The Cuban experience in Developing Agrometeorological Bulletins for the Agricultural Sector

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Abstract

The article gives a general overview of the development of agrometeorological bulletins in Cuba, the information they contain and the use of various techniques to produce value-added information. The authors depict in chronological order the various stages of the development of agrometeorological bulletins, the purpose of which is to provide timely information to the agricultural sector in Cuba, and describe Cuba's experience in developing such bulletins. This involves the use of modelling as an indispensable tool for adding value to the bulletin service, in applications such as the evaluation of hydraulic conditions, assessment of crop growth and development, calculation of crop yields and the figuring of trajectories in cross-border disease surveillance systems. Some comments are offered on the use of the Geographic Information Systems in drawing up agrometeorological bulletins in Cuba. Certain economic benefits are described, for instance the use of the information provided by the agrometeorological bulletins for forest fire prevention and for the evaluation of the impact of extreme phenomena in the tobacco sector, for example through the Agrometeorological Monitoring System for Tobacco Farming.

Introduction

The drawing up of agrometeorological bulletins to meet agricultural communities' needs for meteorological and biological information is a topical problem in many regions of the world. In order to provide this service effectively, it is imperative to know the various agricultural users' needs, to ensure that the information they receive is reliable, authoritative and timely, and to present it in the most appropriate form, corresponding to their interests.

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This information can simply be the result of meteorological and biological observations, or it may fall into the category of agrometeorological information, meaning that it has added value insofar as it has been processed or is the product of scientific research. By making appropriate use of the information contained in agrometeorological bulletins, farmers can make preparations so as to minimize the effects of adverse weather conditions and effectively use favourable weather conditions to achieve high yields.

The requirements of living organisms in terms of atmospheric conditions are extremely varied. These requirements differ not only between species, but also from one variety or race to another, and what is more they may vary significantly between two stages of development. In certain stages of growth and development, weather can have a strong impact on yield, or may even threaten the existence of the living organism. A great deal of information is therefore drawn up for farmers by agrometeorologists. It is usually distributed by means of agrometeorological bulletins.

The Cuban experience in drawing up agrometeorological bulletins

According to Pérez *et al*. 2001, the Cuban experience in advising the agricultural sector through a National Agrometeorological Bulletin has undergone three historic stages of development since 1905. Each has well-defined characteristics, and together they established the methodological basis for the current system.

According to these authors, the first stage involved a modest agrometeorological network of about 40 stations randomly located and operated mainly by volunteers in agricultural experiment centres, sugar plantations and foreign fruit companies, and by meteorology amateurs. The information was processed, analysed and then distributed in the General Digest of Climatological Conditions and Harvests of the Secretariat of Agriculture, Industry and Commerce (Carbonell, 1905). The Secretariat attached much importance to this information because of its close links with the country's agricultural sector.

Although this agrometeorological network had no coordinated phenologic and phytologic methodology, it nonetheless provided abundant and varied agrotechnical and biological information on the entire country. It offered information on the status and vitality of crops and livestock, the onset and impact of plagues and diseases, assessments of the main crop yields and the effect of weather phenomena on them. This information was complemented by market data concerning the various products from ports and agricultural markets.

The agrometeorological information service flourished during this stage of development. The agrometeorological network used few consumables and placed high priority on the simplest types of biological and agrotechnical observation, which at the same time was of great use for local agrometeorological analyses.

The second phase was influenced by the Second World War. In the 1940s, the National Meteorological Service, then known as the National Observatory, became part of the Cuban Navy. As a result, the meteorological network was strengthened for the synoptic and climatic objectives of the times, but there was no central authority capable of drawing up an agrometeorological bulletin of interest to the country's agricultural sector. This period, during which agrometeorological information in Cuba was more or less blacked out, continued until the beginning of the 1970s.

Starting in 1963, the Academy of Sciences of Cuba organized and increased the number of meteorological observing stations. It strengthened the network of stations of its Department of Meteorology, which merged with the former National Observatory, thus creating the Meteorology Institute in 1965.

During this period, the methodologies contained in the WMO Manual on the Global Observing System and Guides to Agrometeorological, Climatological and Hydrological Practices began to be applied. These standards made it possible to optimize density for specialized networks, taking into account the climatic, topographic and land-use characteristics of each area. The aim was that the stations should cover the representative characteristics of all types of terrain: plains, mountains, plateaux, coasts and islands, and of all surface cover: forests, various types of crops, urban areas and rural areas.

In 1969, the Department of Agricultural Meteorology was established to provide services to the country's agricultural sector. Later, in 1974 and 1975, under the auspices of a WMO project, 18 agrometeorological stations were built, representing the beginning of a specialized network designed specifically for agrometeorology.

The third phase began in the first ten days of July, 1978, when the systematic publication of the National Agrometeorological Bulletin began under the direction of Bidzinashvili (1978). It was entitled "Ten-Day Agrometeorological Supplement to the Agricultural News of the Agricultural Information Centre of the Ministry of Agriculture".

In order to ensure that information was conveyed effectively through the agrometeorological bulletins, the Department of Agricultural Meteorology worked closely with other departments of the Meteorology Institute active in various fields (including the stations network, forecasting, climate, atmospheric physics, pollution control and atmosphere chemistry). It used an extensive data base of meteorological information from various observing networks belonging to the Meteorology Institute, the National Institute of Water Resources and the Ministry of Agriculture, along with agrotechnical and biological information from the agrometeorological stations of the Meteorology Institute and the central administrations of the Ministry of Sugar and the Ministry of Agriculture.

The primary source of systematic, ten-day information for the agrometeorological bulletins comes from the weather and agrometeorological data provided by 71 weather stations, of which 18 are agrometeorological stations, and from precipitation data reported by some 630 rainfall stations. Agrometeorological and phenological observations are carried out and standardized according to a single methodological plan, outlined in an instruction manual for agrometeorological observations at stations and posts (Meteorology Institute, 1976). The information is received through various channels on the 1st, 11th and 21st day of each month, and follow a pattern designed for the handling of large volumes of meteorological and biological data. This information is complemented by massive, simplified phenological observations, mainly carried out for short-cycle crops (Méndez *et al.*, 1988) and for wild plants in Cuba (Pérez and Planas, 2001).

The second most important source of information is synoptic summaries of the ten-day periods and outlooks for the next ten days, long-term precipitation and air temperature forecasts and spatial distribution maps of the main weather elements.

Climatological and agroclimatological data are the third and final source of information (Palenzuela *et al.*, 1982). This includes: average air temperature over years (the norm), months and ten-day periods; absolute air temperature highs and lows; and the mean, earliest and latest dates over a period of many years when the average air temperature went over 20.0°C and 25.0°C. The mean, earliest and latest dates of the onset and end of the dry and rainy seasons are examined, as are the mean and absolute maximum amounts of precipitation over years, months, ten-day periods and periods of 24 hours, and the number of days with rains of various magnitudes (equal to or over 1.0 mm or 5.0 mm, for example). Other information includes the mean and maximum values of productive soil water reserves in the root zone of the soil, the mean, earliest and latest dates for the beginning of the development stages of the main crops, data on the duration of the main inter-phase periods and the agroclimatic requirements for the main crops and for livestock.

Once the information received from the different sources is compiled and analysed, specialists in the Agrometeorological Service continue to add value by using the latest agrometeorological techniques, some of which are taken from the literature published by the Food and Agriculture Organization of the United Nations (FAO) and WMO. Others have been developed by researchers at the national level. It is thus possible to keep an eye on certain agricultural activities in the country and also on the weather and climate that affect them. Among these, we may mention:

The use of modelling as a tool for the drawing up of bulletins in the Cuban Agrometeorological Service

Menéndez *et al.*, 2001, described in detail the use of modelling applied to the drawing up of agrometeorological bulletins. A few examples can be found below:

Models for the evaluation of the water conditions for crop growth and development:

In order inter alia to evaluate agrometeorological vegetation conditions, assess crop yield forecasts (Solano and Vázquez, 1998; Solano *et al.*, 2001a), forecast productive soil water reserves for sowing (Solano and Vázquez, 1999a; Solano *et al*., 2000a), monitor agricultural drought (Solano *et al.*, 2000b) and produce early warnings, the specialists of the Agrometeorological Service use a simplified model for the agroclimatic water balance in the soil (Solano *et al.*, 1999).

The input data for this model include effective precipitation determined from loss coefficients as a function of soil slope and texture, reference evapotranspiration according to the Penman-Monteith equation modified for Cuba (Menéndez *et al.*, 1999) and crop evapotranspiration, calculated taking into consideration their coefficients proposed by Allen *et al.*, 1998.

On the basis of this balance, an index of crop water availability is drawn up. When it is compared with precipitation and crop water requirements, it makes it possible to determine the vegetation conditions, expressed through the humidity index as modified for crops (Solano *et al.*, 2001a). These calculations are done every ten days. Based on an analysis of the crop humidity index, the dry periods can be determined and an agrometeorological forecast of soil humidity reserves for sowing in rain-fed agriculture can be drawn up.

The Cuban Agrometeorological Service uses a model to assess agricultural droughts. The model indicates the beginning, intensification, propagation, end or absence of an agricultural drought (Solano and Vázquez, 1999b; Solano *et al.*, 2000b).

A monitoring system has thus been developed that is capable of evaluating and mapping out forecasts for sowing humidity reserves over ten-day periods for the entire country. It is based on the agrometeorological forecast model for humidity reserves for rain-fed sowing, the use of the tools for the Geographic Information Systems (SIG) and long-term climate forecasting (Solano and Vázquez, 1999a).

Because of the frequent climate anomalies which have occurred in the past thirty years, the agrometeorological monitoring system has been modified, and early warnings have been issued for the agricultural sector. With the information from long-term extreme precipitation and temperature forecasts drawn up by experts from the Long-Term Forecast Group of the Climate Centre of the Meteorology Institute, a group of agricultural meteorology experts employs various models to determine with sufficient advance warning the conditions of vegetation, the evolution of agricultural droughts, forecasts for sowing humidity reserves and the risk of fire in vegetation.

According to Solano *et al.*, (2001b), the techniques used to evaluate the current and future beginning, spread and intensification, and end of an agricultural drought are quite capable of following the evolution of such extreme events in conditions of rain-fed agriculture. The use of objective evaluation techniques for the agrometeorological indices characterizing certain extreme events has produced a digital data base of ten-day periods, with information on the indices in question for every square kilometre. The results achieved with these techniques are extremely important for agricultural planning, especially for sustainable, rain-fed agriculture.

In Cuba, as in many other parts of the world, there has in the past 20 years been an increasing amount of forest fires. This has pointed to the need to take measures to prevent and control such disasters. Forest fires are closely related to dry weather periods and drought. Cuban experts therefore use certain models which take into account actual precipitation, atmospheric evaporation and soil and vegetation characteristics that directly or indirectly influence the humidity content of living vegetation and of dead parts of this vegetation. Together, they determine an agrometeorological risk index for forest fires, which makes it possible to issue long-term early warnings (Solano *et al.*, 2001c). The index was evaluated with information from 435 days of reported forest fires in the western part of the country in 1999 and 2000, and it was able to account for some 97 per cent of the fires that started during the period under consideration. It is a valuable long-term (10-days or more) indicator of the risk of forest fires in the tropical conditions found in Cuba.

Crop yield calculation models:

One of the models used in the Cuban Agrometeorological Service for the calculation of net biomass production and crop yield is the one proposed by De Wit (Food and Agriculture Organization of the United Nations 48, 1978). The model's only meteorological inputs are solar radiation, mean diurnal air temperature and type of crop. The output is the economic yield of the crop, expressed in kilograms per hectare.

At the national level, we have developed models for the forecast of yields in the sugar cane industry based on a large volume of yield data. The sugar concentration process was studied, and simple regression outlines were drawn up to express the dependence of industrial yield on environmental factors (Arveladze *et al.*, 1988). In Cuba, precipitation during the vegetation season is the limiting factor for sugar cane biomass growth. The requirements of the sugar crop in respect of this factor have been determined on the basis of a vast collection of data records of precipitation and sugar cane production, using physical and statistical parameters (Arveladze *et al.*, 1991). These "Climate - Sugar Cane Industrial or Agricultural Yield" regression models are used in operational work, to draw up bulletins during the sugar cane harvest months (November to April). The analysed agrometeorological information is presented every ten days, and is promptly provided to decision-makers in the Ministry of Sugar.

Trajectory models:

The agrometeorological bulletin service that is provided to tobacco companies monitors blue mould rot, with an atmospheric trajectory model. The model is used to evaluate and forecast the possible arrival of spores in our country and its subsequent dissemination throughout Cuba (Marín, 2001), and is also used for research.

The trajectory model employed by this service is the HY-SPLIT4, which was developed by the National Oceanic and Atmospheric Administration (Draxler, 1997). Using this model, future trajectories can be calculated from suspected foci of the disease so as to forecast the possible arrival of blue mould rot spores. Trajectories can also be retraced back from new foci to determine the possible sources of the spores.

Once these trajectories are calculated, the user receives a special notice that may forecast the possible arrival of the pathogen in the near future, or may provide an analysis of recent conditions. The possible arrival of the spores at a given site may be announced. These notices provide the model's output: images of the projected trajectories. They also analyse the current weather conditions at the places where the trajectories originate, and provide information on the conditions along the trajectory or trajectories and at the site where the spores might arrive and be deposited.

Other applications of trajectory models in cross-border disease surveillance through agrometeorological bulletins are described by Marín *et al.*, 2001.

The use of Geographic Information System techniques

The Cuban Agrometeorological Service has attached a great deal of importance to the spatial representation of agrometeorological information. The use of Geographic Information Systems began about ten years ago, with the advent of appropriate computer technology. According to Vázquez (2001), specialists of the Agrometeorological Service rely on a Geographic Information System that processes and stores agrometeorological information in different scales and with different levels of complexity. This system is the main tool for the processing, analysis and representation of basic agrometeorological information, for the implementation of surveillance systems and for the issuance of early warning advisories of important agrometeorological indices, including crop vegetation conditions, productive water reserves, agricultural drought and vegetation fire risks. The information is systematically published in the various types of bulletins put out by the Agrometeorological Service at the national, provincial and local levels.

The agrometeorological bulletins have the dual task of providing information and training by disseminating agrometeorological information to a large number of people with different needs. Their main purposes may be summed up as follows: to evaluate systematically the impact of climate and weather on agricultural production, which allows farmers to make tactical, short-term decisions for their main agricultural and technical activities; to help find the best strategy for long-term agricultural planning so as to ensure that projects are economically and socially consistent with climate conditions in areas under development; and to help create and update a reliable meteorological, agronomic and biological data base capable of improving operational services for agriculture and of supporting appropriate research so as to develop effective agrometeorological forecasts.

Cuban agrometeorological bulletins currently have the following sections: Headlines; Past meteorological and agrometeorological conditions; Meteorological and agrometeorological conditions expected for the next period (future); and in some issues, Moon phases.

The scientific and technical information provided by agrometeorological bulletins allows officials, researchers, technicians and producers to make timely decisions in their respective institutions with sufficient notice to mitigate the negative effects of weather on crops and livestock and to take full advantage of the weather whenever possible. Such information is becoming more important as Cuba, like many other developing countries, moves towards sustainable, low-input agriculture, and farming becomes more sensitive to the impact of weather and climate change.

Some examples of the economic benefits of using the information provided in the agrometeorological bulletins are given by Solano *et al*., 2001d, and by Lopetegui *et al.*, 2001. They respectively relate to forest fire prevention in Cuba and the impact of extreme weather phenomena on the tobacco sector. For the former, a specialized system for the provision of agrometeorological information has been devised. The system uses bulletins and other types of early warnings for the prevention of forest fires, and has been borne out by a cost-benefits analysis. The direct and indirect losses and damages caused by forest fires in an average year were first calculated, and then the cost of the agrometeorological forest fire prevention service was determined. It has been demonstrated that the implementation and maintenance of the monitoring and early warning service, training, procurement of required equipment and research would cost a fraction of the value of the damages the system can effectively prevent. As for the impact of extreme weather phenomena on the tobacco sector, an analysis is now under way of the economic implications of the use of the agrometeorological bulletin to provide the necessary tools to tobacco farmers in the province of Pinar del Río, with the objective of minimizing the impact of weather and climate on growth, development, productivity and leaf quality and to assess the feasibility of using this system for other crops and in other locations. Clearly, extreme weather events have a strong impact on this crop, which suffers considerable losses. In five tobacco harvests, the losses have been assessed at 11.3 million Cuban pesos. With the use of the agrometeorological monitoring system as reported in the agrometeorological bulletin, 20.9 million pesos of losses were averted in the 1998-1999 and 1999-2000 harvests, or US$ 8.3 million.

Conclusions

For nearly a century the agrometeorological bulletins have made it possible to keep Cuban farmers informed of the impact of weather and climate on their activities.

The timely agrometeorological information that they provide has helped both the agricultural authorities and farmers to make decisions. They are thus able to take tactical, operational and strategic measures with sufficient notice in the short, medium and long term to ensure the best possible use of favourable weather and climate conditions and to minimize damages and/or losses when conditions are unfavourable.

In recent years, an agrometeorological culture has developed among users of the agrometeorological bulletin. Officials of the agricultural sector, government organizations and international governmental organizations such as FAO have on numerous occasions acknowledged the usefulness and importance of agrometeorological information provided by agrometeorological bulletins.

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