, etc.);
- Production of output maps for the mean planting dates, both as actual values and as departures from the medium conditions (at the beginning of each agricultural season);
- Production of output maps of the mean cycle length for the main crops (technical inquiries);
- Production of output maps of the mean Water Requirements Satisfaction Index for three planting dates, water storage capacity of the soils and for the main crops (three for Afghanistan);
- Production of output maps of the mean yield for wheat, maize, barley and rice crops, plus tables;
- Calculation of decadal rainfall probabilities (Pearson III Law);
- Calculation of decadal PET probabilities for the mean stations (Gauss Law);
- Determination of favorable crop planting dates using water balance and rainfall probabilities. Notion of agrometeorological risk;
- Production of output maps of the average NDVI for Afghanistan (1998-present);
- Determination of "average" dry and wet period in days (Using Markov's Chains);
- Determination of "median" starting and ending of rainfall season. Daily records not yet obtained;
- Determination, for irrigation purposes, of the relationship between Pan A Evaporation and actual ET;
- Determination of agro-ecological zones (on climatic basis: rain and temperatures) for Afghanistan. Using Principal Component Analysis (PCA) method;
- Relationship altitude vs. length of growing season (using/drawn by Hopkins phenological approach);
- Determination of relationship between elevation and PET, to correct PET values against elevation (draw isoclines on mountainous areas);
- Table of exact location of selected stations using Differential Global Positioning System (DGPS) instrument;
- Map of location of selected stations;
- Mapping of agro-ecological zones: New map obtained through climatic approach;
- Map of hydrologic basins of Afghanistan;
- Map of capacity soil storage (water–retaining) and useful deep soil; and,
- Tables for probabilities calculated by incomplete Gamma law (decadal rainfall) and Gauss law (PET), for the stations where the data series are available and sufficient.

Analyses Related to the Agroclimatic Risk Atlas for Afghanistan

This document is in preparation and will be edited as a technical document serving as reference for major climatic elements influencing agriculture. The *Agroclimatic Risk Atlas in Afghanistan* should include the analysis of the variables: rainfall, temperature, radiation, potential evapotranspiration, water balance, and wind.

Data Transmission

In the FAAHM Unit, 33 Codan radios to transmit the data from stations to the Kabul office have been purchased and will be installed soon. The existing radios and e-mail connections available at the FAO sub-offices level within the country can be used for transmitting agrometeorological information. For some areas, the recorded data are physically carried during the organized field trips or by the stations' staff.

Outputs and Products

Tasks of the future agrometeorological service, after its complete establishment, should be to:

- Provide all agro-climatic information on the Natural Ecological Regions (agro-ecological zones) for Afghanistan; especially regarding rainfall, temperatures (air and soil), wind, radiation, air and soil humidity, snow, and frost;
- Help with the planning and improving of agricultural projects and institutions according to the renewable and natural resources available by providing information, which will be precise and applicable;
- Establish a basis of knowledge permitting changes in time concerning the climate or natural elements related to weather reporting, and the impacts on overgrazing, deforestation, desertification, drought, and variation of biological diversity;
- Define the microclimatic (water and energy balances) zones, with specific characteristics, which are worthy of special attention from the programmers and decision makers of agricultural projects when determining these enhancements.

The results and products of agrometeorological projects will also contribute to the development, planning, and design of agricultural projects in Afghanistan. Consequently, these efforts will take into account the following objectives:

- Providing useful information for soil and water conservation;
- Reducing the risk from unusual or extreme meteorological events;
- Improving availability and management of irrigation water;
- Assuring adequate aeration through adequate drainage;
- Assuring adequate water availability for economical crop production;
- Selecting more suitable crops for the climate;
- Optimizing climate fertility interactions on yields;
- Forecasting wheat yield and phenological phases;
- Preparing adequate agrometeorological bulletins and climatic advice (that farmers can use for improving dry land and irrigation agriculture production).

At this stage, the agrometeorological project can provide for agricultural research, agricultural production, meteorological departments, FAO projects, various technical

documentation products, and guidelines for expanding over-all activities related to agrometeorology.

Yield Forecasting Model for Wheat in Afghanistan

The practical applications of agrometeorological forecasting resulted in the development of scientific hypotheses to define the process description to which agrometeorological conditions affect crop production. These relationships will be defined with the help of statistical processing of agrometeorological observations data. They are described by prediction equations that enable the calculation of the expected yields 1 or 2 months in advance using a crop simulation model. There are a variety of generic forecasting methods that can be applied to crop forecasting. The WRSI in percentage of "area averaged" is used as a predictor to build the Afghan model at the level of agroecological zones. Phenological forecasts of crop and natural fodder development are not finished yet. The degree-days method with different thresholds that cover the staple plants in Afghanistan is also used.

These forecasts should be distinguished as very important, as compared to many other types of agrometeorological forecasts. Phenological forecasts include: 1) dates when field operations are initiated in winter and in spring; and, 2) the beginning of the growing cycle (dates) for main plant development stages (critical phenological phases for crops and pasture plants regarding water, frost, etc.) and for harvest time. The majority of phenological forecasts are characterized by an adequate validity.

As said above, to determine the dates of main crop development stages and duration of the inter-stage periods, we use the method of cumulative active temperatures (interrelationship between the plant growth and development factors).

Decadal Agrometeorological Outlook Using Rainfall Probabilities

For each station the following parameters are calculated: tables of rainfall probabilities, and decadal PET probabilities. It is useful to know in advance the probable water availability for crops during the next period for each agricultural area. This helps us analyze the agrometeorological risk in advance and inform the farmers through Extension Services so they can make better decisions.

Agrometeorological 10-Day/Food Security Monthly Bulletin and End-of-Season Rainfall Analysis

Advice to farmers has not yet begun. This list shows the kind of advice that can be given regularly to the farmers through research institutions in Afghanistan:

- Choice of the new species/varieties to be introduced in Afghanistan (FAO emergency-improved seed production in Afghanistan);
- Sowing and re-sowing dates according to the prevailing weather conditions;
- Sowing density and number of plants per hole according to the character of the started rainfall season;
- Dates for application of fertilizers (weather forecasts at short-time step);
- Period of treatment against pests and diseases (weather forecast at short-time step);
- Date of the winding (weather forecasts at short-time step);
- Dates of harvesting;

- Dose/quantity of water supply for irrigation according to prevailing weather conditions for the sites;
- Particular advice in early summer, when good or bad snowfalls occur during the winter and expected water availability for irrigation purposes (importance of the area that can be grown): What the farmers have to do in concordance with the snow that falls during the current rainfall season (or not);
- Kinds of horticultural greenhouses, orientation, type of films, film thickness, heat needs in calories, water supply under greenhouse conditions, heat supply during the winter, how many months we have to warm the greenhouses, more accurate kind of heater that has to be selected for each particular agroclimatic region, etc.;
- Windbreaks and spacing between the trees, the types of trees (porosity), and space protected behind the trees. Determining which kind of trees are the most efficient; and,
- Irrigation design and scheduling taking into consideration agroclimatic (max-water requirements) conditions for the respective regions.

Common agrometeorological studies with agricultural/irrigation projects, universities, etc. This affects the way that we can use weather as a production factor for agriculture.

Different technical notes were prepared on how we can use the products that are issued by Operational Agrometeorological Service (agroclimatic information). Agrometeorological projects are organized through field inspectors with frequent field trips consisting of three teams with different itineraries countrywide. The aim is for crop monitoring of conditions and phenological stages; verification between model results and field reality; and especially to collect timely recorded data.

Training and Workshops in Agrometeorology

The project organized several 1- to 2-week workshops (seven sessions) for more than 40 participants at each session. More than 200 participants were trained. The sessions have been organized by international experts with the help of national counterparts, other consultants, and specialists from the AMA, the Irrigation Ministry, and the Agriculture Ministry.

The training involved staff of various levels including training of the trainers (higher technician and engineers) as well as field observers (crop and pasture condition, pest and diseases, crop phenology) and the training of agrometeorologists (university degree) in charge of the management of an operational agrometeorological service or complete agrometeorological station.

The training sessions have been organized at the AMA's training room (Kabul/Airport), followed by general practical sessions on the field. The trainees work in agrometeorological stations/services after their training, including some students from other ministries and NGOs.

The agrometeorological training course for field staff and observers for rainfall and snowfall stations focused on the following aspects**:**

- Role of agrometeorological stations/network for food security MAAH/FAAHM and early warning system.
- Presentation of selected sites for Afghanistan;

- Presentation of ordinary rain gauges;
- Rain gauge installation;
- Rain measurements;
- Snow measurements: depth and water equivalent;
- Preliminary quality control data;
- Data archiving; and,
- Data transmission: radio and e-mails.

The agrometeorological training course for observers (field staff for complete agrometeorological stations) focused on the following aspects**:**

- Meteorology and agrometeorology (notions).
- Instrumentation (practice of observation and working instruments: rain gauge; snow gauge; rain recorder and graph examination; temperatures records (mean, mini, and maxi thermometers); soil thermometers and soil temperature; grass temperature; humidity recorder and graph examination; psychrometer - welt point and relative humidity in % using of the tables; Class A Evaporation pan with anemometer and temperature; anemometer/weathercock (wind vane); heliograph Campbell-Stokes (sunshine recorder); establishment and maintenance of agrometeorological stations (Instruments: installation and reliability). 1st degree; proper use of instruments and observation practices and how to maintain the installed equipment; quality of recording and reporting/archiving; and, data transmission (radio or e-mail).

Required Software

To achieve all the planned tasks, various software products have been used; most are listed below:

- Word-processing, spreadsheet, databases **(**Microsoft Office Professional);
- Statistical and processing (StatGraphics Plus);
- Drawing geographical maps and graphics **(**Windsurfer);
- E-mail/Internet management;
- Geographical Information System (ArcView, ArcGIS); and,
- Agrometeorological software: (AgroMetShell).

Conclusions

The requirements for a fully operational Agrometeorological Services in Afghanistan have been presented. Two issues are of fundamental importance: (1) the rehabilitation of pre-war existing meteorological stations and the installation of new stations; (2) the capacity-building at local level through intensive on-the-job training courses and the use of advanced agrometeorological tools. In this way, it is possible to provide technical advice to the MAAHH, as well as to other decision makers related to food security issues.