Improving Agrometeorological Bulletins

Proceedings of the Inter-Regional Workshop

15-19 October 2001
Bridgetown, Barbados
Improving Agrometeorological Bulletins

Proceedings of the Inter-Regional Workshop
15-19 October 2002, Bridgetown, Barbados

EDITOR

M.V.K. Sivakumar

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FORESHORD

The global demand for cereals has been continuously increasing due to the growing population growth and world’s farmers will have to produce 40 percent more grain in 2020 to meet the nutritional needs of the global population which estimated to reach 7.5 billion by that time. Much of this population growth will occur in the developing world where the farming community is comprised mainly of small farmers with limited means. These farmers lack the financial resources need for investing in inputs such as improved seeds and fertilizers and hence the yield levels in their farms have remained either stagnant or have been declining.

In much of the tropics, especially in the semi-arid tropics, farming systems are mainly rainfed and are affected by inter-annual as well as intraseasonal climate variability. Farmers had to adapt to the range and frequency of shocks that climate variability brings and they have tried to use the available knowledge and information to develop their coping strategies. Farmers urgently need weather and climate information for operational decisions and there is convincing evidence available from different parts of the world that judicious application of meteorological, climatological and hydrological knowledge and information, including long-range forecasts, greatly assists the agricultural community to develop and operate sustainable agricultural systems and increase production in an environmentally sustainable manner. Also the growing concerns with the need for achieving greater efficiency in the natural resource use while conserving the environment are placing a much greater emphasis on understanding and exploiting climatic resources for the benefit of agriculture and forestry.

The importance of the type of weather information needed for a decision making process depends upon the nature of the decision itself. For example, present weather and short-term forecasts are used in making daily operational decisions, while the analyses of past climate data are especially useful for planning decisions. Predictions of yield and the incidence of disease and pest potential are usually based on current and past weather conditions in a specific agricultural area and crop type. Medium and long range forecasts, coupled with past climatological data, are valuable for long-term planning decisions related to crop decisions. The need for reorienting and recasting meteorological information, fine tuning of climatic analysis and presentation in forms suitable for agricultural decision making and insulation of marginal farmers with small holdings from the adverse impacts of weather vagaries has become more pressing.

It is indeed gratifying that through the technological advances in the past decade in the domain of information dissemination and exchange
such as the developments in communications and electronic media, in particular the ever expanding cyberspace linkages through internet and World Wide Web, we are now have improved methodologies and tools to reach the farming community. The enhanced computing power that is available today is making data manipulation much easier than ever before. We need to take advantage of the new opportunities to obtain and provide information to the users in a cost-effective way.

The Twelfth Session of the Commission for Agricultural Meteorology (CAgM-XII) of WMO considered the need to improve agrometeorological services to improve agricultural production and to conserve the environment. It emphasized the importance of timely provision of agrometeorological information in a user-friendly format.

In order to discuss a number of the above issues, WMO, the National Oceanic and Atmospheric Administration (NOAA) and the Caribbean Institute of Meteorology and Hydrology (CIMH) organized an Inter-Regional Workshop on Improving Agrometeorological Bulletins in Bridgetown, Barbados, from 15 to 19 October 2001. The purpose of the workshop was to assess the current status of preparation of agrometeorological bulletins in the six Regions of WMO and determine the different ways and means to improve the contents of these bulletins to facilitate timely and efficient on-farm operational decision-making that relies on agrometeorological information. Twenty-five participants from twenty-one countries, including several from the Caribbean region, attended the Inter-Regional Workshop. All Regional Associations were represented.

I am pleased to note that the Inter-Regional Workshop addressed a number of important topics mentioned above relating to improving the agrometeorological bulletins including the challenges and the regional and technological perspectives. Brainstorming sessions during the workshop helped the participants in bringing out the major issues in improving agrometeorological bulletins and in prioritization them and also in developing a number of recommendations for future action. I hope that the papers presented in this volume will serve as a very valuable source of information for all users and providers of agrometeorological information.

G.O.P. Obasi
Secretary-General
World Meteorological Organization
Workshop Opening
Welcome Address

C. Layne

Distinguished guests, participants, ladies and gentlemen.

Barbados is pleased to have been selected for the hosting of this Inter-Regional Workshop on improving Agro-meteorological Bulletins. First, I wish to extend to you, both on behalf of the government and people of Barbados and at the personal level a warm welcome to our shores. We are especially happy with your presence in Barbados at a time when there is an obvious decline in the number of visitors to our islands, as a consequence of the events of the past weeks.

Your programme for the next five (5) days indicates that a number of important and relevant topics are scheduled to be discussed. It is my fervent wish that during your deliberations some consideration will be given to addressing the needs of small and developing NMS. Progress for us in the area of application of meteorology to agriculture which is considered by some to the most weather dependent of all human activities, has been glacial at best and non-existent at worse. NMSs such as ours have been experiencing difficulty in building capacity even limited to effectively make a contribution to the enhancement of agricultural production and food security.

Specifically, all efforts on the part of my predecessors as well as my recent attempts to obtain adequate resources for the training of an agro-meteorologist have been unsuccessful. The building of capacity is an important pre-requisite to the effective and efficient delivery of timely and useful agrometeorological information to the farming community.

The increasing demands for food and concerns with the need to achieve higher efficiency levels in the use of limited natural resources have placed greater emphasis on understanding and exploiting the relevant climatic resources for the benefit of agriculture and related sectors.

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Recent events in USA have further challenged the meteorological community and, more than ever before, there exists the urgency, as well as a definite need to do more to enhance our skills in operational, experimental and theoretical aspects of agricultural meteorology.

This mission provides further opportunity for National Meteorological Services to earn recognition, improve their creditability and visibility and in so doing, contribute in a meaningful way to the national economy.

As I understand it, the purpose of this workshop is to assess the current status of preparation of agro-meteorological bulletins in the six (6) regions of WMO, as well as to determine the different ways and means to improve the content and value of these bulletins.

Your programme for the coming week seeks to adequately address these and other lesser objectives.

I wish you well in your deliberations and hope that you will be able to experience some of the natural friendliness and hospitality of the local community. May your sessions be fruitful and successful and your stay in Barbados enjoyable and problem-free.
Opening Remarks

M.V.K. Sivakumar

On behalf of the Secretary-General of WMO, Professor G.O.P. Obasi, I have great pleasure in welcoming you all to this opening ceremony of the Inter-Regional Workshop on Improving Agrometeorological Bulletins. I seize the opportunity to thank the Meteorological Services of Barbados, in particular, Mr Chester Layne, Director and Permanent Representative of Barbados with WMO, for agreeing to host this meeting in Barbados. Dr Colin Depradine, Principal, of the Caribbean Institute of Meteorology and Hydrology (CIMH) who is the local coordinator for this workshop has been most cooperative in coordinating the arrangements for this meeting and I convey my thanks to him. Mr Tyrone Sutherland, Permanent Representative of the British Caribbean Territories with WMO has been guiding us right from the beginning in the organization of this event in the Caribbean and I would like to offer my sincere thanks to him for agreeing to be here with us today and deliver the keynote address. I am very pleased that Dr Ray Motha, President of the Commission for Agricultural Meteorology of WMO and Mr Lihwu Akeh, Vice-President of the Commission are both with us here at this workshop to guide us and help us develop appropriate recommendations for use by all the members of the Commission. We are grateful to the National Oceanic and Atmospheric Administration (NOAA) for agreeing to co-sponsor this workshop.

Why do we need an Inter-Regional Workshop to discuss how we can improve agrometeorological bulletins? Let me present some rationale for the workshop.

It is estimated that by 2020, the world population will reach 7.5 billion and that much of this population growth will occur in the developing world. To meet the increasing global demand for cereals, the world's farmers will have to produce 40 percent more grain in 2020. Although the global production of cereals and global cereal yields rose over the period from 1986-88 to 1996-98, the average per capita cereal production for the world remained stagnant over
the period and actually fell in Africa and the Middle East regions. This disturbing trend has many implications for food security of the growing populations of the world.

In the developing countries, where adoption of improved technologies is too slow to counteract the adverse effects of varying environmental conditions, climate fluctuations are indeed the main factors which prevent a regular supply and availability of food, the key to food security. It has been demonstrated that judicious application of meteorological, climatological and hydrological knowledge and information, including long-range forecasts, greatly assists the agricultural community to develop and operate sustainable agricultural systems and increase production in an environmentally sustainable manner.

There are increasing demands for timely and effective agrometeorological information for on-farm applications. The growing interest in the possible impact of natural and human induced climate variability and long-term climate change on agriculture and forestry have created new demands for information from, and assessments by agrometeorologists. The need for reorienting and recasting meteorological information, fine-tuning of climatic analysis and presentation in forms suitable for agricultural decision making and insulation of marginal farmers with small holdings from the adverse impacts of weather vagaries has become more pressing.

Developments in communications and electronic media, in particular the ever-expanding cyberspace linkages through Internet and World Wide Web are changing the way people view information dissemination and exchange. The potential to enhance the international exchange of ideas, concepts, data and information at the global level is expanding rapidly. The enhanced computing power that is available today is making data manipulation much easier than ever before. Revolutionary changes in audio-video media make it easy to take the information to users. Geographical Information Systems and other spatial modelling tools make it possible to integrate biological, physical and socio-economic factors in a holistic manner. Hence the opportunity exists, more than ever before, to obtain and provide information to users through a variety of sources. Also it is now possible to reach a larger audience using cost-effective means that were just not available even a few years ago.

Therefore, the challenge in front of the agrometeorologists around the world is that more than ever before, there is a great need to more effectively integrate and deploy the skills we have developed in operational, experimental
and theoretical aspects of agricultural meteorology to make production in systems of agriculture and forestry more reliable, more efficient and above all more equitable in the world at large. The National Meteorological and Hydrological Services (NMHSs), or other departments providing agrometeorological Services, can contribute to the national economy, and best obtain recognition and remuneration for the investments made in agricultural meteorology, through the effective use of the information by the agricultural community in the widest sense by making the best use of the current advances in the audio-video media and the communications technology.

It is with this background that WMO is organizing this Inter-Regional Workshop on Improving Agrometeorological Bulletins. The purpose of this meeting is to assess the current status of preparation of agrometeorological bulletins in the six Regions of WMO and determine the different ways and means to improve the contents of these bulletins to facilitate timely and efficient on-farm operational decision-making that relies on agrometeorological information.

The specific objectives of the Workshop are to:

1. Evaluate how the NMHSs in six Regions of WMO determine the contents and methods of presentation of information in the agrometeorological bulletins that are issued in their countries;

2. Identify the shortcomings and limitations in the current methods of preparing agrometeorological bulletins;

3. Review the different improved methods and tools to improve the contents and presentation of information in the agrometeorological bulletins and their delivery to decision-makers in a timely fashion;

4. Formulate an effective training strategy to build the capacity of the NMHSs in the different WMO Regions to rapidly implement improved systems of preparing and disseminating agrometeorological bulletins.

Two agrometeorologists from each of the six Regions of WMO, who were nominated by the Presidents of their Regional Association, representatives of the different Caribbean countries who have agrometeorological services and other invited experts will present papers to address the above objectives. I am grateful to all the participants from the different Regions who have agreed to collate information from their Regions and prepared papers for this workshop. I look forward, with much interest, to their presentations.
The programme for the Workshop has been designed in such a way as to engage all the participants in comprehensive discussions on each of the specific objectives listed and develop appropriate recommendations. The proceedings of this meeting will contain the papers presented by the experts as well as the recommendations for improving agrometeorological bulletins. This volume is expected to serve as a major source of information to all NMHSs and other agencies involved preparing and distributing agrometeorological bulletins.

We have much work to do over the next five days and I am confident that the deliberations of this workshop would contribute significantly towards more effective drought preparedness and management at various levels in different parts of the world. On behalf of the Secretary-General of WMO, I wish you all a very fruitful meeting and a pleasant stay in Barbados. Thank you.
On behalf of the Commission for Agricultural Meteorology (CAgM), I want to thank all of the participants for coming to this workshop during these rather difficult travel times. We view this meeting as a very important step in acknowledging the value of weather and climate information for agriculture. The presence of these technical experts from all of the WMO regions gathered here this week will certainly generate excellent discussion and promote worthy brainstorming issues.

I want to extend my thanks to the Permanent Representative of Barbados, Mr. Chester Layne, for providing us this opportunity to discuss these issues in such a beautiful setting. I also wish to thank Mr. Colin Depradine, Principal of Caribbean Institute for Meteorology and Hydrology, for hosting this gathering in a very comfortable location which will facilitate an excellent meeting environment.

I am delighted by the presence of the Permanent Representative of the British Caribbean Territories, Mr. Tyrone Sutherland. His support for this meeting and for this very important topic of discussion is greatly appreciated by CAgM. My final note of thanks goes to Dr. M.V.K. Sivakumar, Chief of the Agricultural Meteorology Division of WMO, and, a very able scientist and advocate of the importance of agricultural weather to the global farming community.

We have a great opportunity here to exchange ideas and experiences, to perhaps establish some useful guidance, and, to formulate recommendations for improving agrometeorological bulletins. We should consider such matters as the quality of content, accessibility of input requirements, information delivery technology, and, of course, user needs. It is obvious that one format will not fit all user needs at the local level. However, standards can be developed to serve as a basic foundation from which bulletins can focus on specific requirements of the local user community.

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We have an opportunity to enhance the recognition that our products are important to assist decision-makers with timely and relevant information.

I sincerely wish you much success with these discussions and with a productive outcome of this meeting.

Thank you.
The Importance of Agrometeorological Information and its Dissemination for Agricultural and Water Resource Management in the English speaking Caribbean

Tyrone W. Sutherland

Dr Ray Motha, President of WMO’s Commission for Agricultural Meteorology,

Dr M.V.K. Sivakumar, Chief of WMO’s Agricultural Meteorology Division,

Mr Chester Layne, Director of the Barbados Meteorological Service and Permanent Representative of Barbados with WMO,

Dr Colin Depradine, Principal of the Caribbean Institute for Meteorology and Hydrology

Participants and Colleagues,

Ladies and Gentlemen,

First of all, let me add my own welcome to all of you to Barbados, especially to those who are visiting for the first time and in particular to our friends from outside of this WMO region. It is always a pleasure for me to be in Barbados and I hope you will also find it pleasant. Indeed, I want to express my special thanks to the Government of Barbados, through you Mr Layne, for once more showing its commitment to meteorology and related sciences by being such a willing host for another gathering of this type. On behalf of the Caribbean Meteorological Organization, which is made up of the English-speaking Caribbean countries, I thank WMO for organizing this workshop and the National Oceanographic and Atmospheric Administration of the USA and the Caribbean Institute for Meteorology and Hydrology for their sponsorship. A special welcome to Dr Motha and Dr Sivakumar; your presence here today signifies the importance that the Commission and the Secretariat place on this workshop.

Ladies and Gentlemen, workshops on any topic related to agriculture and meteorology are always needed here in the Caribbean, as in any other

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part of the world, I’m sure, because of the special importance of agriculture in all our lives. In the Caribbean countries, both islands and mainland, agriculture has a long history of being the mainstay, or one of the most important sectors of our economies. In recent times, however, tourism has taken over as the number one sector in a number of islands, but that in itself has not diminished the importance of agriculture.

In the last decade or two, some primary crops in the Caribbean have been under pressure because of the international trading practices, prices and agreements. Sugar is not what it once was and more recently, the banana industry has been virtually brought to its knees. Banana producers in general comprise a few large plantations or companies, together with a large number of small private farmers. The same may be true, though in different proportions, for other large cash crops. All farmers know of the link between weather and agriculture, but it has been just a few of the larger producers that have had the means to either collect meteorological data, or to utilize information from meteorological or agrometeorological services.

One might ask, what type of agrometeorological data or guidance would a farmer in the Caribbean need on a routine basis? To give a few examples, farmers require information to help them in planning spraying operations for disease and pest control. Most farmers in the Caribbean utilize labour-intensive methods to spray their crops, while larger producers might use crop-dusting aircraft in their operations. How often have we seen expensive crop-spraying operations completely nullified by a sudden change in conditions! In several islands in the Caribbean, guidance of expected wind, temperature and atmospheric humidity, which impact on the effectiveness of this type of operation, has long been sought. Farmers also need information on expected soil and water content, soil temperature and evaporation rates for planting and harvesting activities. Expected rainfall rates are vital to farmers for determining when and how to apply fertilizers to their fields, because we know that the heavy rains we experience in the Caribbean may either wash away soil nutrients or bring in nutrients in soil from elsewhere.

All over the world, irrigation accounts for a large percentage of the vital freshwater resources. In the Caribbean, where we have two distinct seasons – dry and wet – irrigation must be managed properly when water reserves are low. Therefore, agrometeorological information to assist in irrigation planning is very important to both the farming community and water resources management. Indeed, in some of the Leeward Islands, for example, drought is the principal worry for both agriculture and freshwater management.
It is well known that severe weather events, such as tropical storms and hurricanes, have major short- and medium-term impacts on agricultural production. Indeed the entire national economies, often driven by the agricultural sector, may take several years to recover. But here in the Caribbean in recent times, there is a growing awareness that there could be medium- and long-term impacts on agriculture from variations in climate, and indeed on possible changes in climate, so that the need for appropriate information for these events to be provided in a timely and useable manner is now recognized.

How then are we doing in the provision of agrometeorological information here in the English-speaking Caribbean? In general, we could say that our Meteorological and Hydrometeorological Services provide well-established information to the public, the aviation industry and in a few cases, the water-resources sector. In particular, our bulletins of severe weather warnings for floods, tropical storms and hurricanes are well known and heavily relied upon. But these are general to the population at-large. For the most part though, we are still searching for ways to adequately contribute in the area of agrometeorology. During the course of the workshop, you will probably hear that our agrometeorological products are still in the early stages of development.

You will probably also hear that, in addition to the Meteorological Services, several other government units, such as within Ministries of Agriculture and Water resources, as well as universities and other institutions, may also have independent and compatible or complementary agrometeorological data sets, and may sometimes publish information for internal purposes, but do so without much sharing or collaboration with others. It is inconceivable to me that in countries as small as we are, with limited resources, we still have little collaboration, or even understanding, between agricultural and meteorological scientists, who should be working closely together. For example, I can recall several years ago when a ministry of agriculture in one of our islands was unable to give a reason for the failure of a particular crop because it lacked the appropriate data of its own, but some time later it was discovered that the Meteorological Service had very pertinent data, but did not even know that it was required.

At the same time, however, we have made significant progress in the medium time-scale predictions, such as in producing seasonal climate outlooks, the need for which, as I indicated earlier, is increasingly recognized. In this connection, I must commend the efforts of our own Caribbean Institute for Meteorology and Hydrology, which is collaborating
with other scientific institutions in developing this skill. As this information further improves and becomes more widely available, it could make a great contribution to the agricultural and water resources management.

Ladies and Gentlemen, with that bird’s-eye view of our state-of-affairs in terms of agrometeorology, I must praise the World Meteorological Organization for organizing this workshop so that this region could share with its colleagues from the other WMO regions around the world, the experiences in providing information to an important economic sector. I know that several of the Meteorological Services of the Caribbean have plans to develop or upgrade their agrometeorological divisions and therefore this workshop will provide important and timely guidance. The information that the workshop provides is equally important to the CIMH, which provides much of the agrometeorological training in the region.

With this in mind, let me touch briefly on one a topic that I have raised several times in WMO. I believe that WMO’s Agrometeorology Programme has a lot to offer developing countries such as ours. There have been many very successful agricultural programmes or experiments carried out by WMO, which have proven to positively impact on specific crop production in developing countries. But I believe that the Programme needs to be oriented – in parallel – towards a broader more grass-root approach. Not many of our Meteorological Services – and more so Ministries of Agriculture or agricultural research institutions - are that familiar with the good work that WMO is doing in this area. Therefore they are not quite sure in which ways they can receive help from WMO in building up their own agrometeorological programmes. I believe that WMO’s Programme should be geared towards a partnership between professionals in the meteorological and agricultural communities and academia, to better understand agricultural problems that have a distinct meteorological influence and to develop products the reach and serve the end user of our products - the agricultural extension officers and the farmers themselves.

Ladies and Gentlemen,

My hope was to give you enough of an insight into the agrometeorological situation in the English-speaking Caribbean, in order to set the tone for what will be discussed over the next five days. I wish you every success in your deliberations and I look forward very much to the outcome of the workshop.

Thank you.
Improving Agrometeorological Bulletins –

the Challenge
Weather information is extremely important for many tactical (day-to-day) and strategical (long-term) agricultural decisions. Tactical decisions include such farm management activities as sowing, cultivating, spraying, and irrigating. Strategical decisions include cropping intentions, management practice, and marketing. While daily rainfall and temperature patterns have a direct influence on tactical decisions, favorable or unfavorable seasonal weather patterns (including long-term trends and variability) may force alterations in cropping patterns and marketing decisions. There are growing demands for timely and effective agricultural weather information for a wide variety of agricultural management decisions, ranging from crop’s response to daily weather to the crop’s adaptation to changing climate.

Agrometeorological bulletins can serve a vital role by providing to the agricultural community relevant decision-making information. The key to a bulletin’s success is to deliver the right information to the right user at the right time. One of the first criteria that must be identified is to determine who the users are. In other words, who needs the information that can be effectively delivered. Then, the user requirements must be established so products that are delivered will serve the necessary purpose.

Before discussing the agrometeorological bulletin in more detail, allow me to start with some philosophical quotes that I found which I will call "food-for-thought" for this presentation.

"An expert is one who knows more and more about less and less until he knows absolutely everything about nothing."

Agricultural meteorology is a highly specialized field that is composed of diverse disciplines. Meteorological and climatological principles are related to agriculture in an array of applications ranging from crop growth and productivity to land resource management. Knowledge of

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Agronomy, crop physiology, hydrology, and ecology are complementary interdisciplinary fields that influence the skills of an agricultural meteorologist. Moreover, the ability to migrate this knowledge into a comprehensive resource base for applications, often employing computer and GIS technology tools, illustrates the complex nature of this expertise.

Depending on the specific application, these resources must be utilized appropriately to process the information needed by the user. The expertise from different disciplines must be drawn together to compile the data, analyze the results, and produce meaningful information for the decision-maker. An open channel of communication between experts in different fields of expertise is essential for a successful bulletin.

A cooperative effort between experts in the various fields, along with proper recognition for their contribution, can be a very effective means for the collaboration, preparation, and dissemination of a quality bulletin.

"It’s a simple task to make things complex, but a complex task to make them simple."

The objectives of a bulletin must be clearly defined. The first, and perhaps, most important objective is to know who the users of the bulletin are. There are a wide variety of potential users with a varying range of information needs. Farmers would like daily information during the growing season to assist their daily activities in the field, such as planting or spraying. They also need information that may be more meaningful on a weekly basis to monitor and manage farm operations like irrigation scheduling. Water budgeting techniques often need cumulative data to best calculate these data. Agribusiness concerns, such as seed and fertilizer companies, may need longer term data to evaluate trends in cropping practices to plan for the needs of the next growing season. Marketing decisions may also depend on the magnitude and severity of weather extremes in other crop areas.

In order to satisfy many of these user requirements, accessibility to appropriate input data is absolutely necessary. Further, this input data must be available on a routine basis to ensure systematic reporting of the informational requirements. Knowing the input requirements, techniques can be established utilizing computer and human resources to prepare the appropriate products for dissemination during the growing season. Pooling of resources can certainly ease the demands imposed to meet deadlines for publication, but this requires explicit coordination among the contributors. While it may initially be a complex task to coordinate resources for the
bulletin, the end result will be an efficient process to satisfy user requirements in a timely fashion.

"Complex problems have simple, easy-to-understand wrong answers."

In many meteorological applications, comparisons of observed data with respect to a standard normal value provide very useful information. For example, rainfall represented as a percentage of the standard 30-year (or 10-year, etc.) normal rainfall is a widely used and meaningful computation. In the application of meteorology to agriculture, there are well-known relationships between rainfall, temperature, and crop yields. The comparisons of each parameter with their respective normal values may be valid as initial qualitative estimates of potential yields. However, more complex analytical computations may be required to quantify the impact of weather on crop yields.

Another important consideration in yield analysis is the influence of technology. Changes in trends of crop yields due to the introduction of technology over a period of time must be evaluated to determine the most representative deviations for trends. Technological changes, introduced by fertilizers, hybrids and varieties of seeds, and farm management practices, often cause step-like changes in the trend values. Crop yields, expressed in terms of departures from trend, are much more representative than departures from a long-term normal, which do not account for trend changes. Thus, while it would be simpler to evaluate weather’s impact on yields with respect to long-term averages for all parameters, the results would not provide a true representation of the actual yield potential.

Whether it is a computation of a derived relationship or a process for the preparation and distribution of a bulletin, a well-prepared plan of action must be carefully developed and implemented to ensure that meaningful and pertinent information is available to the user.

"One thing that is good about procrastination is that you always have something planned for tomorrow."

Whether it is a new data source, a new technological tool for analysis, or, a new desktop publishing capability, it is virtually impossible to reach a steady-state condition in which no additional improvements are necessary. Each new task must be well thought out with respect to the final product. Procedures need to be tested before operational implementation. Feedback from the users is an absolute necessity to ensure the desired outcome. Some of these tasks may be completed in a short period of time. Others may
require a lengthy trial and error process. Inquiries should be encouraged from the user community to offer suggestions for improvement. This important aspect of a successful bulletin not only promotes enhancements of the bulletin but also opens an important channel of communication between the information providers and information users. This is a proactive approach to continually improve the quality, content, and timeliness of the bulletin.

"Short-term gain can be long-term pain."

Hasty solutions that seem to remedy a situation may cause more complicated problems to be resolved later. One of the most notorious dilemmas facing computer technology was the Y2K problem. While it may have seemed to be an eternity before the year 2000 was reached by the initial computer programmers in the early high-tech age of the mid-1900's, a simple flaw in design ‘thinking’ to conserve space in programming languages created a costly and laborious effort to overcome a potential computer-age nightmare on January 1, 2000. While a focused worldwide effort to correct this flaw succeeded in avoiding major disruptions in service, the effort required tremendous computer resources. This is a prime example of how a simple design oversight can have unintentional consequences in the future. While it is impossible to anticipate some of these problems, a hasty quick fix is usually not the best solution.

"Anything you try to fix will take longer and cost more than you thought."

Some problems may be solved by readily available ‘off the shelf’ solutions. In fact, there are commercial off the shelf (COTS) software packages that may be directly utilized for specific applications. However, no one solution will satisfy all needs. Further, cost restrictions and human resource limitations may prohibit the use of COTS solutions. If the goal is to improve a product or to introduce new technological innovations, then careful consideration must be given to the development, testing, and implementation phases to ensure success. Often, the approach to problem solving entails a trial and error process. A plan of action needs to have a well-defined end product and a set of time lines to meet the desired outcome.

An important step is to establish guidelines for improving the bulletin. The first and foremost consideration is user requirements. If the information is scientifically and technically sound but not useful to the user in the decision making process, then the product will likely be deemed unsuccessful. The next factor to consider is the basic, or minimum, need that
can be satisfied by the product. With this basic but useful information available to the users, a steady-state interest for the product and demand for additional information will be maintained. Finally, as resources expand and cooperation with other sources of information is developed, enhancements to the basic information and more user-friendly products can be achieved.

"If everything seems to be going well, you have obviously overlooked something."

In a newspaper cartoon, an employee meets with his supervisor. The employee notes “I’m pleased to report that I had no problems this week. I only had issues, opportunities, challenges, and valuable learning experiences. To that the supervisor asked “Did you do any work?” The employee responded “It didn’t seem necessary.” There may be frequent relatively benign intervals when users are satisfied with the products or even have just become accustomed to the expected products. During these times, there may be no proactive effort to alter the process or to make any revisions on the bulletin. However, over the course of time, some products may become less useful, may become outdated, or even may become counterproductive. Let me illustrate this observation by an example. A weather station has been reporting reliable precipitation and temperature data from an agricultural area for 30 years. Useful information related to the impact on traditional field crops grown in the area was helpful to farmers during the first half of the period. However, a trend was occurring over time that was not documented by weather observations nor seemed relevant to the observers. Demographic changes due to increasing population and urban growth resulted in a significant alteration in cropping patterns, shifting from predominant field crops to smaller-scale market crops in the proximity of a more urbanized setting. Without proper documentation of these changes, the information provided in the bulletin may become less important due to shifts in demography, cropping patterns, and user needs. Further, without a mechanism for user feedback, some of these shifts may be difficult to ascertain. While the provider of information may think relevant information continues to be included in the bulletin, the dynamics of change have in reality altered its usefulness. The moral of this story is to keep looking for new ideas and ways and means of improving your product, and know what your clients need. What may be considered "good" today, may only be "satisfactory" next month, and "inadequate" next year.
Preparation, modernization and distribution of agrometeorological bulletins – some issues

These discussion points hopefully illustrate the complexity of issues involved in the preparation, modernization, and distribution of an agrometeorological bulletin. Given the current status of a national bulletin, regardless of its content or infrastructure, let's turn to the objective of this workshop; namely, the improvement of agrometeorological bulletins. This is not an easy task. Any standardization of product format must be balanced by the unique informational requirements of the local user community. Any effort to expand or enhance a bulletin must also be accompanied by appropriate training to ensure continuity of service. Training involves all aspects of the bulletin, ranging from those who prepare the products to those who receive the information. The training process must also include an open dialogue, or forum, for an exchange of communication between the providers and users of the products. This helps to ensure an adequate understanding of the intent of the bulletin as well as its limitations with respect to support for the user’s decision-making process.

To establish a guide for improving the bulletin, several issues must be evaluated. These include accessibility of data to meet basic user requirements, sources of routine and ancillary data; technical and human resources available for the product; appropriate user surveys of information delivery mechanisms; a strategy to develop and promote institutional collaboration; and mechanisms to establish appropriate user feedback.

While there are many factors to be considered in evaluating the strengths and weaknesses of a national bulletin, most can be grouped with three main categories. These are input requirements, analytical tools, and information delivery. Each of these categories will be discussed; keeping in mind that the emphasis is on weather and climate information needed by agriculture.

Input requirements

Input requirements refer to the quantity, quality, and timeliness of data that are available for the preparation of the bulletin. The number of reporting stations in key agricultural areas, instrumentation standards and maintenance, data collection and processing methods, data standards and quality control procedures, and, human resources are all factors involved with input requirements. Further, are the appropriate data being collected? This is an essential component that requires technical expertise and resources to meet the input requirements, and complete knowledge of the user
requirements. Thus, appropriate channels of communication between producers and users of the bulletin are an absolute necessity.

The data issue is of utmost importance for obvious reasons. Metadata, or information about the data, is very important documentation to build the solid foundation. Valuable information is available from the location of stations with respect to crop areas and station history with respect to weather and climate patterns. A search for other sources of data, from different operating networks, must be conducted periodically. While some networks provide data for different operating requirements, the information can still serve to improve the density of observations with proper recognition of the sources and proper documentation of metadata files. Some data may not be timely for routine operational assessments but may be useful as they become available for historical analyses or model outputs that are reported on a more periodic basis.

Different types of data can also enhance the quality of the final product. For example, a satellite image of the areal extent of a tropical storm over a crop area provides useful insight about potential storm damage. A special written text, providing more detail of an unusual agricultural weather event, can highlight the magnitude and severity of nature’s impact on agriculture. As an example, as a prolonged dry spell turns into an agricultural drought, reporting this information in terms that the user can identify and may help provide guidance in both daily and seasonal planning. The value of accessible data is measured by how timely the information is translated into a format for the decision-making process.

Another key factor is that the bulletin derives its success from not only weather data input but also agronomic input. Crop type, crop stage, crop condition, and soil information are all necessary input requirements for a comprehensive agrometeorological bulletin. Much of this information is usually available from a variety of sources in different agencies at various national, state or provincial, and local levels. The task at hand then becomes a search for these data sources and perhaps a mutual cooperative agreement, for proper recognition, to ensure access to these data for public dissemination. A very useful model of this arrangement is illustrated by the United States Department of Agriculture (USDA) and Department of Commerce (DOC), who cooperatively operate the Joint Agricultural Weather Facility under a formal memorandum of understanding (MOU). The MOU clearly defines the responsibilities of all participating agencies that contribute to JAWF’s operation. JAWF has existed for over 30 years and is responsible
for publishing the U.S. Weekly Weather and Crop Bulletin, a publication in existence since 1872. Weather data are provided by DOC’s National Weather Service (NWS). Crop data are provided by USDA’s National Agricultural Statistics Service (NASS) and World Agricultural Outlook Board (WAOB).

Pooling of resources from different agencies provides an effective means of acquiring a comprehensive database for the agrometeorological bulletin. It is not uncommon for multiple sets of data needed for this analysis to be scattered across more than one agency. Every effort should be made to coordinate these resources to ensure an efficient process of acquiring the necessary input requirements.

**Analytical tools**

The next category, analytical tools, involves converting the input data into information that can be packaged for delivery in a form that adds value to an existing knowledge base. For example, the simple calculation of growing degree-days, based on daily maximum and minimum temperature observations, can be a very useful indicator of crop phenology. More complex computations of soil moisture and evapotranspiration estimates are crucial in an agrometeorological analysis. Temporal and spatial analyses of data provide more information on historical analogue comparisons and the severity, extent, and deviation of extreme weather events. Additional tools, such as geographic information systems (GIS) technology, mathematical models, and to remotely-sensed observations, provide additional resource enhancements that can convey value-added information for the decision making process. While a great deal of information can be developed given access to technology and resources, a fundamental prerequisite must always be kept in mind in this process of information generation. The right information must be delivered to the right user at the right time.

Another major consideration is what technological tools are available to convert these databases into meaningful, user-friendly information. This may be a relatively easy task if all users require the same information or if there are unlimited resources to satisfy all diverse user needs. However, in reality, neither of the above options is usually feasible. Further complicating the process is the fact that weather’s influence on crops varies over a growing season. In temperate zones, soil temperature is a critical parameter during the planting season, since seeds will not germinate if the soil temperature is too low. In subtropical zones, infrequent freezing air temperatures during critical flowering stages of citrus trees can be devastating. Other information is crucial throughout the growing season.
Data base management techniques allow efficient processing, analyzing, and graphical display of informational products. Automated software routines can expedite end to end information management. Resource constraints may limit the range of software tools available; however, a number of shareware/freeware programs are available to aid analysis. Another very effective approach to enhance the product is to obtain feedback from other technical experts as a product is being drafted. For example, the United States Drought Monitor is produced on a weekly basis and is published in the Weekly Weather and Crop Bulletin. This product is jointly prepared by DOC, USDA, and the National Drought Mitigation Center (NDMC). The draft of both the national map and text is sent out via email early in the week to all 50 state climatologists and other local specialists for their comments and suggested revisions. A rapid response is essential, and a second draft is sent after incorporation the revisions. Finally, after 3 days of iteration, the final product is released electronically on Thursday mornings. The email communication process has proven to be even more successful than anticipated, allowing local experts to assist by email with comments and revisions.

Another powerful technological innovation that can greatly improve the quality of a bulletin is geographical information systems (GIS) technology. GIS allows data sets to be overlaid onto one another. A crop area map can be overlaid over a geographic region. Topographical features, such as river basins, mountains, and deserts can be defined to better define the limits of the crop area. Information on specific crop stages can be next graphically identified. Finally, relevant weather information can be displayed on this map. This graphic depiction can be used to identify how weather anomalies are affecting crops, in terms of both aerial extent and severity.

**Information delivery**

How information is delivered to the users of the product is, finally, of extreme importance. This leads to the third category, information delivery. There are a number of issues that fall into this group. These include clearly defined users, user-friendly information, cooperation and coordination between producers and users of the product, proper training, and, timeliness of information delivery. The form of dissemination is also an important topic within this category. Hard copy publication sent via mail allows detailed text and graphics, but its effectiveness may be hampered by the timeliness of receipt. Delivery by radio allows rapid dissemination but limits the amount of information that may be provided. Internet technology
combines the strengths of detailed information and rapid delivery but is definitely constrained by lack of Internet access in many developing countries.

To be effective in delivering effective information, irregardless of the form of dissemination, the content of the bulletin must be value-added information that is useful to the decision-maker. The product must be delivered or made accessible in sufficient time for the user to make professional sense from the information and use it appropriately in the management process. Key considerations for a successful bulletin are what information does the user need and when does the user need this information? To answer these questions, there must be an established mechanism to allow routine communication between the technical experts who prepare the bulletin and the users of information. Formal lines of communication can be developed through user surveys and open forums. Informal mechanisms, such as telephone, facsimile, or email exchange should also be encouraged. Once established, such mechanisms for communication should become a routine occurrence to accommodate changing user needs, new technological innovations, and more efficient distribution procedures. Constructive feedback mechanisms promote an active dialogue to encourage improvements that not only technically enhance the bulletin but also increase its usefulness. Building upon the minimum requirements, the bulletin can be strengthened and expanded with increasing support and resources to respond to user requests for additional information needs.

Information delivery by Internet communication offers great opportunity to move quality products to the decision-maker rapidly. The computer age technology also allows efficient feedback mechanisms, which in turn may increase the demand for additional information. While these computer resources are limited in many developing countries, Internet technology is rapidly expanding and the cost of computer technology is declining. This offers exciting opportunities for the global community to exchange data and information for the entire user community.

There are numerous and increasing demands for timely and effective agricultural weather information for many agricultural decisions. These decisions range from day-to-day farm management activities, such as planting, spraying, fertilizing, etc. to seasonal and annual agricultural business decisions, such as seed varieties, land-use planning, etc. Daily weather conditions have a major impact on the farm economy, directly affecting crop yield outcome. Long-term weather anomalies and climate
variability may also alter cropping patterns and practices, crop adaptation strategies, and natural resource conservation measures.

An agrometeorological bulletin can assist farmers, agricultural business managers, and government officials in their decision-making processes by providing relevant information in user-friendly terms in time for analysis of the situation. The technical experts who prepare the bulletin must absolutely know who their users are and what are the user requirements. By establishing and maintaining open lines of communication between the providers and users of information, a systematic plan for action can be developed and implemented to achieve the desired objectives.

**Some basic recommendations for improving agrometeorological bulletins**

Some basic recommendations are now presented to guide planners in their goal of improving the agrometeorological bulletin.

- *Don’t promise too much to quickly.* Start with basic, easily accessible weather data and simple derived products. For example, growing degree-days provide a useful indicator of general crop phenology.

- *Relate the weather data to meaningful agricultural information.* While reported weather information may, at times, be useful without further elaboration, its impact on agriculture is the ultimate goal. How does the reported information affect crop growth and yield potential, range and pasture vigor, phenological status, cropping patterns and trends, and land-use changes? How does current weather situation compare to a past known event, which had an impact on agriculture?

- *Don’t oversell the information.* Weather has a direct impact on crop yield potential. However, other factors such as farm management practices (cultivation, fertilization, and migration) and technology changes (seed hybrids, conservation practices) may also influence yield potential. Further, crop production is also influence by acreage which will be driven largely by economic conditions.

- *Establish credibility slowly but surely.* There is an essential need to establish consistency and reliability in reporting. While responsive to changing user requirements and increasing demands for information, there is an absolute mandate to strive toward standards of reporting and effective quality control mechanisms.

- *Implement new products with proper introduction.* Announce to the user groups the intention of new product implementation into the
bulletin and fully explain why it will be made available. Encourage user feedback to promote response, and modify the product as needed to account for significant user recommendations.

- **Be proactive in demonstrating the usefulness of your products.** Always strive to improve the quality of the bulletin with new products and better representation of existing products. Periodic user forums or surveys should be encouraged to maintain the necessary contact with the client of your bulletin.

- **Training and education is an essential component.** This must involve both the providers and users of data and information. Both parties involved in the agrometeorological bulletin must be able to ‘speak’ and ‘understand’ the same technical language.

- **Don’t hesitate to pool resources.** Human and financial resources are very often limited. Ways to achieve maximum efficiency by coordinating and combining resources are to share ideas, exchange experiences, establish standard guidelines, and formulate recommendations for bulletin improvements. With proper recognition for contributions and mutual access to the products, great strides can be achieved more rapidly by a concerted and coordinated effort.

    In closing, let me summarize by saying that successful improvements in agrometeorological bulletins can usually be derived from the quality of input plus a variety of technological tools which yield simplicity of meaningful output.
Improving Agrometeorological Bulletins –

Regional Perspectives
Improving Agrometeorological Bulletins
Perspectives from RA I (Africa)

L.E. Akeh¹ and M. Muchinda²

Introduction

The report below is based on the responses to a questionnaire which was sent (during the month of July 2001) to 54 National Meteorological and Hydrological Services (NMHSs) and 6 Institutions (ACMAD, AGRHYMET, DMC Nairobi, DMC Harare, ICRISAT and the Niger Basin Authority) with the assistance of the WMO Subregional Offices in Lagos and Nairobi; and ACMAD (African Center of Meteorological Applications for Development) and AGRHYMET (Regional Center for Agricultural Meteorology and Hydrology) in Niamey. By 20 September 2001, 29 NMHS and 4 institutions, i.e. 55% of the NMHSs and Institutions had responded to the questionnaire. These were the NMHSs of Benin, Burkina Faso, Cameroon, Djibouti, Egypt, Ethiopia, Gambia, Guinea Bissau, Guinea Conakry, Kenya, Lesotho, Libya Arab Jamahiriya, Mali, Mauritania, Mauritius, Mozambique, Madeira Island (Portugal), Niger, Nigeria, Senegal, Seychelles, South Africa, Swaziland, Tanzania, Chad, Tunisia, Uganda, Zambia and Zimbabwe and the Institutions ACMAD, AGRHYMET, ICRISAT and the Niger Basin Authority.

Oral interviews and discussions were held with the Director of the NHMS of Niger, and his staff in charge of the agrometeorological bulletin production, the Director General of AGRHYMET, and his staff in charge of the agrometeorological bulletin publication, the Director General of ACMAD and the Director General and staff of the Niger Basin Authority (covering all the riparian states of the Niger river).

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Summary of Responses to Questionnaire

Existence of Independent Agrometeorological Service Unit

About 94% of the respondents indicated that they have an independent agrometeorological unit. The NMHSs of South Africa and Seychelles do not have a unit yet. But South African Weather Service is currently trying, in partnership with the Agricultural Research Council (ARC), to develop a dissemination path for weather and climate information for agriculture. Although Portugal is a member of RA I due to its territory of Madeira Island, most of its agrometeorological activities is carried out in the European mainland. All agrometeorological studies and information, namely those disseminated in the form of periodic agrometeorological bulletins are developed for Madeira.

Issuing of Agrometeorological Bulletins and Advisories

All respondents stated that they issue agrometeorological and advisories. The majority of the respondents (75%) issue their agrometeorological bulletins on a ten-day (decadal) basis while one quarter stated that they issue monthly bulletins as well. AGRHYMET issues decadal, monthly and seasonal bulletins for all the nine African Sahelian countries belonging to the CILSS (Inter-State Committee to Combat Drought and Desertification in the Sahel). Less than 1% respondents issue seasonal bulletins.

On the other hand, ACMAD issues seasonal and inter-annual forecasts for agriculture under the CLIMAG (Climate Prediction and Agriculture) project to NMHSs in RA I.

Collection, Analysis and Presentation of Information in the Bulletins

Half of the respondents indicated the method of their data collection. The most widespread method of data collection is by telephone, post and fax, while less than a third collect through E-mail. Similarly, less than 15% of the respondents indicated what type of software is used for data analysis, i.e. Excel, ILWIS and SURFER. However, more than 95% of the agrometeorological units present their data in the form of text, tables and graphics.

Involvement of Agricultural and Extension Agencies in the Preparation and Dissemination of Agrometeorological Bulletins

About 75% of the respondents indicated that agricultural research and extension agencies are not involved in the preparation or dissemination
of agrometeorological bulletins although a few are involved in data collection. However, the 25% of other respondents, which includes in particular institutions such as AGRHYMET, ACMAD, CILSS and the Niger River Basin Authority, that serve the whole continent, a subregion or a group of countries or any NHMS that has a National Multidisciplinary Agrometeorological Committee, involve the research institutions and extension agencies not only in data collection but also in the preparation and dissemination of the bulletins.

**Target Audience for the Agrometeorological Bulletins**

The majority of the agrometeorological units (80%) said that their bulletins are targeted at Government agencies, Non-Governmental Organisations (NGOs), regional and international organisations, whilst the remainder stated that their target audience is the research community, farmers, agencies issuing early warning systems and the general public.

The post is the most common method of reaching the target audience, although a few respondents mentioned the use of the web for information dissemination.

**Effort to Obtain Feedback from Users of the Bulletins**

Eighty percent of the respondents indicated that they have not made any effort in obtaining feedback from users. For those that have done so, however, the process of obtaining feedback is not carried out on a regular or systematic basis.

**Effort to Assess the Economic Value and Benefit of Information Contained in the Bulletins**

90% of the respondents have not made efforts to assess the economic value and benefit of the use of information provided in the agrometeorological bulletins. This may be due in part to the fact that farming in most parts of Africa is largely a risky business because an essential input, climate, is highly variable and most often unpredictable beyond very short time frames. Since very little land is irrigated in Africa, variable rainfall translates into variable production levels. Rural inhabitants are often very poor and depend upon agriculture for subsistence, the consequences of failure to warn or predict natural disasters such as drought for rural inhabitants can be devastating (Channing et al. 2000). These consequences and the issues of poor communication facilities, lack of or poor education of rural farmers, coupled with lack of expertise in NMHSs in Africa, work against an efficient determination of economic values of agrometeorological bulletins.
Effort to Issue Specific Bulletins of a Special Nature

About 70% of the agrometeorological units do make efforts to issue specific bulletins of a special nature to address extreme events such as droughts, floods, forest fires, etc. The rest make to such efforts.

Use of New Techniques such as Simulation Models and GIS

About 60% of the respondents are using some of the new techniques or software, such as WINDISP, IDRISI, SURFER, FAO WRSI (Water Requirement Satisfaction Index) etc. Elsewhere, modern methods are not widely used.

Shortcomings and Limitations in the Current Methods of Preparing Bulletins

Nearly 80% of the respondents cited communication bottlenecks as the number one limitation, which hinder the smooth data collection from weather observatories to the collection centers. Other shortcomings are:

- Poor quality of data
- Lack of adequate computing facilities and appropriate software
- Inadequate training in bulletin preparation
- Poor research/agricultural extension links
- Sparse station network

Comments and Suggestions to Improve Agrometeorological Bulletins

On top of the list for suggestions to improve agrometeorological bulletins was the improvement of communications between meteorological stations and collection centers (indicated by 70% of the respondents). Other suggestions were:

- Organization of workshops on preparation and production of bulletins
- Adoption of uniform bulletin formats
- Closer collaboration between service providers and users
- Closer collaboration with extension agencies
- Acquisition of better computing equipment for data processing and analysis
- Expansion of the station network
- Computerization of phenological observations
- Training of agrometeorological personnel especially in using GIS software
Other Information

One respondent did not answer to this question. However, the rest provided the following additional information:

- Bulletins have a limited circulation
- Efforts must be made to incorporate indigenous knowledge in the bulletins
- The user community must be sensitized on the interpretation of information contained in the bulletins
- The farming community must be educated on the benefits of using agrometeorological information
- The agrometeorological unit should have its own independent communication system
- Training of agrometeorological personnel should be stepped up, especially in strengthening and developing report preparation skills
- Strengthen communication systems for disseminating agrometeorological information to the farming community.

Suggestions for Improving the Timeliness, Quality and User-friendly Format of Agrometeorological Bulletins

This section discusses some aspects of bulletin design and presentation, which could contribute towards improving the quality of agrometeorological bulletins in RA I.

Technical Content

The information presented in the bulletins should be reliable and accurate, and it is essential that the agrometeorological units verify both, quantitative and descriptive data. The inclusion of maps would be more informative as they provide an indication of spatial variability. In most NMHSs in Southern Africa and Sahelian West Africa, agrometeorological units mainly provide a service to the Early Warning System for Food Security, and bulletins will often contain analytical assessments of key early warning indicators.

It has to be kept in mind that rainfall is a key element in the agrometeorological bulletins. In higher latitudes the first factor to control the seasons is the temperature, whereas in Africa we look first to the rainfall
pattern and then to the temperature, i.e. in RA I, precipitation is the most important parameter which determines the space-time characteristics of climatology. However, temperature becomes an important parameter over the highlands and as one move from the equator polewards.

**Scope and Coverage**

It is essential that all bulletins cover certain key topics:

- Current agrometeorological conditions
- Current crop stage (emergence/ vegetative/ flowering/ grain filling/ maturity/ harvest) and condition (excellent/ good/ fair/ poor/ failure)
- Current marketing year staple food supply situation
- Projected following year’s staple food supply situation
- Current price developments
- Current agricultural inputs, credit supply and utilization
- Pest and disease outbreaks

These key topics should be considered rather as a checklist of essential agrometeorological themes to ensure completeness of coverage and not a rigid structure to be followed without any flexibility.

**Size/Length**

A compact and concise report is essential, preferably a one page (front and back) description of the agrometeorological situation in the country, bearing in mind that these bulletins may be directed at senior policy makers and planners who may not always find the time to go through a large document in great detail. However, the size of the bulletin will reflect the situation in individual countries, but in general, quarterly bulletins should not exceed 8 to 10 pages. Careful incorporation of tables, graphs and maps will often help to reduce the length of the bulletin, and each one of these should present a specific/distinct set of information.

**Summary/Highlights Section**

Even a concise bulletin will require some kind of brief overview, which covers the key points of the bulletin which readers can grasp before they go into the report itself.

**Presentation and appearance**

The bulletin should be “eye-catching” in order to gain the reader’s interest. Initial impressions are very often based on appearances rather than
content, and therefore it is essential that the bulletin should appeal to the readers. Use of modern desktop publishing techniques will improve the layout or design of the bulletin. Furthermore, availability of a well-maintained heavy-duty photocopier will contribute towards the attainment of a high quality reproduction.

**Timeliness**

Bulletins must be released as soon as possible after the reporting period. This essentially means that there would be no point in embarking on the exercise of producing the bulletin if strict deadlines are not adhered to. This applies both to the preparation and release of national as well as regional bulletins.

**Dissemination of Information**

Consultation with the user community should take place. The objective is to define the requirements of the user community in terms of product characteristics and format and dissemination channel. Some users may prefer color maps and others averages of areas (e.g. over agricultural districts). Some prefer receiving information via E-mail, while others may be restricted to printed material. Some users may even prefer to get the actual image data for their own processing purposes.

The dissemination of information should benefit from modern communication facilities. Usually in early warning activities information is prepared in the shape of a bulletin providing analysis and comments based on the color maps, time series and data tables and are sent to users. This approach is convenient since this agrometeorological-monitoring bulletin can be prepared in a word processing package based on a pre-defined template. The output file from such a package can be used for the preparation of printed copies. Alternatively, to avoid delay, the file itself should be sent by e-mail to users with e-mail access.

In parallel, an Internet version of such a bulletin can be prepared for incorporation in the NMS web pages or in its own specific web page. It has to be noted that within the scope of this project, only basic web document preparation can be provided, but enough should be available to reach a standard suitable for public diffusion. The above bulletin is envisaged to be issued at a 10-day frequency. It is also desirable to prepare and disseminate periodic seasonal assessments - one reporting on the start of the season, a second reporting on the mid-season status and a final end-of-season report.
Reporting frequency

Users of early warning information would benefit from more frequent publications dealing specifically with the developing weather situation and its impact on staple food crops.

Ten-day periods are considered better and they are a standard reporting period for meteorological data; a month is considered too long to depict the current developing weather situation and its potential impact on food crops. However, for other purposes or applications, monthly or quarterly reporting may be deemed suitable.

Sources of data

Key institutions may include those, whose mandate pertains to the national early warning, remote sensing and meteorology, covering such diverse areas as:

- Crop monitoring and forecasting
- Food procurement, stocks, storage, imports and exports
- Food security situation, import requirement and food shortages
- Inputs supplies
- Socio-economic and nutrition indicators

For a Meteorological Service, equipped with both METEOSAT-PDUS and NOAA-HRPT receivers, outputting data in recognised formats and with required characteristics and analyzing and calibrating various seasons of data, parameters that may be generated include:

- Estimates of 10-day rainfall
- Estimates of number of rain days in a decade/month
- Maximum dry period within month/quarter/season
- Occurrence of 10-day sowing rains (early season)
- Daily maps of rainfall occurrence
- Cumulative rainfall amounts (10-day time step)
- Vegetation index maps (cloud masked 10 day maximum NDVI)
- Maps of large scale inundated areas (time step depending on cloudiness)
- Statistics of selected products – area averages, time series
Terminology/Language

Efforts must be made to stress user-friendly products in the bulletin, e.g. not CCD but “rainfall”; not NDVI but “vegetation greenness”, etc.

WMO Assistance

WMO should offer assistance to NMHSs in terms of guidelines, expertise, materials and capacity building through training workshops.

Future Technologies to Improve Communication in Africa: the ACAMD “RANET” Project System

Currently there are poor facilities within the Africa region for collection and dissemination of information particularly to rural communities. Moreover, the agro-hydro-meteorological services themselves have insufficient access to data. The greatest limitations to the use of information are:

- Inaccessibility
- Obsolescence
- Poor communication reliability

The RANET System is therefore a “Radio Internet” communication network of systems designed to exchange and disseminate agro, hydro and meteorological based information, data and products to urban and in particular to rural communities through radio, televisions and internet facilities.

The aim of RANET is to reduce the vulnerability for climate hazards by passing vital information to rural and urban users in local languages particularly to rural areas of Africa.

- Agro-hydro-meteorological information, e.g. weather forecasts, alerts, seasonal assessments and observations (for agriculture, forestry, water resources etc.)
- Plant diseases and pests (for food security).
- Social (Health, Education, Disaster preparedness, Town planning, Women and children issues etc.)
- Economics (Energy, Technology, Industry, Water resources etc.)

Objectives of RANET

The overall objective of RANET is to establish a mechanism for dissemination of meteorological information and climate prediction
products through the WorldSpace Foundation in audio, graphics, text and video form (i.e. multi-media).

The specific objective is for the regional development institution:

- Capacity building
- Repackaging of information
- Public awareness
- Introduction of new information and communication technologies within the rural areas.

**Further Objectives and Benefits:**

- To bring further co-operation with other rural projects – health, education, information, local issues.
- Raise awareness at a national level (i.e. with government and other funding bodies) of the positive contribution that the NMHSs are making to society.

**Components of RANET**

The Ranet system is an integration of two independent sub-systems namely:

- Radio and Internet
- Radio and television

Through these means the rural communities are provided with audio and video agrometeorological programmes (entertainment programmes inclusive). The audio programmes are provided through a FM radio transmitting station having radiation power of 60W, capable of covering a 25-50 km range radius in an officially allocated FM frequency. The programmes are picked on the FM transmission channels with the radio receivers.

On the other hand, the video programmes as provided through established TV viewing centers equipped with video machines

**Radio and Internet**

In the radio and Internet system a satellite digital receiver is used to download data (in ZIP format) from the WorldSpace satellite on an African Learning Channel (ALC) through the PC Adaptor-64K and specially installed software. The downloaded data are then further processed to meaningful formats for storage and retrieval.
Pilot Projects -Radio and Internet

The Radio and Internet project is presently located at ACMAD because of its position as the Center for Information Development (CID). It also serves as a data collection platform for the center’s research and development needs.

The transmission of data is by a special Internet arrangement to South Africa via Niamey, as South Africa is the only African country with an uplink station to the WorldSpace satellite (Boulahya 2001).

Recommendation

In the survey above 80% of respondents identified communication bottlenecks as the main limitation to data gathering in real time due to inaccessibility and poor reliability of the existing communication facilities in the continent. It is in this vein that the RANET System is presented to the meeting to recommend the new technology for the timely data collection for producing agrometeorological bulletins and dissemination in real time to end users to the next year’s 13th (XIII) Session of the Commission for Agricultural Meteorology (CAgM) for adoption.

Indeed, the Twelfth Session of the Commission for Basic Systems in December 2000 noted with interest the development of the RANET Project, which was a cooperative effort initiated by ACMAD in order to improve access to climate and weather-related information throughout Africa. RANET made it possible to receive information in the form of bulletins, reports, observations, satellite imagery and products of NMHSs that were placed in the public domain. The Commission agreed that the utilization of RANET in developing countries in Africa, Asia and South America should be encouraged and promoted (WMO 2000).
References


Improving Agrometeorological Bulletins
Perspectives from RA II (Asia)

Gholamali A. Kamali¹ and Byong-Lyol Lee²

Introduction

The WMO Regional Association II (Asia)

The terms "RA II" and/or "Asia" are used to describe that area including the countries and territories encompassed in the WMO Regional Association (RA) II (Asia). The 34 Members of RA II, are listed alphabetically below:

- Afghanistan, Islamic State of
- Bahrain
- Bangladesh
- Cambodia
- China
- Democratic Peoples Republic of Korea
- Hong Kong, China
- India
- Iran, Islamic Republic of
- Iraq
- Japan
- Kazakhstan
- Kuwait
- Laos Peoples Democratic Republic
- Macao, China
- Maldives
- Mongolia
- Myanmar
- Nepal
- Oman
- Pakistan
- Qatar
- Republic of Korea
- Republic of Yemen
- Russian Federation
- Saudi Arabia
- Sri Lanka
- Tajikistan
- Turkmenistan
- United Arab Emirates
- Uzbekistan
- Viet Nam, Socialist Republic

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The RA II covers a vast expanded area of the Indian Ocean and a part of the Pacific Ocean, and contains a large and diverse range of ecosystems, including desert, forests, rivers, lakes and seas. The desert extends from east to west, encompassing Central and Western Asia.

The Asian region is the fastest growing economic region in the world. The strongest economies in the Region are those of Japan and the Republic of Korea. In the last few years, a number of countries - most notably some member nations of the Association of South-East Asian Nations (ASEAN), China and India - have had impressive economic growth. The oil- and gas-producing countries, the Gulf Cooperation Council (GCC) and the Islamic Republic of Iran, have wealthy economies. The total population of the RA II was estimated to be around 3.395 million inhabitants by the end of 2000. Asia has two of the world’s most populated countries, China and India. The region also includes some of the least developed countries such as Afghanistan, Bangladesh and Nepal.

Compared to the other WMO Regional Associations, Asia includes the highest mountains, the rainiest areas and the driest deserts, with their associated variation in culture and biodiversity. Over the long period of human occupation in Asia, exploitation of natural resources, urbanization, industrialization and economic development have led to land degradation and environmental pollution. Climate change and climate variations also represent future stress.

The major challenges to the development of nations include natural and environmental disasters, climate change, climate variability, water management, over-fishing of coastal and sea resources, freshwater resources management and development, land use and land degradation, energy availability, tourism management, poverty alleviation and conservation of biodiversity. Weather and climate observations are required to address these issues, which are of relevance to the present social and economic conditions as well as for those of future generations.

The Need for an Official National Meteorological Service

Governments have historically established official NMHSs in many forms to provide daily forecasts and information services to the public, specific data and information to decision makers and planners on the countries’ natural resources, and advice to authorities in civil aviation, agriculture, forestry and marine transport, water and energy, tourism and others. The NMHSs cooperate at the regional and global levels by exchanging meteorological observations according to national obligations and commitments of regional and international agreements and conventions.
The NMHSs in the RA II vary in size, status of advancement, geography and state of development and, therefore, are highly differentiated in capabilities. The gap is wide, from the most developed NMHSs having super-computers for modeling and specialized meteorological centers, to the less developed NMHSs having limited budgets, shortages of observation instruments, spare parts, and consumables, lack of calibration equipment, data collection, processing and communication facilities, and under-qualified staff.

The legal basis for the creation and operation of NMHSs varies between countries. Some were established under national laws (Acts of Parliament or Royal Decrees, etc.), while others were established by other subsidiary forms. Institutionally, some NMHSs report directly to ministers, prime ministers, and heads of state; others constitute departments reporting to non-ministerial systems; still others are established as units or divisions of departments.

Most NMHSs fall under the ministries of communication and transport, and/or the directorates of civil aviation. Few have combined services of environment and meteorology or hydrometeorology. Many also have the responsibility for seismology. Therefore, practices vary widely among the countries of RA II in respect to the extent to which the NMHSs are assigned national responsibility for monitoring, research and service functions related to environmental/geophysical disciplines of oceanography, hydrology, seismology and ionosphere physics.

The Role of NMHSs

The main role of NMHSs is the provision of weather and climate information, environmental monitoring, and other related services and activities to meet national responsibilities to contribute to the safety, wellbeing and protection of property of all citizens, and to provide sustainable social and economic development. In addition, they help to meet international commitments and obligations under various conventions, in particular the effective implementation of the WMO scientific and technical programmes.

The NMHSs are normally the official voice in issuing weather warnings for public safety, and are the primary national authority and official source of information and policy advice on the present and future states of the atmosphere and on other aspects of weather and climate in respect to policy development.
The NMHSs provide essential meteorological and related services for public safety and welfare. They collect and exchange meteorological and related data and associated products, especially through the practice of free and unrestricted data exchange agreed upon under Resolution 40 of the Twelfth Congress of WMO. Furthermore, they contribute to and support national strategies for sustainable development. They sustain environmental research and development of relevant applications, and maintain the integrity and continuity of long-term national climate records.

**Current Status of Agrometeorological Bulletins in RAII**

In order to assess the agrometeorological activities and related bulletins in RA II countries, a questionnaire was prepared and sent through the WMO Secretariat to all Member countries of RA II. The replies have been reviewed and briefed for consideration in an Inter-Regional Workshop. Out of 34 Member counties in RA II, 14 countries, namely Bangladesh, Qatar, Japan, Nepal, Viet Nam, South Korea, Uzbekistan, Kazakhstan, Mongolia, India, Thailand, China, Laos and Iran responded to the inquiry.

**Existence of Independent Agrometeorological Service Units**

The first question is related to the availability of agrometeorological services, dates of establishment, service providers and related bulletins. All 14 countries informed us that they were furnished with an agrometeorological service, which issued agrometeorological bulletins. Such activities in the 11 counties were conducted within their NMHSs.

However, in Qatar, agrometeorological activities are conducted within the Ministry of Agriculture, while in two other countries, Japan and Viet Nam, such operations are managed jointly by the Ministry of Agriculture and the meteorological organizations.

The Republic of Kazakhstan is the first country in RA II that initiated agrometeorological operations in 1922. Later on, India, China and Viet Nam joined this area of activity in 1945, 1953 and 1960, respectively. Bangladesh was the last country to begin agrometeorological operations in 1986.

**Issuing of Agrometeorological Bulletins and Advisories**

The collected replies indicate that, with the exceptions of Qatar and Laos, all countries issue agrometeorological bulletins for their users on a regular basis. These bulletins are prepared in different forms in various countries because of independent observational methods.
In Uzbekistan, weekly bulletins are provided during the cultivating period to identify the best time for crop management. In Nepal, weekly bulletins just represent climate information. In Iran, weekly, monthly and seasonal bulletins include climate as well as soil and canopy information. Ten-day bulletins are regularly prepared in all countries except Qatar, Nepal, Thailand, India and Laos, and include different types of information. In Bangladesh and Japan only climate information is provided, while in the other countries, including Viet Nam, South Korea, Uzbekistan, Kazakhstan, Iran, China and Mongolia climate, soil and canopy parameters are observed and included in 10-day bulletins. In Mongolia, in addition to the above-mentioned types of information, pasture and animal husbandry related matters are also contained in 10-day bulletins.

In Bangladesh, Qatar, Japan, Kazakhstan, Thailand, India, and Laos no monthly bulletins are prepared, while in other countries monthly bulletins with information on soil, climate and canopy are given to users. In addition to weekly, 10-day and monthly bulletins, other kinds of publications, such as seasonal bulletins are prepared for each product based on observed climate, soil and canopy parameters in Bangladesh, Viet Nam, Uzbekistan and Iran. In particular, in Viet Nam special reports are prepared for climate related impacts on vegetation, forest, farming and other agricultural sectors.

**Collection, Analysis and Presentation of Information in the Bulletins**

The next questions explored sectors that provide agrometeorological services in the countries. The responses indicate that horticulture farming, fisheries, animal husbandry, forestry and crop production activities are archived in the NMHSs of Member countries. Bangladesh performs exclusively in the farming sector, while Japan, Nepal, Viet Nam and Thailand perform their duties with a wider scope in all the above-mentioned sectors.

However, there are still several countries that cover only part of this wide range of activities. In this context, 10 countries perform their duties in horticulture, 8 countries in animal husbandry and forestry, and 3 countries in agrometeorological observation.

In response to the operation of research stations on agrometeorology, it was revealed that in Bangladesh, Nepal, Kazakhstan and Laos there are no agrometeorological stations and agricultural centers merely record data for users. Agrometeorological observations in these countries depend on case requirements.

The number of agrometeorological stations vary between countries: Qatar has 3, Japan 7, Iran 23, Thailand 32 and China 34 stations. In Viet
Nam, about 15 stations out of the 129 agrometeorological stations are classified as principal ones and the remaining ones are subsidiary/auxiliary stations. In Uzbekistan 2 stations out of 5 are considered as specialized agrometeorological stations and the other 3 stations are called operational substations.

The Republic of Korea owns one principal and 9 auxiliary agrometeorological stations. In Japan there are a total of 7 stations for this purpose. In India, there are several agrometeorological stations that conduct study and research activities in four different regions, namely Pune, Rahur, Anand and Bangalore.

In Mongolia, two agrometeorological stations observe parameters on wheat and potatoes, and twelve other stations perform activities related to cattle, sheep and goats.

The agrometeorological weather forecast is one of the most important items focused on in these bulletins. In this context, short- and long-term forecasts bear particular importance in each bulletin, and users widely apply their information.

Short-term predictions are used in cultivating operations, with the suitable dates for the application of pesticides, irrigation, planting date and so on in different short-term periods.

Long-range forecasts based on statistical methods also appear in the bulletins issued by some countries, such as Bangladesh, Nepal and Laos. These kinds of predictions lack agrometeorological forecasts and they are only good for weather predictions with a leading time of 48 hours. In other countries, further to weather predictions, there are agrometeorological forecasts that may include some pieces of advice in the bulletins.

It should be noted that diverse requirements by users upon request might be met through the preparation of special bulletins giving the probability index in the forecast. Such special cases are among the additional obligations of these Services. Agrometeorological forecasts depend on the variety of vegetation and climate of the countries.

Considering the variety of climates in different Asian countries, most of the existing cultivated plants in the world are cultivated in the countries of this region. In this regard, for each cultivated plant, which has a prevailing role in the country, the agricultural meteorology related to it is studied and included in the bulletin provided.

Wheat is the main and important agricultural plant crop is studied
and observed in Bangladesh, Iran, India, and China. Parameters related to rice are observed in Korea, Uzbekistan, Iran, Thailand, India, China and Laos. Fruit trees and other orchard plants are also being observed from agricultural meteorology point of view.

Barley, maize and vegetables such as tomatoes, cucumbers, potatoes and flowers, grapes, oily plants and other cultivated and orchard plants are among the other cases that are considered for study and research in the field of agricultural meteorology. Some individual bulletins are provided in this regard for users.

All the countries in the region have agrometeorological databanks, including phenological observations for different cultivated plants, and data for soil and climate. Users classify these data for further processes. In some countries, the derived and analyzed data are available. Data quality controls based on standards are regularly accomplished.

The periods covered with climate data vary among the countries. The period ranges from 4 to 25 years among countries, but the maximum climate data period does not exceed 25 years. In some countries, climatic information covers a period longer than 70 years but data on soil and plants cover often relatively short statistical periods. Information in databases is recorded on paper. However, data files are usually provided on soft copies for the users.

Agricultural and meteorological statistics and data, including general information and bulletins for agricultural meteorology are offered free of charge in all countries, but in other countries, such as India and Iran, agricultural and meteorological data and statistics are free of charge only to researchers and scholars. The other users are expected to pay the relevant charges based on approved tariffs.

In Kazakhstan, additional costs for giving agricultural and meteorological data and statistics and bulletins received from private sectors are born by the user.

The Governmental sections receive agricultural and meteorological data and statistics free of charge.

**Involvement of Agricultural and Extension Agencies in the Preparation or Dissemination of Agrometeorological Bulletins**

The ways of transferring agricultural and meteorological data and statistics to the users are different among countries. In some countries, such information is disseminated on-line and via direct communication links. In
other countries, these data are provided on paper and mailed to users. In Bangladesh, Nepal and Laos, information is prepared on hard copy and sent to the users.

In Qatar, Japan, Viet Nam, Uzbekistan, Kazakhstan, Iran, Thailand, China and Mongolia, agrometeorological data and bulletins are provided in the form of hard copy and soft copy data files. In most countries of the region, news and information are broadcasted through the mass media in critical situations, particularly to farmers.

Mongolia, China, India, Thailand, Iran and Uzbekistan have a mass media system to disseminate necessary data during the growth period. One of the most important duties of NMHSs is Early Warning to mitigate the impact of natural disasters. In agrometeorological operations, these types of warnings can play a crucial role in improving service functions and lead to a better financial situation for farmers.

Regarding the personnel working in agricultural meteorology in RA II, responses indicated that the personnel training ranges from high school diplomas to doctorate degrees. Most personnel are working in the observation section and have a diploma or an associate of arts. At the professional level, a smaller number of personnel working in the station have Bachelor of Science or Doctorate degrees.

Of course, the number of experts in agricultural meteorology research sections is larger than of those who work in stations and executive parts. In the agricultural meteorology section, India enjoys the greatest number of experts holding Bachelor of Science or Doctorate degrees in its agricultural meteorology sector. In China there are six Bachelors of Science and two Master of Science degree holders. The number of personnel in these stations is distinguished from those of agricultural meteorological research sections.

In Thailand, there are about 113 experts, out of which 97 have diplomas and Masters of Science degrees. In Uzbekistan, there are 110 such experts and in Kazakhstan there are 130. More than 80% of them hold diplomas and the rest hold Bachelors of Science and Masters of Science. In Iran, there are 85 people, with 29 people having associate of art degrees, 40 people having Bachelor of Science degrees and the rest have Masters of Science and Doctorate degrees.

Considering the job training courses, the different agricultural meteorological training courses are held according to the needs of the sections. Bangladesh, Qatar and Laos are an exception, but in the case of
other countries different on-the-job training courses are justified and maintained.

Most countries hold their training courses in accordance with the Regional Meteorological Training Centers (RMTC’s) rules for the agricultural meteorological courses. Joint training courses with universities is another kind of training which is being organized in most of the member countries.

In many countries in RA II, there are no training courses at all for a Master of Science or a Doctorate degree in the field of meteorology, forcing the people to continue their studies in the agriculture branch in other countries. Bangladesh, Qatar, Nepal, Kazakhstan, Laos and Mongolia have no advanced degree meteorological courses.

In order to provide specialized and skillful manpower in the field of agricultural meteorology, these countries usually use universities and facilities of other countries, regarding them as related educational branches. In Japan, there are 4 universities, which can grant Doctorate degrees in the field of agrometeorology. In Viet Nam, agricultural meteorology can be studied in a provincial university under the agriculture and natural resources career. This university holds the training courses in sections of the Master of Science and doctorate courses.

In South Korea, about 11 universities offer agricultural meteorological courses at the Bachelor Degree level, and each of them is located in one province of the country. The required manpower and specialists are trained according to local requirements.

In Uzbekistan, the department of atmospheric physics offers specialized courses for the agricultural meteorology. In Iran, the University of Tehran has established an agricultural meteorological field, and students are trained in the Master of Science section. At present, people are dispatched abroad to obtain the Doctorate degree in agricultural meteorology.

In Thailand, students are trained for Bachelor of Science and Master of Science in the University of Bangkok in the field of agricultural meteorology.

In India, opportunities for higher education, including Bachelor of Science, Master of Science and Doctorate degrees are available. There are several universities offering these degrees, including many agricultural universities.

In China, the Nanjing Meteorological Institute, the Agricultural
University and Shenyang Agricultural University are responsible for the training of experts for agricultural meteorology and provide the required manpower in this vast and varied country.

Other countries secure their manpower in the field of agricultural meteorology at the Bachelors level and above from other countries. More cooperation from the Members of the RA II regarding the training field has been proposed by all of the Member countries.

In the question relating to the participation of the private sector in agrometeorological activities, it was revealed that among the 14 countries, only Japan has both the public and private sectors operating in such an area. In the 13 other countries of this study, the Government is primarily responsible for agrometeorology.

**Target Audience for the Agrometeorological Bulletins**

In most countries, users of agricultural and meteorological data and statistics and their products, such as bulletins, are connected to governmental sectors. Farmers do not receive the information directly from the yearbooks, but they receive it through the Ministries of agriculture and natural resources, forests and pastures and animal husbandry.

In South Korea, Uzbekistan and Mongolia, the meteorological organization, in addition to providing data for the agricultural Ministry, offers such information directly to the farmers. In Kazakhstan, Iran, Thailand and India, these data are transmitted to the large farming and industry companies in addition to related agricultural ministries and organizations in the government sections. Sometimes specific bulletins are provided for these users. In all countries researchers and staffs of TV broadcasting and public media are considered important and essential users.

**Effort to Obtain Feedback from Users of the Bulletins**

The process of obtaining feedback is not carried out on a regular or systematic basis.

**Effort to Assess the Economic Value and Benefit of Information Contained in the Bulletins**

Evaluation of the effects of agrometeorological information and bulletins on the agriculture indicates that the farming is the sector most influenced by this information.

The analysis of the questionnaire shows the following rates of effectiveness:
60% in Qatar and Viet Nam, 90% in South Korea, 75% in Kazakhstan, 50% in Iran, 80% in India and China. In the horticulture division the rates of effectiveness is 25% in Qatar, 10% in Viet Nam, Kazakhstan and South Korea, and 20% in Iran and India.

For forestry, the rates of effectiveness are 10% in Viet Nam, Iran and India. For animal husbandry, the rate is 5% in Qatar, 10% in Viet Nam and China, 15% in Kazakhstan, and 30% in Mongolia. For fisheries, the evaluated rate of effectiveness is 10% in Viet Nam.

The results of the analysis indicate that most activities in the regional countries occur in farming and other activities like horticulture, fishery and animal husbandry, with variations according to the countries. In addition, there might be other activities of lesser importance.

**Effort to Issue Specific Bulletins of a Special Nature**

Early warnings are given in the forms of notifications and announcements by the NMHSs in all the countries, and are distributed to the authorities in the agrometeorological division to adopt measures for mitigation of the impact of natural disasters.

In some countries these warnings, in addition to NMHSs, are made by other organizations. For instance in Qatar early warnings are announced by the agricultural and water resources divisions. In Viet Nam, the Ministry of Agriculture is responsible for early warnings. In South Korea, they are made by a joint committee comprised of the Korean NMHS and the Rural Development Administration. In Laos, early warnings are made for users and relevant organizations by a joint committee from the weather prediction division and the flood prediction and warnings sector.

In some of the above-mentioned countries, there are defined systems to consider these early warning issues to mitigate the consequences of natural disasters.

**Use of New Techniques such as Simulation Models and GIS**

Regarding the data processing for agrometeorology, the countries provided different answers. Viet Nam uses GIS and modeling methods. Bangladesh, Nepal, South Korea and Laos do not yet have GIS and modeling in operational service yet. Japan uses GIS and modeling in prediction and crops growth measurements. Uzbekistan uses satellite data in agrometeorology considering cultivation area and functions. Kazakhstan uses GIS and modeling for grain prediction in agrometeorology. Mongolia, India and Thailand use various software facilities to make the agrometeorological data operational.
Shortcomings and Limitations in the Current Methods of Preparing Bulletins

Regarding the recommendations for the development of data transmission, the Member countries in the RA II stated that for a better use of agricultural meteorological information, data transmission and distribution should be accomplished through the design of Web-sites for the Internet.

For those who have no access to the Internet, these data can be distributed through traditional methods. In any case, the data transmission networks differ among Member countries.

At present, some countries are completely modernized and computerized, and others have not yet acquired the hardware and software facilities for a quick data transmission. However, any promotion and development should be recommended considering the existing situation of the countries.

The responses of the countries to the questions, show evidence that all countries welcome the establishment of a specialized Web-site in agricultural meteorology. It is believed that the best solution for improving and speeding up the flow of information is the use of the Internet and the establishment of a Web-site.

Comments and Suggestions to Improve Agrometeorological Bulletins

At the end of the questionnaire, the appropriate recommendation for the promotion and improvement of the situation of the agricultural meteorology in the RA II were requested.

From the results obtained from distributed questionnaires among the countries as well as the existing information in RA II regarding the agricultural meteorology, the following suggestions are proposed:

- Holding of more training workshops and giving consideration to short courses in agricultural meteorology.
- Exchange of data and agrometeorological knowledge between member countries and also the Inter-Regional exchange of these materials.
- Exchanges of experts between Member countries as a necessary way to improve the knowledge of agricultural meteorology.
- The use of meteorological forecasts and short- and long-term agricultural meteorological recommendations should be included in specialized bulletins for further notice.
Performance of joint research between Member countries to solve common problems considering agricultural meteorological affairs.

The use of GIS, modeling and joint training should be considered.

Implementation Strategies in RAll

For the provision of agrometeorological information in the form of a bulletin, the numerous steps from collecting raw data to final delivery to end-users should be taken. Depending upon domestic requirements and resources available, each country provides a region-specific set of agrometeorological information in diverse ways and formats. Unique formats have been employed in their contents, the methods of delivery, etc.

Bulletins also should communicate with end-users, including receiving feedback from them, and giving a focus to communication skills and methods. In addition, analysis tools, raw materials as well as human resources with appropriate expertise are required. Thus, any effort to make improvements on existing agrometeorological bulletins should include systems analysis of the whole scope of steps and methods that we should take during the production processes.

Components of Agrometeorological Bulletins

The common features of agrometeorological bulletins include giving general descriptions of agrometeorological characteristics of certain regions during the specific growing season through reflecting regional priorities in terms of agricultural production and resource management. Depending on the requirements and priorities of end-users, the description details or expertise levels of the contents vary to a great extent. In general, due to the shortage of expertise as well as the limited space of the bulletin, quantity or quality of information is often insufficient. Despite of all these limitations, the essential components for a successful bulletin can be identified as follows:

1) End-Users:
   - Farmer, Associations, Extension, Researchers, Policy-Makers and General Public

2) Communication
   - Sharing, Dissemination, Feed-back

3) Form:
   - Digital / Document based (Paper)
   - Bulletin, Brochure, Letter, Note, Leaflet, etc.
4) **Data Format**
   - Text, Numeric, Table, Chart, Figure, Image, Map, etc.

5) **Methods**
   - Phone, Fax, TV, Radio, PC-Network, Internet, Dedicated line, etc.

6) **Contents:**
   - Type: General, Advisory, Warning, Recommendation, Suggestion
   - Weather/Climate/Forecast/Prognosis/Diagnosis information
   - Extremes, Energy Balance (Flux), Special Weather Phenomena (Flood, Drought, Frost, Heat wave, Fire, Landslide, Cold injury, etc)
   - Applications to crops, Fruit, Grass, Forest, Animal Husbandry and Fisheries
   - Impact on Growth, Development, Yield, Population, Reproduction (Phenological data, Eco-physiological parameters, etc.)
   - Incidence of diseases, Insects, Pests and Weeds
   - Farm Management (Cropping, Irrigation, Sowing, Harvesting, Post-Harvest, Spraying)
   - Resource Management (Water, Air, Soil, Biome)

7) **Developers/Producers/Authors/Publishers/Editors**
   - Meteorologists, Agronomists, Entomologists, Ecologists, Agrometeorologists,
   - Soil scientists, Virologists, Epidemiologists, etc.

8) **Raw Materials: Meteorological, Agronomic data, Non-Agricultural data**
   - Observed, Processed, Derived, Estimated (inter-/extrapolated)
   - Numerical Weather Prediction (NWP) model outputs, Agricultural model outputs
   - Domestic or Foreign Origin

9) **Tools**
   - Statistical packages, Graphic tools, GIS, Simulation models,
10) Institution/Organization
- Meteorological, Agricultural, Hydrological, Others
- Research Institutes, Extension Office, University, Private Sector, Cooperation
- Local, Central (Federal), Regional, Global Organizations

Any bulletin should contain enough information to meet user requirements with the highest priorities in the region. In order to reflect these requirements, diverse data, tools, skills, techniques etc. should be also available to disseminate bulletins that have desirable levels of accessibility, relevance, timeliness, and accuracy.

**Delivery methods available**

Methods for the delivery of agrometeorological information can be classified into different groups depending on format and delivery. In terms of format, agrometeorological information can be disseminated in document, video, audio, and digital forms. Also, regarding the methods of information delivery, they can be grouped into mail, broadcast, phone fax, networks, by hand, etc.

There are several groups of methods of the communication of agrometeorological information. The classification below may seem too arbitrary, but it allows combining the format and delivery types into document-based, media-based, telecommunication-based, computer network-based and digital file-based methods.

1) Formats of information
- Documents, Video, Audio, Computer digital

2) Methods of Delivery
- Mail, Broadcast, Phone, Facsimile, Network, by Hand

3) Combined Classification
- Document-based: Bulletins, Brochures, Letters, Notes, Others
- Media-based: Radio, TV – Public, CATV, satellite Journals
  - Newspapers – General, Agriculture
  - Magazine s– Monthly, Quarterly, Others
  - Scientific Journals

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• Telecommunication-based: Phone, Fax, Mobile, PDA, Others
• Computer Network-based: PC-Network, Internet – web, ftp, gopher, E-mail
• Digital File-based: CD, Floppy disk, Tape, Others

**Shortcomings and Limitations**

**Contents**
- Large uncertainties in forecast-based information
- Relatively simple and brief descriptions with historical data as reference
- Not very different from synoptic observation, insufficient number of elements
- Lack of detailed information to meet user’s requirements
- Impossibility to deal with all diverse requirements
- Difficulties in timely delivery for on-farm applications
- Poor relevance of contents to end-users to some extent
- Lack of expertise, skills, techniques, tools in manipulating materials

**Methods**
- Data collection: sparse density of observations, non-automated data collection, poor quality control, insufficient number of elements, non representation of agronomic fields, delayed data collection and archiving, poor data management, etc.

- Data manipulation: insufficient knowledge and experience in data handling, insufficient number of raw data, expensive data processing software (e.g. remote sensing)

- Analysis process: poor understanding on mechanism and algorithms, lack of expertise and fundamental related information, lack of an integrated analysis system, mostly dependent on imported tools,

- Evaluation/Assessment: few evaluation systems, no experience in quantification of values and benefits, no criteria or references available, difficulties in nation wide survey or sampling, confounding effects by multi-factors, directly or indirectly.

- Publishing: poor hardcopy quality, limited space, poor skills in design and layout. High cost in time and money.
• Delivery: Many options but only one or two feasible, less efficient in case of non-specific users, high cost for special customers, time-lag due to delays, no guarantee of delivery on-farm site,

• Communications: mostly one-directional information dissemination, late response to or time-lagged outcomes from information provided, unstable and poor network performance, relatively high cost of advanced communication services in developing countries, no communication to remote or isolated regions.

Tools

Data Collection

Automatic Weather Stations (AWS), receiver and analysis systems for remote sensing, delayed data retrieval over remote location, few standardized agronomic data, sparse spatial resolution, unstable data collection due to poor connections, frequent missing data due to sensor sensitivity, limited sources for additional data collection. Long-term forecasts, with great potential in agriculture, are highly uncertain.

Data Management

Lack of dedicated computer equipment (server with sufficient capacity) for archival and database management system with high performance for large size of data manipulation,

Analysis: Statistics, GIS, Models

• Expensive software required to handle complicated data analysis
• High cost of GIS packages with appropriate attributes and vector data for spatial analysis
• Complicated simulation models to conduct integrated assessment in agro-ecosystems
• Very difficult to develop own analysis system. Even calibration/validation requires time, labor and money.

Presentation

• Graphics, Hard Copy, Design, Layout
• Finding comparatively easy part to equip with necessary tools for presentation

Infrastructure

Human resources: Always the most critical limitation in every agrometeorological activity in developing countries.
Organization:
- Sometimes no dedicated organization to take care of agrometeorological bulletins
- Poor collaboration between meteorological offices and agricultural offices.
- Reduced priorities in agrometeorology because of poor recognition of importance
- Bureaucratic barriers against interdisciplinary solution-finding efforts

Hardware
- Limited availability of computer facilities, with poor networking capacity at national level
- Insufficient surface observation with few supplementary boundary-layer observations
- Limited remote sensing such as RS, RADAR, Global Positioning System (GPS) technology and analysis system in related institutes

Software
- No auxiliary computer software available for additional support

Financial Sources
- Lack of continuous support to secure financial sources for operational services

Information Systems
- Limited supplementary data supply system from non-agricultural sectors

Public Recognition
- Low-level reputation from the general public or poor recognition by the public of the importance of agrometeorological services

Social Efficiency
- Low system performance at social level in terms of investment efficiency
- Low cost/benefit rate compared to that of developed countries
Implementation strategies

Strengthening of National Infrastructure

Priority
Overall performance of agrometeorological bulletins can be evaluated in terms of their contribution to user requirements in terms of timeliness, effectiveness, feasibility, practical aspects, economic value, infrastructure enforcement, productivity, system stability, etc. Above all, the national priority on agriculture will be a critical driving force for a successful bulletin at a farmer’s site or at governmental offices. Given the highest priority, it is natural to have strong support from the government in finance, human resource, facility, equipment, research projects as well as other facilities.

Recognition
End-users such as farmers also can play an important role in activating agrometeorological bulletins by their strong demands for agrometeorological information for their farming. Obviously, the farmer’s recognition of the importance of agrometeorological information should be high enough for all information leading to increases in productivity or the stability of agricultural production to a considerable extent.

Expertise
In order to meet the user’s requirements on time, there should be a sufficient number of experts available in almost all disciplines of agriculture and other supporting disciplines such as computer technology, etc. Except for several developed countries, most countries suffer from a shortage of domestic experts in this regard. This necessarily leads to a poorer quality of agrometeorological information. The problem lies in the fact that securing a sufficient number of experts appears to be non-feasible, for the time being, in many countries due to limited resources or limited chances of educating or training to such an advanced degree of expertise in a short period of time.

Resources
Furthermore, systematic operation for the distribution of agrometeorological information will inevitably rely on national infrastructure such as communication networks, mass media, transports, and other delivery tools. Among the diverse components of agrometeorological bulletins, timely delivery of information is the most critical factor in the effectiveness of the overall performance of a bulletin. When this requirement fails to be met, the total value naturally becomes small or even worthless in certain cases.
Willingness

Finally, the willingness of utilizing the level of understanding of agrometeorological information with appropriate application skills of end users are two other critical elements that will decide the effectiveness of agrometeorological information systems at the operational level. Therefore, continuous education or training for end users on new knowledge, technology, and tools is very important to accomplish the ultimate goal at farmers’ sites. National agrometeorological service should include on-going education systems for various levels of end-users in agriculture.

| Policy + User Requirements + Expertise + Resources + Communication + Effectiveness |
|---------------------------------|---------------------------------|
| NationalPriority                | User’s Willingness              |
| National Infrastructure         |                                |

Improvement of Current System Efficiency

The feasible alternative to infrastructure strengthening is to improve the efficiency of the current system for agrometeorological bulletins as much as we can improve the use of available resources at the moment. This can be partially achieved by enhanced expertise through intensive education and training of developers or information providers. They would then be capable of carrying out research to develop more sophisticated applications after such education, even with the limited source of raw data.

Another way to improve agrometeorological bulletins is to enhance the overall layout and design for better user-friendly interfaces with easily understandable formats. Many skills need to be elaborated for better weather observation, data retrieval, archiving, manipulation, management, analysis, hardcopy, publishing, etc.

Above all, good communication skill with end-users is an essential element that decides the applicability of information to farmers’ decision making. Thus, any direct distributors of information to farmers should recognize the importance of communication skills with relevant strategies depending upon the level of end users to understand their requirements.

Various types of collaborations can be made to create a synergy effect among the agrometeorological bulletins and the related offices or institutes or organizations, domestically, regionally and globally. Sharing of resources from different offices can contribute greatly to the strengthening
of national agrometeorological services, for example, human resources with
diverse expertise, hardware resources such as facilities and equipment,
software resources, etc.

1) User recognition
   - Education / Training

2) Applications
   - Introduction/Modification/Implementation/Development

3) Resources
   - Experts
   - Training/Education
   - Tools
   - Upgrade
   - Skills
   - Elaboration

4) Communications
   - Technology (hardware, software) improvement
   - Skillful communications with end-users

5) Collaborations
   - Based on mutual benefit
   - Continuous collaboration

6) Operation
   - Sufficient manpower
   - Mechanical stability

**Essential Subjects to be considered for better bulletins**

1) **Contents: Accessibility, Timeliness, Relevance and Accuracy**
   - Quality – Specialization, Expertise, User-oriented, Appropriateness, Feasibility
   - Quantity – Diversity, Extended coverage, Detailed description
   - Standardization – format, lay-out, processes
   - Timeliness – Information (in advance or forecast-based), On-time delivery
- Efficiency – Automation of processes (drawing, coloring, editing, printing, etc.)

2) **Tools: Easy, User-friendly, Cost-effective, Compatible and Standardized**
   - Statistical packages
   - Image processing
   - Presentation tools
   - Analysis tools
   - Simulation models
   - GIS/RS Technology

3) **Resources: Accessibility, Continuity, Sufficiency and Reusability**
   - Raw Data: Meteorological, Agricultural, Non-agricultural
   - Expertise
   - Computers
   - Networks
   - Interfaces
   - Infrastructure
   - Organization

4) **Applications: Diversity, Differentiated, Applicability and Practicability**
   - Farm management
   - Food security
   - Market implications
   - Early warning
   - Risk management
   - Resource management

5) **Collaborations: Continuity, Cost/Benefit and Willingness**
   - Domestic
   - Regional
   - International
6) Communication: Accessibility, Cost Effectiveness, Performance and User-friendliness
   - Information Network
   - Interface
   - Skills
   - Feedback

7) System Operation: Performance, Relevance, Ease, and Cost Effectiveness
   - Server
   - Data-Base Management System (DBMS)

8) Processing/Manipulation/Preparation: Timeliness, Feasibility, Smoothness,
   - Data > information > bulletin > on-site application

9) Economic Value/Benefits: Final decision on a new system will be made considering its economic value or the social benefits of its applications

10) Special Edition: Explanatory or evaluative descriptions on abnormal or extreme weather phenomena with their consequences or impacts on agriculture can be published in a special edition of the bulletin whenever needed.

**Suggestions from Korea’s case**

This section introduces recent collaborative activities in agricultural weather information services among institutions as well as key concepts for understanding agrometeorological services in Korea. KMA (Korea Meteorological Administration, NMHS) and RDA (Rural Development Administration) agreed upon the establishment of the Joint Committee for Agrometeorology at the national level to strengthen the national agrometeorological services in data collection, information production, research, and services to end-users in 1999. Several joint projects in agrometeorology by RDA/KMA have been initiated since 1999. The projects being developed are:

- Strengthening of the Joint Committee of Agrometeorology
- Extension of observation network for agricultural weather
- Production of the detailed Agrometeorological information based on numerical weather forecasts
- Development of seasonal and inter-annual weather forecasts for agricultural applications, Information network system for supporting agrometeorological research
- Improvement of Agrometeorological information services at national and regional levels.

Strengthening of programs for the education and training of Agrometeorologists are impending priorities of the government. RDA and KMA play a major role in establishing the National Agrometeorological Center, through close collaboration with universities, scientific societies, and other relevant institutions. It is believed that advanced infrastructures and services in agrometeorology will be established in the next 5 years, which can contribute to regional and global societies by sharing experiences and the know-how expected to be gained from this achievement.
Improving Agrometeorological Bulletins - Perspectives from Regional Association III (South America)

Manuel Carvajal\textsuperscript{1} and Yumiko Marina T. Da Anunciação\textsuperscript{2}

Introduction

In South America it is very important to disseminate information on the close relationship between climate, agricultural production and productivity. The NMHSs have the priority to make institutions and authorities working in the agricultural sector aware about this reality.

The agricultural and livestock yield are based on two conditions, the first is relative to the management of some resources and inputs (soil, crops, animals, varieties, breeds, agricultural labors, pastures develop, plagues and diseases control, irrigation, drainage etc.). The second is relative to the influence of climate, more like a manageable factor than a menace.

There is an urgent need to achieve efficient production systems to obtain high yields in a sustainable way. The development of efficient food security systems in each country around the world makes it necessary to use new technologies for more efficient use of natural resources while assuring at the same time their preservation for use by the future generations.

The remarkable development of the communications in the last decades, in particular the worldwide communication in the cyber-space through the Internet and the world wide web, changed the way the people look at their environment. It created opportunities for the exchange of knowledge and ideas, data, concepts and information, hence allowing a fast development in the knowledge area.

There is a need to create awareness in the people, scientists and authorities (decisions makers) about the importance of applying correctly\textsuperscript{1}

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the meteorological data in the planning and sustainable development of the agricultural sector.

To achieve this goal, it is necessary that meteorological data associated with agricultural information be made available in an rapid, systematic and opportune manner. The agrometeorological bulletins, documents containing information of diverse meteorological parameters related with agricultural aspects, have been one of the most practical means in most of countries.

**Background**

The South America Regional Association (ARIII) has been established by 13 countries: Argentina, Bolivia, Brazil, Colombia, Chile, Ecuador, Guyana, French Guyana, Paraguay, Peru, Surinam, Uruguay and Venezuela.

Twelve countries, with the exception of French Guyana have NMHSs. Nine countries have Agrometeorological sections, excluded Guyana, Paraguay and Surinam. The Agrometeorological Sections are organized:

- as a Department in most of the countries
- as an office in Peru
- as a Division in Brazil.

**Methods and Materials**

A survey was carried out by sending a questionnaire by Internet to all RA III countries. Some problems were encountered to contact Bolivia, Colombia, Chile and Paraguay and hence, no answers were received.

In the case of Bolivia, the questionnaire was sent by fax because the e-mail was wrong, but no answer was received. In the cases of Colombia and Chile, no answer was received, however we visited all the meteorological service web sites of these countries (IDEAM and METEOCHILE respectively) and, hence, some information was obtained.

As a consequence, not all the countries in RA III have been analyzed and they reflect the current condition of eight nations of South America.
Agrometeorological Bulletins

Issued Bulletins

All the countries issue Agrometeorological Bulletins, except Surinam and French Guyana. Most bulletins are carried out by NMHSs, with the exception of Ecuador (Ministerio de Agricultura y Ganadería (MAG) where an agreement exists with the Instituto Nacional de Meteorología e Hidrología (INAMHI)) within an International project with International funds (World Bank); and of Venezuela, which carries out the bulletin with their Instituto Nacional de Investigaciones Agropecuarias (INIA) with meteorological information provided by the National Meteorological Service.

Geographical coverage

Bulletins have a different geographical coverage (Table 1), with six of them covering the whole country, but at the same time some of them are made according to the administrative classification (states, counties, regions, etc.).

As can be seen from Table 1, none of the countries cover completely the country's surface, because there are some areas that are not appropriately analyzed for different reasons. The most common reason is the scarce agricultural production associated with the lack of meteorological/climate information due to the limited number of meteorological stations in the area.

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*1 = National / 2 = Regional / 3 = Province / 4 = Department

Table 1. Geographical Covering of Agrometeorological Bulletins in South America (ARIII).
**Frequency of issue**

The frequency of issue of Agrometeorological Bulletins varies from one country to another (Table 2), the preparation of decadal bulletins (10 days) and monthly bulletins being the most common in Argentina, Brazil, Colombia and Chile. Ecuador and Peru cover both periods and Venezuela only monthly. This group is around 77%.

Daily emissions are made in Brazil, Colombia, Peru and Uruguay only for limited areas. Weekly issues are made in Colombia, Chile, Ecuador and Peru and in the case of Ecuador the bulletins are also transmitted by radio. In the mentioned countries, with the exception of Colombia, special advise bulletins are also prepared which are discussed further. Peru is the only one that issues an annual agrometeorological bulletin.

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*1 Daily / 2 Weekly / 3 Decade (10 days) / 4 Monthly / 5 Annual

**Table 2. Frequency of diffusion of Agrometeorological Bulletins in South America**

**Content**

*Climatological and / or Meteorological Information*

The nature of information available in the agrometeorological bulletins of South America is given in Table 3.

In Argentina, Brazil, Colombia, Ecuador, Peru Uruguay and Venezuela (88%), the information presented is mainly meteorological: precipitation and extreme temperatures, associated in most cases with agricultural information, in particular in those issued daily and weekly.
Table 3. Information available in the Agrometeorological Bulletins of South America.

On the other hand, the bulletins containing 10 days and monthly information include, besides rain and extremes temperatures, other meteorological parameters like wind (velocity and direction), relative humidity, sun radiation and/or sunshine. Data on ETP and atmospheric pressure are less common. In most of them, reference is made to humidity conditions versus crop water requirements like the humidity index and water balance might be applied.

The climatic information in the bulletins issued by Brazil, Chile and Peru (38%), include the description of climatic conditions and climatic behavior and their possible influence in the crop development. The forecasts of future climatic conditions for the following 10 days or month are presented (according to the frequency of the bulletin) based on tendency and historical information.

**Agricultural information**

References are made concerning phenological phases of crop development and how the climatic conditions could affect or will be affecting the crop development. The days for sowing and harvesting based on the agricultural calendar of each area are analyzed.

Special emphasis is made on some crops, which have been classified for the analysis as: 1) main crops a) short physiological cycle, b) perennial and 2) other crops.
1) Main crops:
   a) Short physiological cycle: corn, wheat, rice, soybean, barley, cotton, sorghum, beans and potato in Argentina, Brazil, Colombia, Chile, Ecuador, Peru and Venezuela.
   b) Perennial: banana, vine, coffee, sugarcane, oil palm and oranges in Brazil, Colombia Chile and Peru.

2) Other crops: mango, pineapple, cocoa, apple, peach, leguminous crops, olives, *Medicago sativa* (most of them are mentioned exclusivity in the Peru’s bulletins and some in Chile’s bulletin).

Peru and Venezuela are exceptions, as they are the only ones mentioning the *Medicago sativa*. Venezuela is a particular case because of its investigations made in the livestock area through the INIA. The other countries provide information about grasses but little about livestock, in the same way they do not provide information about the market and its behavior.

**Final users**

The principal target users are the general public, farmers and association of producers, technicians, authorities and commercial companies (Table 4). The country’s entire information of public character is offered, mostly to guide farmers, associations of producers, technicians and authorities (Brazil, Colombia, Chile, Ecuador, Peru and Venezuela). Argentina is the only one sending information to commercial companies.

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*1 Public character / 2 Farmers / 3 Association of producers / 4 Technicians / 5 Authorities / 6 Commercial companies

**Table 4. Final users of Agrometeorological Bulletins in South America.**
Means of diffusion

Means of diffusion of agrometeorological bulletins is shown in Table 5.

All countries use the Internet (Wide World Web) for the diffusion. With the exception of Uruguay, all the NMHSs have their portals (Argentina, Brazil, Colombia, Chile, Ecuador, Peru and Venezuela). This is followed by diffusion through the written press like newspapers or magazines (Argentina, Brazil, Colombia, Peru, Uruguay and Venezuela), through the radio (Ecuador, Peru and Uruguay), by fax and only to specific users (Argentina and Uruguay), by mail with same approach that the previous one (Brazil and Peru). No country of the Regional Association uses the television as a means of diffusion of their Agrometeorological Bulletins.

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*1 Internet / 2 Press / 3 Radio / 4 Fax / 5 Mail / 6 Television

Table 5. Means of Diffusion in South America.

Preparation and / or associated diffusion

With respect to the question as to whether research or extension agencies participate in the elaboration and / or diffusion of Agrometeorological Bulletins, it must be mentioned that a complete participation exists in Argentina, Colombia and Ecuador and in the case of Peru these institutions are users.

The diffusion is carried out exclusively by other agencies in Uruguay and in Venezuela, where the bulletins are elaborated by the National Institute of Agricultural Investigations (INIA) and it is therefore considered that preparation and diffusion are shared. Brazil does not have any participation with other institutions.
New Technologies applied

The existence and availability of new technologies in the world made it possible that some countries of the region have implemented some of them. Geographical Information Systems (GIS) are employed in Brazil, Colombia, Chile and Peru and the use of specialized programs is common in Brazil, Colombia, Chile, Ecuador, Peru and Uruguay.

Application processes have been studied in Argentina; Satellite images are used in Brazil and numeric models are employed in Uruguay.

Economic analysis

The analysis of the economic contribution to the agricultural sector through the information edited in Agrometeorological Bulletins is unfortunately not carried out in any country of the Association.

With or without price to the user

In Argentina, Ecuador and Venezuela the bulletins are free, on the other hand in Peru and Uruguay they have a specific cost. The situation in Brazil is different, as some bulletins are for free distribution and others for sale, according to user's type. The price for the users in Colombia and Chile is not known.

Special advise bulletins

Special advice or alert bulletins are issued in Argentina, Brazil, Colombia, Chile, Ecuador, Peru and Uruguay, when the conditions of time or climate are adverse for agriculture and are specific for affected areas. Venezuela does not issue this type of bulletins.

Chile diffuses special bulletins for "cold hours" directed to fruit farmers (May -September) and decadal bulletins about the "degree days" for agricultural labor (October - March) only for certain regions of the country.

Shortcomings and Limitations

A summary of shortcomings and limitations is given in Table 6.

Bolivia, Colombia, Chile and Paraguay are not included in this point because no answer was obtained about the questionnaire.
Lack of economic resources is an important constraint for the NMHSs of the region. In the particular case of Ecuador, the bulletins have been historically issued with external financial support (International Organizations, USAID and nowadays the World Bank), it would be needed to institutionalize the bulletin preparation.

Similar problems arise regarding human resources, because of the limited number of officials assigned and the lack of training in specific areas needed for the improvement of the content of bulletins. Limitations of human and economical resources is a constraint in Argentina, Brazil, Ecuador, Uruguay and Venezuela.

A common deficiency exists in quantity and quality of information; most of them are related to some meteorological parameters in certain areas, as the stations are insufficient to cover the entire surface dedicated to the agricultural production.

The limited agricultural information could be a consequence of the scarce participation with other institutions. The nations that consider this condition as an obstacle are Argentina, Brazil, Ecuador and Venezuela.

Among the limitations identified were the lack of equipment (Argentina, Peru and Venezuela) and the lack of specialized software (Argentina, Brazil and Venezuela). The type of system used for diffusion constitutes an obstacle for Ecuador and Peru.
Conclusions and Recommendations

According to the present analysis and with the contribution of the countries sending their input on how they would improve their bulletins, the following alternative solutions were identified:

Training courses of technical assistance in:

- Standardization of methods, presentation, contents and diffusion,
- Application of new techniques for the elaboration and analysis of information,
- Identification of the type of information useful for the livestock sector,
- Aspects of vegetable physiology under adverse conditions,
- Implementation of new technologies like GIS, Radar, Images from satellites, GPS and mathematical / simulation models,
- Methods to foster /make the active participation of the users in the content and analysis of the bulletins,
- Systems or methods to analyze economic contribution given through the agrometeorological information.
- Effective Administration of climatic, meteorological, agricultural, livestock data and their relationships.
### ANNEX I

#### Users

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#### Bulletin Users

#### Diffusion

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#### Bulletin Diffusion

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#### Shortcomings & Limitations

![Diagram showing the distribution of shortcomings and limitations]
## ANNEX 2

### South America - Regional Association III (AR III)

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<td>Argentina</td>
<td>Servicio Meteorológico Nacional Fuerza Aérea 25 de mayo, 658 Capital Federal</td>
<td>Mrs. Liliana N Nuñez <a href="mailto:agro@meteofa.mil.ar">agro@meteofa.mil.ar</a> phone/fax: +54-114-514-4230/ 514-4257 <a href="http://www.meteonet.com.ar">www.meteonet.com.ar</a></td>
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<tr>
<td>Brazil</td>
<td>Instituto Nacional de Meteorología Ministro da Agricultura, Pecuária e Abastecimento Eixo Monumental Sul – Via 1 Brasilia – DF</td>
<td>Mr. Alaor M. Dall’Antonia <a href="mailto:alaor@inmet.gov.br">alaor@inmet.gov.br</a> phone/fax: +55-61-343-2190/ 344-0700 <a href="http://www.inmet.gov.br">www.inmet.gov.br</a></td>
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<tr>
<td>Chile</td>
<td>Dirección Meteorológica Ministerio de Defensa Nacional Casilla 63, Correo Aeropuerto Internacional Arturo Merino Benitez Santiago</td>
<td>General de Aviación Hugo Oliva Aupt <a href="mailto:dimetchi@meteochile.cl">dimetchi@meteochile.cl</a> phone/fax: +56-2-676-3437/ 601-9590 <a href="http://www.meteochile.cl">www.meteochile.cl</a></td>
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<td>Colombia</td>
<td>Instituto de Hidrología, Meteorología Y Estudios Ambientales Ministerio del Medio Ambiente Diagonal 97#17-60 Piso 1,2,3,7 y 10 DC Santafè de Bogotá</td>
<td>Mr. Carlos Castaño Uribe <a href="mailto:pablol@ideam.gov.co">pablol@ideam.gov.co</a> phone/fax: +57-1-635-6035 / 635-6130 <a href="http://www.ideal.gov.co">www.ideal.gov.co</a></td>
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<td>Ecuador</td>
<td>Instituto Nacional de Meteorología y Hidrología (INAMHI) Iñaquito 700(36-14) y Corea Casilla Postal 16-310 Quito</td>
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Improving Agrometeorological Bulletins
Perspectives from RA IV (North and Central America, and the Caribbean)

Oscar Solano¹ and Ramon Frutos²

Abstract

Routine agrometeorological information in the form of bulletins, advisories and press releases are important for farm management activities, and for implementing effective strategies at the policy maker level, in an effort to boost production, promote socio-economic development and enhance food security. Advance information and communication technologies (ICTs) can be utilized to provide more accurate and user-friendly agrometeorological bulletins to farmers and other agricultural interests. Agrometeorological information is part of a continuum that initiates with scientific knowledge and understanding of how the weather and climate influences agricultural production, and ends with the evaluation of the effectiveness of implementing the information to increase yields. This paper reviews the status of agrometeorological bulletins in Regional Association IV of the World Meteorological Organization, and makes some recommendations for improving this service to the farming community.

Introduction

The agricultural sector contributes significantly to the Gross Domestic Product (GDP) of many countries in North, South and Central America, including the Caribbean. In Belize, for example, its contribution to GDP was in the order of 21% in 2000 (Ministry of Agriculture and Fisheries, 2001).

A direct inter-dependence exists between the crop or forest, the weather and the soil. Although the influence of the weather on agricultural production is well understood, it is evident that seasonal and inter-annual

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climate variability has been, is, and will continue to be the principal source of fluctuation in global food production (WMO 2001)

Global food production is essential to enhance economic development and alleviate the scourge of poverty. The provision of timely, accurate and cost-effective agrometeorological forecasts and information has proven to be a useful resource base or tool which, when implemented, can help farmers make management decisions and guide policy-makers in adopting strategies that will promote food security.

It cannot be over-emphasized that agrometeorological information at adequate time intervals, and in a format friendly to users can go a long way in helping farmers make critical decisions such as for example applying for a loan to cultivate hot peppers or not, to spray or not to spray, to apply fertilizer or not to apply fertilizer, to deploy workers or not to deploy workers etc. This is only one level of users who can utilize agrometeorological bulletins operationally. Special bulletins for agricultural technicians and policy-makers for example, can provide guidance on the introduction a new variety of corn that can boost the socio-economic condition of a rural community; or it may help decision makers promote a new breed of livestock or a non native cash crop such as soybean, to help farmers in a diversification programme. The use for agrometeorological information is endless.

With the advent of new information and communication technologies (ICTs) such as: the Internet, Satellite Technology, and Geographic Information Systems (GIS), agrometeorological services now have sufficient data and data processing facilities at their disposal, to produce more streamlined and user-friendly bulletins that meet the diverse needs of the agricultural sector. In the past, and even today, the contents of agrometeorological bulletins lack coherence, because while they are generally intended for farmers, their scale and complexity is that for technicians and policy-makers. Therefore, providers of agrometeorological bulletins must recognize their users, the user’s needs, and satisfy those needs within the context of agrometeorological bulletins and specialized advisories.

**Current State of Agrometeorological Bulletins in RA-IV Countries**

Questionnaires were sent to National Meteorological and Hydrological Services (NMHSs) of the 26 countries that make up the Regional Association IV (RA-IV) of WMO. Seven of these countries responded, namely: Belize, Dutch Antilles, Canada, Colombia, Cuba, Saint Lucia, and Venezuela. The authors also used information taken from the
Very few of the NMHSs of RA-IV have an independent Agrometeorological Service. Countries that can boast of such departments are Canada, Colombia, Cuba and the United States.

Few NMHSs of RA-IV produce specific agrometeorological bulletins; bulletins for Agriculture and Forestry, or agrometeorological warning and advisories. Among the few that do provide such agrometeorological products are Belize, Cuba, Saint Lucia, and Venezuela. In other countries of the region such as Canada, the United States and Mexico, the agrometeorological bulletins are produced by inter-institutional co-operation of the National Meteorological and Hydrological Services and other institutions that are concerned with crop production and diverse agricultural activities.

In general, the information collected by institutions that produce agrometeorological bulletins comes from different sources, namely: meteorological, agrometeorological, and hydrological observation network, and from institutions that provide information on the state of crops, forests, livestock and crop yields. The information is transmitted via the global telecommunication system to regional centres. The data is then channeled to national centres. Depending on what interests are served — local, national, or regional — this primary data is disseminated for different time period; e.g. daily, five-day, weekly, ten-day, or monthly.

The meteorological information collected is validated and later simple statistical methods are applied to compute statistical summary of averages, extreme values and other statistical information. Complex statistical methods are utilized for the analysis of anomalies and trends.

In some NMHSs the reference evapo-transpiration, water balance and the potential and estimated yields are calculated using established models and methods, and using tools such as Geographic Information Systems, to produce simple maps of meteorological events of interest that influence or can influence agricultural parameters considered in the bulletin.

Even the spatial distribution of some expected agrometeorological conditions are calculated; for example, the vegetative conditions of crops, the comfort of the farm animals, the presence and the evolution of agricultural drought, and the availability of water for plant growth and development.
All this information is processed by personal computer using word processors, electronic spreadsheets, and database management systems. Other applications that permit the use of models and Geographic Information Systems are used by some NMHS to obtain formats that will present more adequate information that farmers can easily interpret.

The frequency of delivery of bulletins depends upon national, regional and local interests. For example, daily deliveries are done in Canada and Mexico, weekly in the U.S. and Venezuela, five days in Colombia and Cuba, and monthly delivery in Saint Lucia.

The format and the contents of agrometeorological bulletins differ markedly from one country to another.

Generally, the content of bulletins comprises various subjects that can be grouped under different headings:

- **Significant features of the past and present weather and climatic conditions at the national level, or at the regional and local levels.** These are presented in the form of graphs, tables, drawings, maps, satellite imagery and text. Average and extreme values of meteorological, agrometeorological and hydrometeorological elements are also presented. These elements are important in agricultural production and decision-making.

- **Existing agrometeorological conditions.** Written text describes the state and the phases of development of agricultural crops, forest plantations and farm animals. In addition, comments are made on the soil-water regime, the state of agricultural drought, flooding, dangerous conditions of forest management, etc. All this information is complemented with maps, graphs, drawings and tables.

- **Expected meteorological conditions** — the weather and climate is analysed for the next time period that the bulletin will cover. This could be for the next twenty-four (24) hours, for the next forty-eight (48) to seventy-two (72) hours, for the next five (5) days, ten (10) days, month or for the entire cropping season.

- **Expected agrometeorological conditions** — the possible effects of expected weather and climate on cultivated crops, tree plantations and on farm animals at different stages of development and on their yields.

In general, agricultural researchers and extension agencies are the people who provide information on cultivation, state of crops and farm...
animals, their phases of development and their yields. They also participate in one way or another in the preparation and publication of bulletins, as is the case with Canada, Cuba, the United States, Mexico and Belize. In other countries, for example, Colombia, the NMHSs does not depend on the support of agricultural researchers and extension agencies for the preparation of their agrometeorological bulletins.

The purpose of both the agrometeorological bulletins and agriculture meteorological bulletins is to satisfy the principal demands of a vast sector that is directly involved in crops and animal production, so that they may make appropriate decisions at different levels of production. For example, farmers want to know the date when the water regime in the soil will guarantee the beginning of the cropping season, so that they can apply for loans at the banks; prepare land for planting; insure their crops; apply additional water by irrigation; apply insecticide, herbicide and fertilizer; know the presence, evolution, and duration of drought, and know the optimum date when boreholes should be maintained, etc.

Bulletins reach the user by fax, electronic mail, Internet, telephone, radio programs, printed leaflets, personal delivery and other means that safeguard their opportune arrival for decision-making.

The services for agrometeorology and hydrology for agriculture use feedback information, consisting fundamentally of the results of research, cultivation, development phases and state of agricultural crops, farm animals and tree plantations. In general, there are no organized systematic forms of obtaining feedback from the users. However, even though in some cases it is continuous, it is not an established routine. In Cuba and Venezuela, at the end of the agricultural campaign period or termination of subscription, users are asked to express their opinion on the information provided. The responses have always been satisfactory and the users have asked that their subscription be renewed. This serves as an indirect way to assess the quality of the information given and the validity and accuracy of the forecast.

In most cases, yearly evaluation is conducted on the cost of preparing the bulletins. Some of the expenses considered are: the cost associated with the salaries of technicians and professionals that work in the production of the bulletins, the expense for material used in its production, the expense for its diffusion, and the depreciation of equipment and other epigraphs. In Canada, it is estimated that the benefit derived from the use weather information in relation to its production cost is a ratio that exceeds 6:1. In Cuba, the agrometeorological service is commercialised. This service includes agro-
meteorological bulletins and, even though a part of this information is offered as a public service, the agrometeorological activity is profitable, yielding a profit of 25% on the investment during the last few years.

In general, the meteorological services that produce bulletins for agriculture follow systematic guidelines when reporting meteorological and agrometeorological conditions. They use satellite imagery and ground truth (actual surface data); and if there is a danger that extreme weather and climatic changes are likely to occur, they relate this to the users by means of extraordinary bulletins, electronic mail, web pages and other means of divulging the information. When climatic conditions are extreme, warnings are sent out to inform farmers of the presence of these conditions. These warnings can be found in bulletins produced in Canada, Colombia, Cuba, the United States, Mexico, Nicaragua, Saint Lucia and Venezuela.

The models that simulate the growth of crops are used in just a few countries of the region. References about their use are found in bulletins produced in Canada, Costa Rica, Cuba and the United States. A similar situation but perhaps more critical is the use of Geographic Information Systems. References indicate that it is only used in Canada, Cuba and the United States, although in countries such as Colombia they are used in the preparation and extrapolation of maps.

Some Limitations in the Efficient Provision of Agrometeorological Bulletins and Information

Among the limitations that can be pointed out are the following:

- Lack of resources to develop and implement typical agrometeorological bulletins that are at par with the increase necessities of the user.

- The slow response to the needs of the farmer for useful agrometeorological information. At the present time, merely adding some agrometeorological information in the public meteorological bulletins cannot satisfy these.

- The arrival of the Internet has given the NMHSs an excellent source to obtain and diffuse agrometeorological information. But this technology is not easily accessible to, or usable by farmers.

- New techniques and methodologies in the analysis of agrometeorological data, and their presentation are not well known to many specialists who are engaged in the preparation of bulletins for the NMHSs.
It is necessary, therefore, to seek international and inter-institutional expertise that can provide technical assistance and training to agrometeorologists, so that they can observe the experiences of other countries that have already been strengthened in this field, and so add a greater value to the bulletins. In this way they can make them user-friendlier to the farmers.

It will be necessary therefore, to increase the agrometeorological observations, the equipment and the specialized personnel to obtain a net increase in the rendering of information to farmers through agrometeorological bulletins and other relevant information. Today, the networks of meteorological and agrometeorological observing stations are not sufficient to cover all the areas of agricultural interests in most of the countries of Region.

**Conclusion**

The provision of timely and accurate agrometeorological information in the form of bulletins, advisories and press releases is indispensable for cost-effective crop management and food security. Agrometeorological information is part of a continuum that begins with scientific knowledge and understanding and ends with an evaluation of the information. The science transcends national borders, but the remaining components that have been the subject of this presentation differ from developed to developing countries. These differences are specifically a function of the availability of human, financial and natural resources. Whatever the setting, the information provided to farmers must be accurate, timely, and cost effective. The benefits gained by implementing agrometeorological information must outweigh the cost of processing and disseminating the information.

**Recommendations**

Some recommendations to improve agrometeorological bulletins and information to farmers and decision-makers in the agricultural sectors are as follow:

- Most agrometeorological units within NMHS of member countries require institutional strengthening in personnel and resources.
- Training should be aimed in advanced information and communication technologies (e.g. GIS, Agrometeorological Models, INTERNET, and Web Page design), so that agrometeorologists can provide the best possible advice to farmers.
- NMHS must devise strategies to foster inter-institutional collaboration for the preparation of agrometeorological bulletins.
- Providers of agrometeorological bulletins and information must keep in contact with users, know their needs, and meet those needs with accurate, timely, and cost-effective agrometeorological information.
- A concerted effort is required to improve agrometeorological network of observing stations.
- Member countries are encouraged to organize National Agrometeorological committees or councils.
- Member countries NMHS in collaboration with the agriculture agencies should encourage the development of phenological databases for the most important crops, fruit trees, pest and forest species.
- National Crop Calendar registers should be developed in collaboration with agriculture agencies to familiarize agrometeorologists with the agriculture activity in his district and country.
- Agrometeorologists and Agricultural personnel should be trained in risk management skills, and developing early warning systems for crop and livestock protection.

**References**


Specimens of agrometeorological bulletins published in WMO Regional Association IV

Figure 1. Canada

This figure is from the Internet: www.gov.mb.ca/agriculture/climate/waa_50500.html
Figure 2: The Prairie Farm Rehabilitation Administration Product, Canada

This figure is from the Internet:

www.agr.gc.ca/pfrastructure/maps/dprec1.htm
Figure 3. Cover Page: Joint Agriculture and Weather Facility Bulletin, U.S. (Electronic Version)

This figure is from the Internet:

www.USDA.gov/oce/waob/jawf/wwcb.html
Figure 4. Agrometeorological Bulletin from Cuba
Figure 5. Cuba: Forecast of Soil Moisture Reserve for a Dry Season Crop.
**Agrometeorological Forecast for Farm Operations, Belize Central America**

**FARMS in: Stann Creek Valley/ South Stann Creek/ Toledo / Cayo and Belize Districts**

**Forecast Prepared... Time: 10:00 am Day: Friday Date: October 26, 2001**

**Updated Every Three Days...**

**Synopsis:** A cold front will cross Belize by Saturday evening ahead of a broad cold airmass that will push cooler air over Belize through Tuesday of next week. A marked increase in rainfall will accompany the frontal passage beginning today.

**Friday through Sunday!**

*Chance that the 6th Day of October (i.e. Oct 26 - 31) will be WET or DRY is: Airport: WET 44% DRY 56%; Belmopan: WET 52% DRY 48%; Central Farm: WET 47% DRY 53%; Pomona: WET 54% DRY 46%; Punta Gorda: WET 59% DRY 41%.*

**OUTLOOK: Cloudiness and Rainfall (Next 48-72 hours):** Cloudy with showers outbreaks increasing over the Northern, Central, and Southern Agricultural Zones through Sunday. Showers will decrease later on Sunday through Monday. Twelve (12) Tropical Storms expected this season, with seven (7) becoming Hurricanes and three (3) CAT III or stronger!

**One cold front expected over Belize in October.**

**Weather Parameter**

<table>
<thead>
<tr>
<th></th>
<th>Today... Pri 12 Oct.</th>
<th>Day 1 Sat 13 Oct</th>
<th>Day 2 Sun 14 Oct</th>
<th>Day 3 Mon 15 Oct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative Humidity (%)</td>
<td>90%</td>
<td>90%</td>
<td>94%</td>
<td>93%</td>
</tr>
<tr>
<td><strong>Rainfall (mm/24h):</strong></td>
<td><strong>15 - 25</strong></td>
<td><strong>20 - 30</strong></td>
<td><strong>20 - 25</strong></td>
<td><strong>10 to 15</strong></td>
</tr>
<tr>
<td>Wind (Kmph/ Kts)</td>
<td>E: NE 8 to 16</td>
<td>N - NW 15 to 25</td>
<td>N - HW 10 to 20</td>
<td>N - NE 8 to 16</td>
</tr>
<tr>
<td>Sunshine hours</td>
<td>8 - 10 h</td>
<td>5 - 7 h</td>
<td>5 - 7 h</td>
<td>8 - 10 h</td>
</tr>
<tr>
<td>Temperature °C / °F</td>
<td>Coast Min 25/77 Max</td>
<td>Min 31/87 Max 32</td>
<td>Min 25/73 Max 20</td>
<td>Min 29/68 Max 30</td>
</tr>
<tr>
<td>Inland</td>
<td>19/67</td>
<td>31/87</td>
<td>19/67</td>
<td>20/68 Max 30</td>
</tr>
</tbody>
</table>

**FARMS in Corozal and Orange Walk Districts**

**Forecast: Cloudiness, Rainfall & Wind (Next 36 - 48 Hours):** Cloudy to overcast today, Friday through Sunday with outbreaks of showers increasing. Showers diminishing as the cold front zone moves offshore.

**Outlook: Cloudiness and Rainfall (Next 48-72 hours):**

No.  
Next Update: 10:00 a.m., Monday, October 29, 2001  
Citrus Research and Education Institute (CREI)/ Agricultural Unit, National Met. Service.  
Form revised 14/01/97. R. Frutos (Agrometeorologist).

---

**Figure 6. Three-day Agrometeorological Forecast from Belize**

This figure is from Internet: [www.hydromet.gov.bz/Agro_forecast.html](http://www.hydromet.gov.bz/Agro_forecast.html)
Figure 7. Agrometeorological Bulletin Web page from Belize
HIGHLIGHTS

Wet weather is proving favorably to the newly planted crops and timber trees. The soybean crop that was planted in the Orange Walk District last week has germinated. The fertilizer applied at pre-planting is contributing to the vigorous vegetative growth. Similar scenario is being experienced in corn, rice, sugarcane root crops, fruit trees, pastures and timber trees. Whilst this type of weather has benefited the aforementioned crops, it has negatively impacted the hot pepper and vegetable crops. Heavy rains are damaging the quality of peppers by creating abrasions in the fruit while vegetable such as tomato and sweet pepper are more frequently being invaded by pests and disease.

The Importance of Irrigation in Coco yam

The coco yam (Xanthosoma sagittifolium (L,) Schott) is one of the oldest domestic crops in Central and South America. Nevertheless, it remains in the category of being and under-exploited and poorly understood crops (O’Hair, 1999). In Belize the current acreage is estimated at 200 acres. The average yields obtained by producers are 16 tons per acre. Most of the crop is grown for home consumption with periodic exportations occurring from time to time.

The coco yam is a herbaceous plant, 3 – 6 ft in height that produces a cylindrical main corm or the base and 10 or more side corms, which are the edible portioned. White, pink and yellow cultivars are known.
List of Web-sites Related to Agrometeorological Information in RAIV

Belize
- http://bzewxcrop.iwarp.com
- http://hydromet.gov.bz

Canada
- Drought Watch
  http://www.agr.ca/pfra/drought.htm
- Government of Newfoundland and Labrador
  http://www.gov.nf.ca/agri/soils/agromet.htm
- Winnipeg Climate Center
  http://www.mb.ec.gc.ca/ENGLISH/AIR/WCC/agrom.htm
- Canadian Society of Agrometeorology
  http://www.oac.uoguelph.ca/~csam/
- Manitoba Agrometeorological Centre of Excellence

United States
- USAID Famine Early Warning System
  http://www.info.usaid.gov/fews/fews.html
- The California Weather database
  http://www.imp.ucdavis/WEATHER/weather1.html
- Georgia Automated Environmental Monitoring Network
  http://www.griffin.peachnet.edu/bae/
- ICASA
  http://agrss.sherman.hawaii.edu/icasa
- AWIS Weather Services, Inc
  http://www.awis.com
- National Drought Mitigation Center
  http://enso.unl.edu/ndmc
- Washington State University (Public Agricultural Weather System)
  http://frost.prosser.wsu.edu
- Response Farming
  http://www.davis.com/~wharf
- Global Soil Moisture Data Bank
  http://climate.envsci.ryters.edu/soil_moisture
• USDA-World Agriculture Outlook Board
• University of Nebraska
  http://enso.unl.edu/agmet/
• New York State Agricultural Experiment Station
  http://www.nysaes.cornell.edu/pp/faculty/seem/magarey
• Pacific Northwest Cooperative Agricultural Weather Network
  http://mac1.pn.usbr.gov/agrimet
• Centre for Precision Farming
  http://www.silsoe.carnfield.ac.ukcpf
• Oklahoma State University
  http://radar.met.r.ou.edu/agwx.agwx.html

Others:
• FAO
  Remote sensing imagery, Agrometeorological data, tools and information
  http://metar.fao.org
• Agrometeorological crop forecasting

• WMO
  http://www.wmo.int/
Improving Agrometeorological Bulletins
Perspectives from RA V (South-West Pacific)

Ah Kee Chan¹ and Richard N. Whitaker²

Introduction

The information in this paper is drawn from a survey conducted among countries in the WMO RA V Region. Unfortunately only 7 countries responded to the questionnaire and they are Australia, New Zealand, New Caledonia, Philippines, Fiji, Indonesia and Malaysia. Nevertheless some useful information can be drawn from the results of the survey.

Agrometeorological Services

Generally agrometeorological services were provided together with other services of the National Meteorological and Hydrological Service (NMHS) and not through an independent unit. Two countries have services that are joined together with other climatological services while one was integrated with general weather forecasting services. Only one country indicated that it had an independent agrometeorological unit.

Types of Agrometeorological Information Provided

Agrometeorological information given in bulletins/advisories included summaries of immediate past weather, current weather and forecasts for the next immediate period. The weather elements were generally described with respect of their deviations from normals. The time periods used for describing and forecasting the weather vary from 1 day to 2 months. Consequently, the frequencies of preparing and distributing agrometeorological bulletins were also from 1 day to 2 months.

Information relevant to agriculture contained in the bulletins included soil moisture conditions, cropping advisories, evapotranspiration, agricultural warnings, soil temperatures, crop phenology, influence of weather on crops, etc.

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² Bureau of Meteorology, Australia
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Collection, Analysis and Presentation of Information

Weather information was usually obtained from a network of weather stations that, in some cases, included automatic weather stations. Sometimes, other non-meteorological agencies were involved in collecting the data. The data were collected and analysed in a data center and results were often presented in text and graphical forms. They were sent to clients via fax, phone, postal services and e-mail. A few countries have them on their web-sites or the Internet. One developed country provided Internet access to near real time AWS data, satellite and radar imageries.

Involvement of Agricultural Agencies

Usually, no agricultural agencies are involved in the preparation of the bulletins. However, in many countries agricultural agencies were involved in the distribution of the information.

Target Audience

A variety of people in the agricultural sectors were targeted. These include farmers, land-users, agricultural researchers, extension workers, land development personnel, foresters, etc. One NMHS mentioned the use of seminars to disseminate services to users.

Feedback

In general, no systematic or regular feedback mechanisms have been established in the NMHSs. A few countries conducted occasional surveys to assess their services. Only one country carried out regular surveys for this purpose, and one used seminars or talks with users to evaluate their products.

Assessment of Economic Values

The developing nations, in general, did not assess the economic values of their services. They might not even know whether the information provided were useful or not. Two countries indicated that they have done some form of economic assessment on their services. One nation obtained some idea on the benefit of its agrometeorological services by estimating the negative impact of extreme weather on agriculture.

New Techniques

Most countries reported increasing use of new technologies like GIS and simulation models. Generally GIS was used to perform spatial analysis of meteorological elements. Downscaling from outputs of general climate
models through regional modeling and statistical means were also used in a few countries. One country mentioned the development of crop-weather models.

**Limitations**

Inadequate finance, human resources, technology and coverage by national network of weather stations were common reasons given by developing countries for the ineffectiveness of their agrometeorological services. One country felt that lack of capacity of users, particularly rural farmers, to understand and use the bulletin limited its usefulness.

The lack of communication or contacts with users was also mentioned as a limitation to the usefulness of the bulletins. Due to the lack of feedbacks, the NMHSs might not be providing what the users really want. In some cases, the information provided does not have sufficient spatial detail to meet needs of small farmers. Too long time was taken to collect, analyze and distribute information that by the time the bulletin reached the users, it was no longer relevant or useful. Timeliness is an important factor in agrometeorological services.

One country felt that serving the diverse needs of users that included public media and agricultural sectors affected the types and amounts of information supplied.

**Suggestions for Improvement**

For developing countries, assistance in the form of finance, training and transfer of technology will certainly improve the agrometeorological bulletins. They also need help in the management of database. Sharing of resources within a region may also help in improving the bulletins.

NMHSs need to take greater effort to communicate with the users so that they may the needs of their clients. One good means is to hold regular dialog sessions with users. NMHSs need to listen more carefully and learn to talk in the language of the users in order to be relevant and useful in their services.

In some countries the bottleneck may be the lack of ability of users especially farmers to understand and use the bulletins. It seems that some sort of training and awareness needs to be conducted among users in order to benefit better from the bulletins.
NMHSs should make an effort to reduce the time for getting the bulletins to the users. In this aspect, automation of data collection, analysis and distribution will greatly help in this area. Countries that have the capability for putting information on the Internet, will certainly be able to reach more clients and in a much faster manner.
Improving Agrometeorological Bulletins
Perspectives from RA VI (Europe)

Zoltán Dunkel¹

Abstract
A questionnaire with 13 questions was circulated in the RA VI region as well as in the other regions. The original questionnaire suggested by the WMO Division for Agricultural Meteorology was a little modified. The targeted audience was representatives of the ‘experts in agrometeorology’. As in case of any questionnaire it is always difficult to find the appropriate channel to get useful information. To collect as much information as possible not only the National Representatives in the Region but the members of RA VI Working Group of Agricultural Meteorology and members of the COST Action 718 were asked formally and informally as well. We have got 31 answers from 30 countries and one from the editor of MARS Bulletin. The Region has got 49 members. It means that we have got answers from more than 60 per cents of the asked region. The evaluation of the answers was not easy because from many countries not only one short answer was given but sometimes two-three answers. The people were asked not only to answer the questionnaire but submit few examples. The total amount of the submitted materials, the answers and the examples, takes more than 500 pages. This paper evaluates the collected information about the state-of-the-art of the agrometeorological bulletins in the RA VI but we can cover only that part of the Region where we have got answer from.

Introduction
The paper summarises the information could be drawn from a survey conducted among the countries in the WMO RA VI Region. The evaluation follows the questions that were given in the questionnaire. It had 13 questions but the answers are grouped. To help the understanding of the survey two Annex are added to the evaluation. The first one summarises the answers, the second one shows few examples. Of course there was not enough place to show every submitted examples.

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**Agrometeorological Units**

The majority of the meteorological institutes and services in RA VI operate independent ‘agrometeorological unit’. Among the 30 answering countries, 17 operate independent units, 13 do not. Except one small country, every respondent informed that somebody deals with the ‘agrometeorology’ within his/her service. Sometimes there is a heavy complaint among the agrometeorologists that nobody deals with the ‘agrometeorology’ but to the surprise of the author, the majority of the responses reported independent units for agricultural meteorology. Taking into consideration that the evaluation focused on the bulletins and the national meteorological institutes and services, we have got answer only from one side of our world. Using this questionnaire we could collect information from the NMHSs but very few from the university and research institutes. Notwithstanding this limitation, we have got a more or less good impression about the state-of the art of the agrometeorological bulletins’ organisation background. It appears that the situation is satisfactory in RA VI.

**Agrometeorological Bulletin**

Concerning the ‘Bulletins’ question, 23 countries issue some kind of bulletins. We have got negative answer for this question from 7 countries. More or less the same statistic could be given about the involvement of extension services. In nineteen countries the agricultural research institutions and extension services are involved in the preparation of the ‘Bulletins’. Sometimes very difficult to highlight what is behind the statistics. Without any evaluation, in the Appendix some extracts are shown from the submitted answers. In case of few countries not only one central bulletin is issued but some regional bulletins are prepared as well. The frequency of the ‘bulletins’ differs very much from country to country: Monthly or decadal issue (5 countries), five-day or weekly issue (9), 3-4 times per week (3), daily (6) and more than one issue per day (one) were reported. In case of the other 6 countries the frequency of the issue was not clear. One respondent calculated only with the traditionally printed bulletins which contains phenological information beside the climate summary with some evaluation from point of view of weather influence on agricultural activity. Others reported the modern techniques too, the internet or SMS system as ‘bulletins’.

**The types of Bulletins**

The form, size, and contents of the bulletins change from country to country but there is a more or less common structure of every bulletin issued in form of hardcopy or disseminated electronically. The majority of the
respondents (15 countries) gave a short description of their bulletin, the rest (13 countries) submitted smaller or bigger examples or added the address of web side. The submitted homepage addresses are given in Annex 2 (short summary of the answers). Of course it would be impossible to show all submitted examples but as an illustration of the collection, few copies of the typical part of the submitted bulletins are presented. (Apologies to those whose bulletins are not shown in this present paper). As a conclusion we can summarise that the ‘Agrometeorological Bulletin’ should consist of two parts. The first part could be a diagnosis, the second part a forecast. Both parts could contain beside the meteorological data, phenological information and yield parameters. The diagnosis could be short or detailed, regarding the impact of the meteorological factors in the last period (day, week, moth or season) upon the evolution of the growth status of the main crops, estimation of agrometeorological conditions for the growth, development and yield formation of the crops, the sequence of the phenological phases, available soil moisture and soil water deficit at various depths, the advance or delay of the vegetation development and indication of favourable weather conditions for each crop. Beside the meteorological data, the bulletin should deal with the soil moisture as well. The forecasting part could contain information on the perspectives of the meteorological conditions for the next period, day and week. Among the possible meteorological information we have to mention the minimum and maximum expected temperature and rainfall probability, prediction of phenological stage, rate of growth and development of crops and their expected yields and dates of harvesting, expected available water content, as well as certain necessary recommendations for the farmers for the use of different technologies in accordance with the new conditions. Various annexes on daily values of mean, minimum, maximum and normal temperature (as graphics) and distribution of precipitation, available soil moisture and water deficit over the examined region are also included in the bulletin. In both parts, various types of maps are always a core part of the bulletin.

The Target Audience of the ‘Bulletin’

For this question ‘no’ answer was given from 4 countries. One country gave the ‘subscription possible’ answer which means that if somebody is interested in the bulletin, the person can get it but the distributor is not interested in the type of the customer. The ‘farmer’, the real and desired end-user was mentioned only in 9 cases. The target of the bulletin is the government in 7 countries. The extension services or private companies was mentioned in 12 countries. Research institute was marked in 7 countries. The answer to this question was not restricted to one user. The ‘typical’ answer
was to mention at least two or three possible users of the bulletin. The results of this question was not really surprising that the user of the bulletin is not ‘the farmer’ himself. Taking into the consideration the frequency of the bulletins, and the distribution method, it is not really surprising. On the other hand, one has to ask whether it is really the job of the agrometeorologist community to reach the real end users. Maybe we have to reach only the effective intermediate audience eg., extension services.

**Feedback from the Users and Economic Value of Bulletin**

On the question of regular efforts to collect feedback from the users, many countries (20) replied in the negative. Only one third of the answering countries, 10 countries, gave a positive answer for this question. This result somehow coincides with result of the answer given for the previous question that the target audience of the ‘Bulletin’ is ‘the farmer’ in case of 9 countries. This of course does not mean that the agrometeorologist community is not interested in the results of its efforts to produce a nice and useful bulletin. It would be very nice to collect feedback regularly from the users and show a good cost/benefit ratio. Regarding the economic value of the ‘bulletin’, a majority of the countries (16) responded that no effort is made to collect such information. Very discrete answer came form 6 countries (some, it is difficult, partly, etc). The author participated in a cost/benefit ratio examination of meteorological products and has got his experience about the difficulties of such type evaluation. Hence he agrees with the answer of one country: ‘that’s hard to do’. This question is much more difficult than the previous one. Only one country gave a quantitative response in saying that the use of agrometeorological prognosis enables reducing loses in agriculture by 20-30 %.

**Extreme Events**

Different answers were given for this question. To evaluate the answers, only two categories were used. If the ‘bulletin’ deals with the extreme events in anyway the answer was scored as ‘yes’. The answer was also regarded as ‘yes’, if any activity was reported under the flag of dissemination of agrometeorological information concerning this theme. We have added one score to the ‘negative’ answer if dealing with extreme events was mentioned as regular warning activity of the meteorological institute, service. Using this type of categorisation, we have got 17 ‘yes’ answers for this question and 13 ‘no’ answers. The mentioned possible extreme events were drought, forest fires and floods. Nobody mentioned frost as a possible dangerous event.
Use of New Techniques

We have received various answers for this question. From 9 countries came definitive ‘no’ answer for the possible use of modern techniques. Some countries gave a very detailed answer, the others submitted only list of the tools. The direct use of remote sensing techniques for agricultural meteorology aren’t yet fully developed. Few countries mentioned it as a possible complementary tool for the preparation of agrometeorological information. We can mention one exception. It is the MARS bulletin. It is not really surprising because the basic activity of the EU Joint Research Centre is the application of remote sensing. Unfortunately it is not yet public information. Beside the JRC, few other countries use NOAA AVHRR data, making some efforts to systematically compute NDVI and use this information to detect the state-of the art of vegetation or use it as input parameters in plan models. Different types of simulation models of soil moisture, plant-growth and pest and disease interactions are used in few countries as an important tools both in standard information service (via the bulletin) and giving extraordinary custom reports or studies for crop commodities, governmental organisations, plant protection research and service. It is possible that in many countries the GIS is used for agrometeorological applications but perhaps not reported in their responses.

Limitations

Unfortunately 9 countries did not give any answer for the question about the shortcomings and limitation in the current methods from the few responses we can conclude that the real limitation factor in issuing high quality and detailed bulletins, is the lack of human resources, the suitable trained and skilled expert. Concerning the bulletins distributed in printed and in hardcopy form few respondents mentioned the lack of funds for printed materials as limitation and added that it is necessary to find financial support from public authorities. Many said that the publishing of the hard copy should be continued until all the farmers are connected to the Internet. This approach concerns the basic problem of the usefulness of the traditional type bulletin in the everyday agricultural practice. The farmer subscribes to the bulletin almost rarely, partly for lack of money, but the main reason is probably in rather late processing and delivery of it by mail. Internet version is often not readily available to the farmers due to lack of commodity. Delays in printing of up to 3 or more, sometimes 7 days, minimises the possibility to present meteorological forecasts in the bulletins. It is not true for the Internet version. This leads us to the general evaluation of processing and dissemination of agrometeorological information which is a much wider theme than the
evaluation of the ‘bulletin’. Few respondents mentioned the less difficult, but existing problem concerning the everyday preparation of the bulletin, i.e. time availability, problems in the measurements of special parameters of particular relevance to agrometeorology, lack of knowledge of local conditions, difficulties in obtaining of phenological data, etc. Other limitations include the personnel available to produce the regional texts and fax sheets, although the models run automatically each morning for filling tables. Shortcomings in quality are sometimes the precipitation forecasts of the numerical model.

Comments and Suggestions

Among the 30 answering countries 12 did not added any comments and suggestion to the methods of preparing of agrometeorological bulletin. We can divide the suggestions into two groups. The first group deals with the dissemination techniques of the bulletin, the second gives idea on how to improve the content and the preparation of the bulletin. Maybe the real background of the present survey was collecting ideas to standardise the format of the bulletin. Only two respondents made an explicit mention of the need for standardisation of the bulletin format. Concerning the distribution of bulletins, all respondents agree that the best way of effective distribution of the agrometeorological information is the electronic distribution: web or online information. In case of the preparation and content, we need good quality data, meaning that they should reach a certain degree of accuracy. There is no need for a lot of stations in a plain valley, but the coverage should be greater in an area with a complex topography. There is a lack of appropriate methods of interpolation. Finally, the methods of dissemination and presentation of the agrometeorological information should be revised and updated. Among the special needs of agricultural meteorology, it was mentioned that short range forecasts of precipitation and better measurements and forecasts of the relative humidity are of importance. Additional methods of analyses and visualisation (including GIS technique) of the agrometeorological information should be applied. For example, some additional sophisticated methods for data interpolation could be used for data mapping. Some tables and graphs attracting the users can be also useful. A comparison between current soil and crop status with long-term data or particular time slice can be also helpful to determine the relevant departures. Animated figures can be also helpful when the bulletin is posted on the Internet. On the web page of any bulletin posted on the Internet a counter and a link for a feedback should be used.
Conclusions

Many examples which were submitted proved that the traditionally prepared and distributed ‘agrometeorological bulletin’ continues to be used in many countries in the region. In few countries, reports are made available on the web sites. Nobody reported that the traditional hard copy format is out of date and it is high time to stop issuing it. But from the answers it is apparent that the colleagues dealing with the problem never thought only of the traditionally prepared ‘bulletin’ they tried to evaluate the whole information system of ‘agrometeorology’. Our regular task is to supply the user with really useful information independent of its format. In order to improve agrometeorological bulletins, the following suggestions were made:

- developing procedures to identify user needs and requirements
- improving communication between agrometeorologists and users of agrometeorological information
- promotion and integration of new techniques (GIS, remote sensing and satellite imagery applications) in operational agrometeorology in order to identify, assess, monitor and prevent of risks;
- use of improved methods, procedures and techniques for the dissemination of agrometeorological information
- more active applications of models for yield forecasting, water balance, etc.

From the point of view of common action, it would be very desirable if WMO could include in its short-term work plan a proposal to develop and issue a technical note about the preparation of ‘agrometeorological bulletins’.

Acknowledgements

The author expresses his sincere thank to every colleague for his/her effort and help to produce this summary. It was a real enjoy to read the answers and see the everyday work and effort of specialists to help the agricultural activity within our Region. A review of submitted examples was the other pleasure of the rapporteur notwithstanding the fact that the submitted papers were not understandable because of language problem but the contents were absolutely clear. Agrometeorology has an international ‘language’ for everybody. With very small ‘training’ everybody can use the agrometeorological bulletins of other countries. The author would like to express his thanks to WMO for the possibility to participate in the present work. It was a real great pleasure.
<table>
<thead>
<tr>
<th>QUESTION</th>
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<tbody>
<tr>
<td>1) <strong>Has your national meteorological, hydrological, hydrometeorological service, institute (NMHS) got an independent agrometeorological unit in your country?</strong></td>
</tr>
<tr>
<td>2) <strong>If not, does somebody deal with 'agrometeorology' in your national service (NMHS)?</strong></td>
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<tr>
<td>3) <strong>Are agrometeorological bulletins and advisories issued by the national meteorological service (NMHS)?</strong></td>
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<tr>
<td>4) <strong>Are any agricultural research and extension agencies in your country involved either in the preparation of dissemination of bulletins or both in your country?</strong></td>
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<td>5) <strong>If yes please inform about the frequency of delivery of these bulletins!</strong></td>
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<td>6) <strong>How is the information presented in the bulletin collected and analysed and in what form is this information presented? (Please do not forget to send me a copy of any kind of bulletin, advisory paper or any 'agrometeorological information' printed in newspapers, etc in your country)</strong></td>
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<td>7) <strong>What is the target audience of these bulletins and how are they reached?</strong></td>
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<tr>
<td>8) <strong>Is there any regular effort to collect the feedback from the users of these bulletins?</strong></td>
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<td>9) <strong>Have any efforts been made to assess the economic value and benefit of the use of information provided in the agrometeorological bulletins?</strong></td>
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<td>10) <strong>Is there any effort to issue bulletins of a special nature to address specific extreme events such as droughts, floods, forest fires, etc?</strong></td>
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<td>11) <strong>To what extent new techniques such as remote sensing techniques (near-to surface or satellite born surface mapping, etc), simulation models (plant-growth, plant-soil-atmosphere, etc. models) and GIS are used in the analysis and preparation of information?</strong></td>
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<td>12) <strong>What are the shortcomings and limitations in the current methods of preparing agrometeorological bulletins?</strong></td>
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<tr>
<td>13) <strong>Please submit your comments and suggestions to improve agrometeorological bulletins!</strong></td>
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<tr>
<td>14) <strong>DID THEY SEND ANY COPY?</strong></td>
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<td>15) <strong>ANSWERING PERSON(S)</strong></td>
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<td>ANNEX 2</td>
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Individual farmers subscribe the bulletin almost rarely, partly for lack of money, but the main reason is probably in rather late processing and delivery of it by mail. Internet-version is often not attainable or dear for them. Terms of processing lead to a 5 – 7 days of retardation, which minimize the possibility to present meteorological forecasts in the bulletins (this is not true for the Internet-version).

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<td>12</td>
<td>Individual farmers subscribe the bulletin almost rarely, partly for lack of money, but the main reason is probably in rather late processing and delivery of it by mail. Internet-version is often not attainable or dear for them. Terms of processing lead to a 5 – 7 days of retardation, which minimize the possibility to present meteorological forecasts in the bulletins (this is not true for the Internet-version).</td>
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<td>14</td>
<td>yes</td>
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<tr>
<td>15</td>
<td>Mr. Jaroslav Valter</td>
</tr>
<tr>
<td></td>
<td>DENMARK</td>
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<tr>
<td>1</td>
<td>No</td>
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<tr>
<td>2</td>
<td>Danish Met. Service has an automatic operational production and dissemination of data to a system: Agrimeteorological Information System (AMIS), managed by Forecasting Services Department</td>
</tr>
<tr>
<td>3</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>The Danish Institute of Agricultural Science, <a href="http://www.agrsci.dk">www.agrsci.dk</a></td>
</tr>
<tr>
<td>5</td>
<td>updated daily, some four times a day</td>
</tr>
<tr>
<td>6</td>
<td>The Danish Institute of Agricultural Science presents meteo data: Pl@ntelInfo (<a href="http://www.planteinfo.dk">www.planteinfo.dk</a>), 10x10 km grid, local forecast for a specific grid point as an SMS on request</td>
</tr>
<tr>
<td>7</td>
<td>subscription is possible</td>
</tr>
<tr>
<td>8</td>
<td>yes</td>
</tr>
<tr>
<td>9</td>
<td>not done so far. Could be interesting what is for instance the economical benefit of reducing the use of pesticides</td>
</tr>
<tr>
<td>10</td>
<td>not specially targeted towards the agricultural society. Warning are issued to general public</td>
</tr>
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</table>
Some of the data in AMIS are produced on the basis of numerical models using the new techniques. DMI is currently working on a system to assess the daily precipitation in 10 x 10 km AMIS grid. Further DMI is investigating the possibility of very short range forecast of precipitation in 10 x 10 grid.

Satellites and weather radar are used for the tracking of precipitation areas. Simulation models are used by the agricultural research organisations (Agrifood Research Finland).

The measurements and forecast of relative humidity near the ground, which is very important for estimating the potential contagiousness of fungi on daily basis, especially in potatoes. If the potential contagiousness is high, the farmer have to protect the crop. However it is the governmental policy to dramatically reduce the use of pesticides, so it is important to know exactly when it is necessary to use pesticides.

Lack of expert personnel.

Very short range forecast of precipitation and better measurements and forecast of the relative humidity.

Mr. Michael Steffensen
Mr. Ari Venalainen
Ms. Lea Leskinen
FRANCE

1. **Yes.** The national agrometeorological unit of METEO-FRANCE is located in Toulouse (France) and is in charge of co-ordination of all agrometeorological activities in Météo-France, software development and production (specifications for new agrometeorological software, software conception and development), international representation (COST actions, World Meteorological Organisation), nationwide studies.

2. - At the national level, a climatological bulletin is issued on a monthly basis by Météo-France the year long. This bulletin is elaborated with climatological data of the national database of Météo-France. - Every month, from April to October, maps of heat unit sums and potential water balance are performed and sent by Internet to a research center on corn seeds. They are used to study the implementations of new hybrids of maize in France, according to the weather constraints. - At the local level, agrometeorological bulletins are made. There are meteorological forecasts for the 7 coming days, agrometeorological data from the past days, and agrometeorological advice elaborated in collaboration with agricultural institutes.

3. Some agricultural agencies (chambers of Agriculture, pest and disease service, ...) write and disseminate their own agrometeorological bulletins. For that, they use the meteorological data of their own network or the meteorological data provided by Météo-France (measurements and/or forecasts). Sometimes, they use the communication means of Météo-France to disseminate the bulletins (for example by answering machines).

4. The frequency of delivery of a bulletin depends on the use of this bulletin. - If the bulletin is elaborated with climatological data (ex: temperature, rainfall...) or agroclimatological data (ex: PET, heat unit sum, ...), the purpose of this bulletin is to assess the impact of the meteorological parameters of previous months on one or many crops, the dissemination is on a monthly basis. - If the bulletin is elaborated with meteorological forecast, the purpose for the end-user (generally farmers) is to manage their work in the coming hours or days, and the bulletins are updated about 5 times a day. **Departmental scale:** Departmental weather forecasting (France is broken down in 95 administrative departments) accessible on answering machines. Some of them are more specialized in ‘agrométéorologie’ and contain the
weather forecasting adapted to the cultures of the department, agrometeorological information over the previous days and the agronomical advice (pest and disease, irrigation...). They are generally set up thanks to collaboration between the Departmental Center of METEO-FRANCE and the Departmental Chambers of Agriculture and/or the Services of the Protection of the Plants of the department. The 3615 METEO-FRANCE (Videotext) provides weather forecasts on each department, for the 7 coming days. These forecasts are updated 4 times a day. Now, from the 36 17 METEO-FRANCE, the user can obtain the departmental forecast by fax. This means of access to information, very much used now by the farmers, will be doubtless gradually abandoned for the benefit of Internet in the next years. Local scale To refine the meteorological forecasts at the local level, France has been broken down in 700 homogeneous zones from the forecasting point of view. There are about 5 to 10 zones per department. The farmers can reach these very accurate, local forecasts elaborated by the Departmental Center of METEO-FRANCE, by 3 hours step and valid up to coming 36 hours, updated at least 6 times per day (ATMOGRAMME). This service represents a true tool tactical decision-making aid for the farmers, since it makes it possible to realize savings on chemical amounts and irrigation. ATMOFAX: ATMOFAX is a service of METEO-FRANCE making it possible to the farmers to obtain by telefax the ATMOGRAMME of their zone of interest as soon on request. This service can be accessible through organisation of farmers such as the co-operatives, the Chambers of agriculture. Each farmer of the group obtains a code of access which allows him to be connected to the fax server of METEO-FRANCE on request and to obtain in the same telephone call its ATMOGRAMME as well as the number of ATMOGRAMME consumed since the beginning of his subscription. This service can be supplemented by the access to the weather reports (up to 7 days) worked out by the Departmental Center of METEO-FRANCE. It is provided by telefax to each farmer by the headquarters of farmers.

For example the bulletin of the Ministry of Agriculture about the state of crops at the national level elaborated with maps of rainfall, outputs of water balance model and output of ISOP. This information is provided by Meteo-France on a monthly basis by Internet. Since 1997, an integrated system called ISOP has been developed between three French participants: the ministry of Agriculture (through its Department of Statistics, SCEES), the institute for Agronomical...
Research (INRA) and the national meteorological service (METEO-FRANCE). The purpose is to produce reliable estimations of the forage production, in order to give objective information to the ministry of Agriculture to estimate real production losses in case of local or global drought. Input data are various and multiple, including spatialized daily meteorological parameters, percentages of soil types, nitrogen status and amounts and frequency of mowing or grazings, estimated from a national survey. The STICS crop model is applied to three kinds of grassland: permanent, temporary and pure legumes. The results are available for 200 regions of forage production (RFP) and synthesised in alert maps and temporal graphs for selected drought-stricken areas. The model is part of the multi-crop simulator STICS and simulates the evolution of grass above ground dry matter and water and nitrogen balances. The current year assessed values will be compared with « Reference » values calculated as statistical values (fractiles) on the period 1982-1996 for each grassland type and each RFP. The STICS crop model needs daily meteorological parameters (temperatures, rain, global radiation and PET). These data should be available for the reference period (1982 to 1996) and also for the current year to provide « real-time » outputs with a short delay. The management practices for mowing frequency and nitrogen supply are estimated from a national survey (8800 fields surveyed in autumn 1998) for the 182 (out of 200) RFP with a representative grassland surface (more than 7000 hectares). The results were translated into direct inputs for the STICS crop model: values of thermal time between mowings, number of mowings, amounts of nitrogen supply during winter and spring, initial nitrogen indices. To take into account the different soil types on which the grasslands are to be found, the EU (1/1 000 000) soil map is used to provide soil map units where only predominant soils are listed. These soils are then characterised by their water capacity and nitrogen mineralization properties per layer and introduced in the system. METEO-FRANCE has developed a service allowing a simple access to the climatological data of the stations managed by METEO-FRANCE. This service called COLCHIQUE is attended to the professional users who need climatological data occasionally or on a regular frequency. The technical institutes, the plant health and agro-alimentary companies, the research centers, frequently need climatological data to refine their studies, to compute crop model or pest and disease model or to estimate crop productions. COLCHIQUE allows the acquisition of a meteorological dataset less than 2 days after measurement, from
about 150 synoptic stations of METEO-FRANCE and approximately 1000 automatic stations. Observations of temperatures, wind, pressure, moisture... are accessible on a daily, 10 day period, or monthly basis and also elaborated products like deviation or ratio to “normal”, hydric assessment... For example, the agricultural institute involved in the sugar beet study collect the meteorological and agrometeorological data of the database of Météo-France using COLCHIQUE. And after, it elaborates every month a specific bulletin taking into account the agroclimatological conditions.

7 Farmers: with for example, bulletins elaborated with forecast information (ATMOFAX, answering machines…) and advice to manage irrigation or to fight against pests and disease. Agricultural technicians, departmental services of the Ministry of Agriculture: with for example, bulletin elaborated by the Ministry of Agriculture (Agreste Conjoncture – Grandes Cultures), For example, agricultural technicians of Chambers of Agriculture or cooperatives in the north of France with the bulletin elaborated by the technical institute involved in the study of sugar beet (Enquête sur la situation betteravière au 15/08/2001). NB: Now, all agrometeorological services provided by Météo-France and described in this document are available by Internet.

8 Yes, for the bulletins disseminated by answering machines, by Minitel, by fax and also by Internet… it is possible to evaluate the success of each service studying the number of end-users and the number of requests. At the departmental level, there are a lot of meetings between the end-users and the delegate of Meteo-France to define the needs, to evaluate the feedback of new services. Sometimes, the Commercial Service of Météo-France make national surveys to assess the impact of services.

9 It is possible to evaluate if a farmer has realized savings on the chemical amounts or irrigation amounts when he has taken into account meteorological information.. But it is difficult to estimate the economic value and also the real environmental benefit at a national level. For that, the Ministry of Agriculture would have to do a survey in partnership with the Ministry of Environment and Météo-France.

10 DROUGHT - In order to estimate and monitor the risk of severe drought and determine the most affected areas, maps on agrometeorological parameters, such as potential water balance or state of available water, are produced on a regular basis or on request. This information is completed with other data like the levels of the water tables and compared with the statistical values. FOREST FIRES: For
more 20 years in the south-east of France, studies and experiments are performed to monitor and prevent forest fires. This activity is one of our core missions. The drought indices calculated by Météo-France are communicated to Civil Protection Agency from June to September. The indices are calculated with meteorological data of ground network, with meteorological forecasts. This information is spatially improved using remote sensing (surface temperature and vegetation index from NOAA-AVHRR). METOFLASH The Météoflash message informs the farmer, by telefax, of the arrival in its zone of a weather phenomenon which can affect the cultures, the cattle, the materials and the program of work. The warning message concerns the phenomena such as storm, strong rain, frost, very strong frost, strong heat. Service is available by subscription through the departmental centre of METEO-FRANCE concerned.

Remote sensing data (surface temperature and NDVI from NOAA-AVHRR) are used by Meteo-France to improve forest fires bulletins. Simulation models are used by agricultural institutes (Chambers of Agriculture, technical institutes, cooperatives...) ISBA is a soil-vegetation-atmosphere transfer (SVAT) scheme developed at the National Center for Meteorological Research (CNRM) at Météo-France which is used to model the exchange of heat, mass and momentum between the land or water surface and the overlying atmosphere. The model is used in so-called stand-alone mode for development, and in coupled mode in which the model supplies the lower boundary conditions to atmospheric numerical weather prediction models or the upper boundary conditions for distributed hydrological models. ISBA is currently coupled to the Météo-France operational numerical weather prediction model (ARPEGE), the Météo-France climate model or GCM (ARPEGE-climate), the non-hydrostatic mesoscale atmospheric model Meso-NH, and the distributed macroscale hydrolgic model MODCOU. In 2002, the purpose is to do an operational service in hydrology and agrometeorology using ISBA liked to MODCOU with interpolated meteorological data in input. http://www.agri-quest.com Agri-Quest is an internet agricultural monitoring service developed by a private agency: real time nationwide mapping and monitoring of vegetation conditions calculated with NOAA-AVHRR data. More than any other economic sector, the food and agriculture industries are affected by climatic risks. Among the various methods available for anticipating variations in productivity, remote sensing offers a wide range of simple techniques tested and proved over the past twenty years by numerous
national and international organizations. For agricultural monitoring, Agro-Quest provides weekly maps and curves that help end-users make objective, real-time analyses of crop potential from sowing time to harvest. They provide two solutions: "Essential" and "Professional" offer. The use of GIS is increasing in France. A lot of organisations involved in agriculture and in agrometeorology use GIS to define agricultural potentialities, to define polluted areas.

12 Weak knowledge of small-scale meteorological conditions (depending on topography, kinds of soil,…) to give advice adapted at each farmer. – Difficulty to obtain phenological observations and to concentrate these data in a centralized database. - Weak collaboration between all the institutes involved in the elaboration and the dissemination of agrometeorological advice (there is sometimes a feeling of competition). Partnerships would be necessary.

13

14 yes

15 Mr. Jean-Pierre Beysson, Ms. Victorine Perarnaud
1. yes, Deutscher Wetterdienst (DWD) has a business unit called 'Landwirtschaft', which means that it deals with agrometeorology.

2. -

3. yes

4. yes, in some cases regional agricultural chambers (or research) gives contributions to the more biological parts of texts (in advisories)

5. In case of backward bulletins: weekly and monthly, in case of forecasts and advisories: daily ('wetterfax')

6. collected: by data flow within DWD, generally from synoptic weather reports, forecasts from numerical model, in addition early reports for plant phenology. analysed (i.e. used and processed): by agrometeorological models. presented: mostly in text and tables, sometimes pictograms in 'wetterfax'.

7. Farmers, vegetable growers, horticulturalists, vine growers, extension service and Agricultural chambers. They are reached by telephone answering machine and by fax.

8. no

9. no

10. There is a service of DWD for forestry. Rather new: [http://www.dwd.de/services/gflw/lw_home.html](http://www.dwd.de/services/gflw/lw_home.html). Here you find 'Waldbrand-Warnindex' at the left side to click on. Regrettable not yet in English.

11. Remote sensing or GIS is not directly used for agromet. information service. Simulation models are used for a lot of agromet. topics (crop and soil conditions, harvest conditions and quality, pests & diseases, etc.)

12. Telephone service (renewed daily) is limited by time (2 to 3 minutes advisories). The daily, regional 'wetterfax' consists of one sheet with results of the most interesting topics of the season. So, second order important information is not given to the farmer. Limitation is also the personnel available to produce the regional texts and fax sheets, although the models run automatically each morning for filling tables. Shortcomings in quality are sometimes the precipitation forecasts of the numerical model.

13. Bulletins (weekly, backward) and advisories (forecasts) should be placed more and more in the internet.

14. 

15. Mr. U. Gärtner, Mr. Hans Friesland
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<th>HUNGARY</th>
<th>IRELAND</th>
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<tr>
<td>1</td>
<td>no</td>
<td>Sometimes yes and sometimes no i.e sometimes the post is vacant</td>
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<td>2</td>
<td>Yes, we do agrometeorological research and there are special services for the agriculture.</td>
<td>When no somebody always deals with agrometeorological matters</td>
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<td>3</td>
<td>Agrometeorological Bulletins are not published any more. Instead, special agrometeorological information called Agrometeorological Information Program (AIP) is given for customers on commercial base.</td>
<td>Yes</td>
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<td>4</td>
<td>No, but there are web sites that include our agrometeorological information (e.g. the web site of an agricultural chamber)</td>
<td>Yes..Teagasc the national agricultural advisory agency</td>
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<td>The AIP is delivered once or twice a week.</td>
<td>Bulletins are issued weekly or monthly...advisories are issued as required and Teagasc have some on their web site</td>
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<td>The AIP is presented either as a plain text (sent via fax) or as a html file that can be seen on Internet. Examples are attached.</td>
<td>Met Eireann has an agmet section in its MWB( monthly weather bulletin) Weekly weather data from Met Eireann and data on the progress of crops appear in the 'Farmers Journal' or in the farming section of our national newspapers.will post samples.</td>
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<td>7</td>
<td>Our customers are mainly agricultural firms. They are mostly reached via fax. The Internet (sometimes with restricted access) is also used.</td>
<td>Agricultural advisers or farmers.</td>
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<td>There is no such regular effort, but some meetings were organised between customers and meteorologists.</td>
<td>No. occasional</td>
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<td>9</td>
<td>no</td>
<td>no</td>
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<td>Yes, last time an analysis was published about the meteorological causes of the inland waters in 1999.</td>
<td>No. only if requested by the publishing media</td>
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<td>Very little used</td>
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<td>The time lag</td>
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<td>More web-based information which is regularly updated</td>
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<td>15</td>
<td>Mr. Gabor Kis-Kovacs</td>
<td>Mr. Denis L. Fitzgerald</td>
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ITALY

1. In Italy a national service on meteorology/agrometeorology does not actually exist, since the service is given locally by regional different Meteorological Services. Some of them got independent agrometeorological units, some do not However, the UFFICIO CENTRALE DI ECOLOGIA AGRAIA edits monthly the BOLLETINO AGROMETEOROLOGICO NAZIONALE (that started in Jan 93 that is posted to about 1000 Associations, services, etc.) SEE: www.inea.it/ucea/ind.htm

2.

3.

4. yes, - ARSSA in Abruzzo region, Notiziario agrometeorologico. Weekly from April to September, monthly for other periods. Via mail, fax tv, internet at www.arsaa.abruzzo.it/car
   - Assessorato Agricoltura regione Campania. Bolletino Agrometeorologico, weekly, via fax, tv, mail
   - ARPA Emilia Romagna. Bolletino Agrometeorologico Regionale. Weekly, radio, internet: www.smr.arpa.emr.it, fax on demand, tv, also ARPA Rivista (bimonthly), mail
   - CSA Friuli Venezia Giulia, Bolletino Agrometeorologico, ineternet, www.agromet.ersa.fvg.it, tv, fax
   - ERSAL Lombardia. Bolletino Agrometeorologico Regionale, weekly and monthly (Agromese), fax on demand, e-mail, tv (www.ersal.lombardia.it)
   - AsSSAM Marhe. Notiziarri agrometeorologici provinciali, weekly, fax or e-mail, www.meteo.regione.marche.it
   - Assessorato Agricoltura regione Piemonte. Daily Dati Rete Agrometeorologica Piemonte: www.green-planet.it

SAR Sardegna. Bolletino Agrometeorologici Circondariali, daily, newspapers, tv, radio, www.sar.sardegna.it

ARSIA Toscana Report mensile andamento agro-meteo climatico e stato culture in Toscana. Monthly mail, fax, e-mail, internet: www.meteo.arsia.toscana/meteo/hpmeteo.htm

- ARPA V eneto. Bolletino Agrometeorologico, three per week in spring, summer, lower frequency in other periods, fax on demand, tv, newspapers, [www.arpa.veneto.it](http://www.arpa.veneto.it)

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<td>5</td>
<td>different forms, see internet for more detailed info if needed</td>
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<td>6</td>
<td>target audience are farmers and farmer associations, services, universities and research institutions, technicians</td>
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<td>some effort comes from people in order to develop user-friendly information</td>
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<td>8</td>
<td>not to my knowledge official efforts</td>
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<td>9</td>
<td>no, but special projects are carried out</td>
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<td>10</td>
<td>many data from models and remote sensing are utilised for information and bulletins</td>
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<td>11</td>
<td>Ms. Federica Rossi, Mr. Domenico Vento</td>
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<td><strong>3</strong></td>
<td>no</td>
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<td><strong>4</strong></td>
<td>Some agrometeorological bodies that maintain automatic weather stations issue reports based on the collected data.</td>
</tr>
<tr>
<td><strong>5</strong></td>
<td>The operational bulletins are issued weekly except for the IMS agromet. Bulletin which is issued 3 times a month - day 1-10, 11-20 and 21-end of month.</td>
</tr>
<tr>
<td><strong>6</strong></td>
<td>The IMS bulletins (samples included) are slightly different in winter and summer. 16 stations are included representing widely different areas in Israel. The basic elements and derived agrometeorological indices are evaluated daily and their combined 10-day means or totals are compared to long-term averages.</td>
</tr>
<tr>
<td><strong>7</strong></td>
<td>customers are: - Governmental offices, Agricultural research &amp; development institutes, Forestry authorities, University libraries, Companies and factories, Engineers, Agricultural managers and Farmers. Today, the customers are reached by mail.</td>
</tr>
</tbody>
</table>
The IMS evaluates feedback based on periodic questionnaires issued to the subscription population. It should be noted furthermore, that the subscription base has increased from year to year in its current format which began in 1994.

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<tbody>
<tr>
<td>8</td>
<td>The IMS evaluates feedback based on periodic questionnaires issued to the subscription population. It should be noted furthermore, that the subscription base has increased from year to year in its current format which began in 1994.</td>
</tr>
<tr>
<td>9</td>
<td>no</td>
</tr>
<tr>
<td>10</td>
<td>no</td>
</tr>
<tr>
<td>11</td>
<td>GIS techniques are in a development stage. Plant-growth is represented through the Penman-Monteith standard FAO model for a short grass. This will be generalized to simulate water requirements of various crops in their phenological stages.</td>
</tr>
<tr>
<td>12</td>
<td>There is currently a 2-3 day delay in the dissemination as the bulletin is issued through the regular mails. Shortly, it will be disseminated by e-mail to accelerate its dissemination.</td>
</tr>
<tr>
<td>13</td>
<td>co-operation between Ministry of Agriculture and the Met Office should be start as soon as possible. Assistance is necessary and welcomed</td>
</tr>
<tr>
<td>14</td>
<td>no</td>
</tr>
<tr>
<td>15</td>
<td>Ms Ora Karni  Mr. Francis T. Gauci</td>
</tr>
<tr>
<td>The NETHERLANDS</td>
<td>NORWAY</td>
</tr>
<tr>
<td>-----------------</td>
<td>--------</td>
</tr>
<tr>
<td><strong>1</strong> no</td>
<td>yes, a special unit for agrometeorology at the Plant Protection Centre of The Norwegian Crop Research Institute.</td>
</tr>
<tr>
<td><strong>2</strong> Yes, focal point of the Royal Netherlands Meteorological Institute (KNMI) is Mr. Marcel Molendijk (<a href="mailto:marcel.molendijk@knmi.nl">marcel.molendijk@knmi.nl</a>)</td>
<td>A liaison officer at DNMI has the responsibility of ensuring good contact.</td>
</tr>
<tr>
<td><strong>3</strong> no</td>
<td>internet applications DNMI and a private company called STORM sell meteograms directly to the farmers.</td>
</tr>
<tr>
<td><strong>4</strong> yes, several agencies prepare and disseminate bulletins. Apart from the commercial weatherburo's, DLV-meteo provides agromet services. DLV Meteo (address: Dr. W. Dreeslaan 1, 6721 ND Bennekom, The Netherlands, Tel.: +31317491511, Email:<a href="mailto:Meteo@DLV.Agro.nl">Meteo@DLV.Agro.nl</a>) is part of the DLV. DLV is a Dutch organisation in extension and consultancy in agriculture and environment.</td>
<td>Yes, The Norwegian Agricultural Extension Service is working in close co-operation with The Norwegian Crop Research Institute on the Internet solutions. They include relevant agrometeorological information in the information bulletins to their members. These are distributed by fax or by mail.</td>
</tr>
<tr>
<td><strong>5</strong> fax, sms and internet products. The frequency of these product depends on the type of product, but on average 3 to 5 times a week.</td>
<td>The printed bulletins are usually submitted weekly during the growing season.</td>
</tr>
<tr>
<td><strong>6</strong> Most products are presented in the form of a fax message. These contain a weather forecast focussed on the type of product, e.g. a plant disease forecast has a weather forecast focussed on a network of 64 automatic weather stations, data are presented on the Internet four times daily. NAES uses together of the local conditions to submit their weekly bulletins.</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Fax reaches cca 1000 farmers through a partner in agricultural advisory service.</td>
</tr>
<tr>
<td>8</td>
<td>Season products are evaluated using feedback and other parameters, e.g. commercial benefits.</td>
</tr>
<tr>
<td>9</td>
<td>That's too hard to do.</td>
</tr>
<tr>
<td>10</td>
<td>SMS service for a regional water board, only sent if forecasted rain are larger than 15 mm.</td>
</tr>
<tr>
<td>11</td>
<td>For most of our agricultural products, a SVAT is used to calculate the canopy climate giving a hourly 5 day forecast. For regional water boards we use the information of cumulative radar images, different GCM's and a GIS package to generate a special rain forecast product.</td>
</tr>
<tr>
<td>12</td>
<td>Too little clients, as benefits are difficult to detect, and too little actual feedback on the performance of the SVAT.</td>
</tr>
<tr>
<td>13</td>
<td></td>
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<tr>
<td>14</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Mr. Marcel Molendijk</td>
</tr>
<tr>
<td></td>
<td>POLAND</td>
</tr>
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</tr>
<tr>
<td>1</td>
<td>no</td>
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<tr>
<td>2</td>
<td>yes</td>
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<tr>
<td>3</td>
<td>yes</td>
</tr>
<tr>
<td>4</td>
<td>yes</td>
</tr>
<tr>
<td>5</td>
<td>decade</td>
</tr>
<tr>
<td>6</td>
<td>see the example</td>
</tr>
<tr>
<td>7</td>
<td>the bulletin is prepared to an order of ministry of agriculture</td>
</tr>
<tr>
<td>8</td>
<td>no</td>
</tr>
<tr>
<td>9</td>
<td>no</td>
</tr>
<tr>
<td>10</td>
<td>yes</td>
</tr>
<tr>
<td>11</td>
<td>no</td>
</tr>
<tr>
<td>12</td>
<td>the lack of funds for training, models, instrumentation and specialists</td>
</tr>
</tbody>
</table>
to improve Agrometeorological Bulletins, it is necessary to develop a better model, and use information about the different types of soil and vegetation, as well as GIS.

<p>| 13 | yes |
| 14 | yes |
| 15 | Ms. Malgorzata Kepinska-Kasparzak | Mr. Fernando Quintas Ribeiro, Ms. Rita Guerreiro |</p>
<table>
<thead>
<tr>
<th></th>
<th>SLOVAKIA</th>
<th>SLOVENIA</th>
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<tbody>
<tr>
<td>1</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>2</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>4</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>5</td>
<td>meteorological and some phenological data are collected and analysed weekly other phenological data are collected and analysed in two weeks intervals during the vegetation season or monthly at the end of the vegetation season and during the winter</td>
<td>no</td>
</tr>
<tr>
<td>6</td>
<td>agrometeorological and phenological informatin is send by mail to farmers and some other institutions dealing with agriculture Short information is published weekly (vegetation season) or monthly (winter) in special newspaper for agriculturists “rolnicke noviny”</td>
<td>all information and analyses are collected at Met office and presented in monthly Bulletin sent every month to 150 places in Slovenia and abroad</td>
</tr>
<tr>
<td>7</td>
<td>the target audience is Biotechnical faculty, all Agricultural high schools, a lot of crop producers and libraries</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>not regularly, last questionnaire in1999</td>
<td>no</td>
</tr>
<tr>
<td>9</td>
<td>partly, questionnaire 1999</td>
<td>yes</td>
</tr>
<tr>
<td>10</td>
<td>no bulletins but papers</td>
<td>yes</td>
</tr>
</tbody>
</table>
Plant-growth, plant-soil-atmosphere models are used to help farmers with irrigation and with plant disease defence.

Specialists in agrometeorology (WMO), preparation of specialists, new modern type of the information dissemination free of charge.

In Slovene agricultural area the improvements of agrometeorological bulletins for farmers are being prepared in a way they could be reached electronically or by fax.
<table>
<thead>
<tr>
<th><strong>SPAIN</strong></th>
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<tbody>
<tr>
<td><strong>1</strong></td>
<td>yes, there is a small section (six people) that is included in the Meteorological Applications Department.</td>
</tr>
<tr>
<td><strong>2</strong></td>
<td></td>
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<tr>
<td><strong>3</strong></td>
<td>yes, there is an agrometeorological bulletin at national level that started to be produced in 1992. In some Regional Meteorological Centers, some agrometeorological bulletins at regional level are issued. On the other hand a national water balance is also available every ten days.</td>
</tr>
<tr>
<td><strong>4</strong></td>
<td>yes</td>
</tr>
<tr>
<td><strong>5</strong></td>
<td>weekly (decadal in the case of the water balance)</td>
</tr>
<tr>
<td><strong>6</strong></td>
<td>the information of this bulletin is collected and analysed through the means of the INM (Synoptic network stations).</td>
</tr>
<tr>
<td><strong>7</strong></td>
<td>the agromet. bulletin is sent to the Ministry of Agriculture that disseminate internally this information. Other users, in particular some enterprises related with the agricultural sector, have interest in this bulletin. In this case they have to pay for receive this information (fax, paper). In the case of the water balance, the information is received free of charge by different Official Institutions and Agencies. On the other hand there is a lot of users that are subscribed to receive the information every ten days and pay for it.</td>
</tr>
<tr>
<td><strong>8</strong></td>
<td>no</td>
</tr>
<tr>
<td><strong>9</strong></td>
<td>not regularly.</td>
</tr>
<tr>
<td><strong>10</strong></td>
<td>yes. There are bulletins of local coverage for droughts, as well as national bulletins and local ones for forest fires danger rate predictions.</td>
</tr>
<tr>
<td><strong>11</strong></td>
<td>not at the moment, but we are now involved in the implementation of these techniques, in particular the GIS as a tool to analyse and prepare the information.</td>
</tr>
<tr>
<td><strong>12</strong></td>
<td>lack of adequate observations (coverage and quality), as well as good methods of spatialisation of the meteorological information.</td>
</tr>
</tbody>
</table>
| 13 | a) In the first place there is a need for data of good quality, meaning they should reach a certain degree of accuracy.  
    b) These data should be adequately distributed from the point of view of the physiography of the terrain. There is no need for a lot of stations in a plain valley, but the coverage should be greater in an area with a complex topography.  
    c) There is a lack for adequate methods of interpolation.  
    d) Finally, the methods of dissemination and presentation of the agrometeorological information should be revised and updated. |
<table>
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<tbody>
<tr>
<td>14</td>
<td>no</td>
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<tr>
<td>15</td>
<td>Mr. Antonio Mestre</td>
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<tr>
<td></td>
<td>SWEDEN</td>
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</tr>
<tr>
<td>1</td>
<td>no</td>
</tr>
<tr>
<td>2</td>
<td>yes. SMHI is very strictly divided into two parts: 1) infrastructure and non-profit assignments (Governmental Service Division) 2) commercial activities with a division called Media and Business Service Division. Inside this services on agrometeorology is available on commercial basis. Mr Christrer Hammar is responsible for the service</td>
</tr>
<tr>
<td>3</td>
<td>No, not as a specific public service. Information on Commercial Services can be found at <a href="http://www.smhi.se">http://www.smhi.se</a> choose Business and then Agri in the English version.</td>
</tr>
<tr>
<td>4</td>
<td>MeteoSwiss and agricultural research institutes</td>
</tr>
<tr>
<td>5</td>
<td>daily delivery of agrometeorological bulletins</td>
</tr>
<tr>
<td>6</td>
<td>distribution by fax, phone and internet</td>
</tr>
<tr>
<td>7</td>
<td>farmers, agricultural research institutes and advisory service centres</td>
</tr>
<tr>
<td>8</td>
<td>no</td>
</tr>
<tr>
<td>9</td>
<td>only estimates</td>
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<tr>
<td><strong>10</strong></td>
<td>Warning are issued at Internet, radio, TV and other media regarding floods and forest fires.</td>
</tr>
<tr>
<td><strong>11</strong></td>
<td>Plant-growth models and GIS have been used, but the commercial service today is mainly special meteorological services to farmers and organisations. At university we are working on models for crop growth and forecasts for pests and diseases, partly at our department and unit of integrated pest management. we have some information on internet, which is available for all. eg we have forecasts for aphids, potato virus y, sclerotinia stem rot, frit flies, late blight, carrot fly</td>
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<td><strong>12</strong></td>
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<td><strong>13</strong></td>
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<tr>
<td><strong>14</strong></td>
<td>no</td>
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<tr>
<td><strong>15</strong></td>
<td>Mr. Roland Sigvald, Mr. Gunlög Wennerberg</td>
</tr>
<tr>
<td></td>
<td>UKRAINE</td>
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<tr>
<td>1</td>
<td>There is no independent agrometeorological unit in Ukraine.</td>
</tr>
<tr>
<td>2</td>
<td>Hydrometeorological Service of Ukraine possesses the agrometeorological sector that includes the system of agrometeorological observation on 178 existed hydrometeorological stations; system of collecting daily and 10 days data; system of data processing, analysis and integration, preparation of analytical materials, prediction and providence with them interested users; system of research and development of metodology on observation and prognostication.</td>
</tr>
<tr>
<td>3</td>
<td>Ukrainian Hydrometeorological Center and regional Centers on Hydrometeorology publish agrometeorological bulletins.</td>
</tr>
<tr>
<td>4</td>
<td>Agrometeorological department of Ukrainian Hydrometeorological Center and Agrometeorological groups of Regional Centers for Hydrometeorology deal also with preparation, composition, and dissemination of agrometeorological bulletins</td>
</tr>
<tr>
<td>5</td>
<td>36 decade agrometeorological bulletins and 1 survey of agricultural year, annually</td>
</tr>
<tr>
<td>6</td>
<td>For composition of decade agrometeorological bulletins there are used materials of meteorological and agrometeorological observation (fenology and determination of humidity store) on 178 State meteorological stations Each agrometeorological bulletin contains 3 parts comprising text, tables and maps: Meteorological conditions of decade. Meteorological characteristics of decade are provided; favourable and unfavourable parameters are emphasized; abnormalities are enlightened and compared with normals. Influence of meteorological factors upon crops vegetation. This part also comprises agrometeorological predictions and computation results scope, probabilistic characteristics for further development of building up agro-meteorological conditions, agrometeorological assessment of weather expected according to long-term weather forecast, (month, season), degree of conformity of expected conditions to needs of crop. Data also provided on expected harvest in comparison with mean long-term and last year indexes. Status of water resources and levels of underground water. A short survey of Ukrainian water resources stage and characteristics of underground water bedding is provided.</td>
</tr>
</tbody>
</table>
Information from meteorological stations and posts (in KH-21 format) are sent to regional Centers for Hydrometeorology and thence to Ukrainian Hydrometeorological Center.

10 days bulletin (has been editing since 1921) is the main periodic information and prognostic agrometeorological issue that is edited for use of the wide range of consumers in agricultural, scientific and research, and senior institutions and organizations.

Bulletins readers’ opinions are periodically collected.

Economic value is assessed periodically. According to experts’ opinion the system of agrometeorological prognostication enables to reduce losses in agriculture by 20-30%.

Special bulletins about extreme events are issued when necessary.

New technologies are used insufficiently. First steps are made in use of remote sensing and crop stage in the framework of TACIS project. Elements of GIS are used on agrometeorologist’s workstation.

Methodology of information analysis and preparation of agrometeorological bulletins may be improved by means of implementation of area assessment of meteorological and agrometeorological parameters obtained remote sensing and use of and models. Form may be improved by presentation of colour diagrams, maps and so on. But taking into consideration bulletin’s edition (i.e. 70 copies) it will be rather expensive.

Ms. Oksana Bogolubova
<table>
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<tr>
<th></th>
<th>UNITED KINGDOM</th>
<th>YUGOSLAVIA</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>yes, the agromet unit is independent and is called ADAS</td>
<td>yes</td>
</tr>
<tr>
<td>2</td>
<td>not applicable</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>agromet bulletins and advisories are issued through Met Office (NMHS) staff on contract ADAS</td>
<td>yes</td>
</tr>
<tr>
<td>4</td>
<td>yes, mainly ADAS</td>
<td>yes</td>
</tr>
<tr>
<td>5</td>
<td>Bulletins are issued weekly</td>
<td>weekly, monthly, annual Agrometeorological Bulletin, Monthly Agrometeorological Bulletin, Advisories concerning fruit trees protection against plant diseases, FHMI Annual Agrometeorological Analyses, some products on internet</td>
</tr>
<tr>
<td>6</td>
<td>Weather data collected from Met Office synoptic network is processed by the Met Office into a weekly summary and transmitted to AgroMet staff at ADAS. An edited example of a weekly bulletin is attached. Information is also produced in tabular form.</td>
<td>newspaper, tv, radio</td>
</tr>
<tr>
<td>7</td>
<td>The target audience is farmers, growers, agrochemical companies and private consultants</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Some feedback is sought from users, but not much.</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>If so, ADAS is unaware of it.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The UK Environment Agency produces monthly reports covering floods and drought. These are available from their web site <a href="http://www.environment-agency.gov.uk/">http://www.environment-agency.gov.uk/</a></td>
<td><a href="mailto:agro@meteo.yu">agro@meteo.yu</a></td>
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</tr>
<tr>
<td>11</td>
<td>Remote sensing is not used in AgroMet Bulletins: Plant growth models are used in some specialised services, not in bulletins. Plant-soil-atmosphere models such as MORECS for evaporation and soil moisture are helpful in compiling sections of bulletins. GIS (ArcView) is used in the production of maps and figures for bulletins.</td>
<td>simple water balance model</td>
</tr>
<tr>
<td>12</td>
<td>Time and funding are limitations in current methods. When bulletin editors are looking for cost savings they sometimes delete the AgroMet section. Our response is to offer a cheaper, monthly summary.</td>
<td>weather-plant, weather-pest and diseases models are not used in operational practice, lack of specialist</td>
</tr>
<tr>
<td>13</td>
<td>To improve agromet bulletins, they must be good value for money with contents users 'cannot do without'</td>
<td>yes</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>Ms. Ruth Patton Mr. Momcilo Zivkovic</td>
</tr>
</tbody>
</table>
ANNEX 3

Figure 1. Two examples of agrometeorological information were published in newspaper. It looks like as part of ‘Bulletin’ IRELAND

Figure 2. Direct information distribution in fax format by METEO FRANCE

Figure 3. Cover page of traditional bulletin issued by DWD, Germany
Figure 4. The cover page of the National Bulletin, ITALY

Figure 5. The cover page of regional bulletin, ITALY

Figure 6. The cover and an inner page with maps showing the territorial distribution of investigated elements, PORTUGAL
Figure 9. Animation of territorial distribution in agromet bulletin
Hydrometeorological Service, ROMANIA

Figure 10. Cover page of annual grometeorological and phenological report SLOVAK REPUBLIC

Figure 11. Evaluation of agricultural year, comparison of the precipitation with previous year, TURKEY
Applications of Meteorological Information to Agriculture in West Africa

Giampiero Maracchi\textsuperscript{1} and Simone Orlandini\textsuperscript{2}

Abstract

The application of agricultural meteorology can be considered particularly important in developing countries, providing information in order to support decision making. Early warning systems, technical assistance during the agricultural season and improving production systems can be considered as the main goals of agrometeorology. In this paper several examples of agrometeorological applications are described. They have been realised by several research institutions in Florence, to support the activity of agricultural producers, particularly for the forecast of rainy season and the monitoring of crop production.

Introduction

In developing countries (DCs), the availability of processed information can represent the basis for the survival of the population. These are two main obtainable goals: food commodities and system sustainability (Hollinger, 1994). In this context, weather/climate application to agriculture can play a fundamental role, providing information to support the decision activities of agricultural producers and politicians (Bacci, 1994). Agrometeorology can propose a wide range of agricultural strategies, among those the farmer can choose the most suitable strategy depending on the characteristics of the environment, to reduce the negative effect of weather variables and the interannual variability of crop production. Important information can be provided with a short time horizon for tactical applications concerning early warning (short cycle varieties, choice of alternative cultural systems, real time seed distribution, irrigation management), and with a long time horizon for:

\textsuperscript{1} Institute of Biometeorology - National Research Council, Piazzale delle Cascine 18, 50144 Firenze, Italy. Tel : +39 055354895, Fax +39 055350833, E-mail: maracchi@iata.fi.cnr.it

\textsuperscript{2} Department of Agronomy and Land Management – University of Florence, Piazzale delle Cascine 18, 50144 Firenze, Italy. Tel : +39 055354895, Fax +39 055350833, E-mail: orlandini@iata.fi.chr.it

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1. agro-economic planning with benefits at national scale (stock, production, import/export);
2. agro-industry production with benefits at international level (yield forecast in main production zones and in different countries).

The main goals of agrometeorology in DCs are directed at improving the stability of production from one year to another and increasing national agricultural production. The main characteristic of agriculture in DCs being the provision of food for farmers themselves, even if the growth of towns in the last decades demands provision of food also for non agricultural activity, all efforts should be made in this direction. The principal aims of agrometeorology can be summarized as the following (Maracchi et al., 2000):

1. Early Warning Systems, the possibility to forecast on an administrative basis lack of production, and therefore the food available to governments, and international cooperation through humanitarian aid to reduce the impact of unfavourable years;
2. technical assistance during the agricultural season, monitoring of the meteorological parameters and comparison with the previous years and with modelled conditions. This enables farmers to be advised on how best to take advantage of favourable conditions or fight unfavourable conditions by choosing the best time to seed, ways to save water through weeding at the right time or to defend themselves from pest and disease attacks;
3. improving production systems, assuming that in many cases in the poorest countries the traditional ways of improving production through the application of technological inputs such as fertilizers and machines is very difficult for financial reasons. Simple techniques to take the greatest advantage from natural and human resources is the only way to improve production and to sustain the same. As climate is one of the main natural driving forces, agroclimatic analysis and advice become crucial to improve the situation.

At present many tools are available to increase the performance of the agrometeorological applications. They allow the monitoring of analysed region, the complete data elaboration to provide information and finally the real time dissemination of information to the end-users. We can indicate the earth observation from the space, the computer science progress, internet technologies, electronic devices development, numerical meteorological model improvement, crop model set up and seasonal climatic models for climate prediction (Maracchi, 2002).
To provide a picture of the present situation, several applications of agrometeorology in West Africa are described in this paper. They are realised following international projects, by several research institutions from Florence (Italy), belonging to the National Research Council and the Accademia dei Georgofili.

**Utilisation of Rainfall Forecast Data Available on the World Wide Web**

This activity has been realised during the agricultural season 2001 in Mali, by the Institute for Agrometeorology and Environmental Analysis Applied to the Agriculture of the National Research Council. The main goal is to advise farmers for the best sowing period some days before the rain in order to help them in taking the right decision. The system is structured in three main sections:

- Rainfall Forecasting section
- Rainfall Estimation section
- Field data section

In the first, through the daily images on WWW it’s possible to forecast the amount of rainfall expected into the decade and give the advise on sowing to farmers (Fig. 1). The second section is involved in rainfall estimate based on GPI, SSM/I, AMSU and GTS. The output of this section is used to validate the information prepared by the forecasting information (Fig. 2). Finally the third section provide field data collected by local institutions in observation areas (Fig. 3). The results obtained in the sections have been compared in order to evaluate the process (Fig. 4).

**Utilisation of Agrometeorological Data “S.I.S.P. - Système Intégré de Suivi et Prévision”**

SISP has been developed by the Institute for Agrometeorology and Environmental Analysis Applied to the Agriculture of the National Research Council and can be considered as an integrated information system for monitoring cropping season by meteorological and satellite data (Di Chiara et al., 1994). The aims of the project are:

- to use and integrate different information sources and analysis procedures;
- to allow the meteorological services a decadal growing monitoring;
- to provide national early warning system with useful information about the evolution of the season.
Figure 1. Forecasting Section.

Figure 2. Estimation Section.
Figure 3. Field Observation and Data Section.

<table>
<thead>
<tr>
<th>DEPARTMENT</th>
<th>REAL SOWING DATE 2001</th>
<th>FORECASTED SOWING DATE</th>
<th>ESTIMATED DATE SOWING DATE</th>
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Figure 4. Comparison among Results obtained in the Three Sections and Evaluation Results.
The system is based on several tools:

- statistical analysis on historical series of rainfall data to produce agroclimatic characterizations;
- a millet (*Pennisetum americanum*) simulation model estimating the effect of rainfall distribution on millet crop growth and yield;
- NOAA-NDVI images analysis monitoring vegetation development;
- decadal reporting produced by national meteorological services and national early warning units.

The final result is characterised by many operation production, giving important advises to the decisions makers, extension services, farmers, businessmen (Fig. 5). Several final considerations can be presented:

- the system has a modular structure and an user-friendly interface;
- data and parameters used are common and easy obtainable;
- the system is oriented to provide national meteorological services with a simple methodology for agroclimatic characterization, seasonal monitoring and yield forecasting;
- METEOSAT images of estimated rainfall could be integrated in the system and used instead of station rainfall data;
- integration of a module for the forecasting of sowing date;
- strengthening and improving of the data collection and dissemination systems.

![Figure 5. Main Products of SISP.](image)
The ZAR (Zones A Risque) Model

This model, realised in collaboration between the Centre for Computer Science Application to Agriculture of Accademia dei Georgofili and the AGRHYMET Regional Centre, allows to identify the zones at current risk for agricultural production on the basis of the following data: rainfall estimates derived from METEOSAT images and agroclimatic characterisation on the territory based on rainfall time series analysis.

From the 1st decade of May to the 3rd decade of July the ZAR model produces the following layers:

- first successful sowing
- sowing failures
- last decade suitable for sowing
- zones where after the sowing failure it is possible to re-sow
- successful sowing
- average growing season onset
- average growing season end
- average growing season length
- length of the current season
- evaluation of the possibility to sow in zones that are not yet sown
- comparison between the actual onset with the average onset of the agricultural season
- comparison between the actual onset with the onset of the agricultural season of anomalous years.

Conclusions

The described procedures can be operationally applied in DCs, providing important applications for the improvement of crop cultivation. Particularly important are the possibilities for optimising the exploitation of water resources, generally representing the limiting production factor of these areas. The range of elaborated information can be very important for successful agrometeorology applications, as well as the possibility of a real time dissemination of information satisfying the end-user needs. Also in these less developed countries Internet can be a good solution to reach the local services, but it is possible to use local or national broadcasting.
References


Improving Agrometeorological Bulletins –

Perspectives from the Caribbean Region
Agrometeorological Services in Jamaica

Dale Rankine

Introduction

Jamaica is an island in the Caribbean Sea with a total landmass of 4411 square kilometers. The island is centered on latitude 18º 15’ North and longitude 77º 20’ West. Jamaica is approximately 145 kilometers south of the island of Cuba. The Island is elongated along west-northwest to east-northeast alignment, roughly 230 kilometers long and 80 kilometers wide at its broadest point. The country has several rugged mountain ranges, with the highest point, the Blue Mountain Peak soaring over 2,256 meters. More than 120 rivers flow from the mountains to the coast. There are several plains, hectares of fertile agricultural lands, towering cliff's waterfalls and dense tropical forests. The island is divided into fourteen parishes and Kingston is the capital city. The population amounts to nearly 2,600,000 inhabitants.

The Meteorological Service

The Meteorological Service currently resides in the Ministry of Water and Housing. There are five major divisions within the service: the National Meteorological Centre, the Caribbean Radiosonde Network, the Radar Section, the Synoptic Sub Station and the Corporate Head Office (which houses the Climate Branch and administrative sections).

The agrometeorology section resides in the Climate Branch section. Currently, no agrometeorological bulletins are issued by the service, but data from the service are supplied to the farming community and on request to other groups with agricultural interests. A high staff turnover rate in the Agrometeorological section severely affected its development. The recent departure of two trained individuals has brought the situation back to the early stages. New initiatives to fully revive this section are underway.

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Agriculture in Jamaica

Agriculture remains one of the key economic sectors of Jamaica. This sector contributes approximately to 7.3% of the Gross Domestic Product (GDP), which represents approximately 12% of the foreign exchange earnings and employs approximately 25% of the population. Sugarcane is the most important crop in Jamaica contributing approximately 45% of the export earnings for all exported crops. Bananas are the second most important crop. Coffee, citrus, pimento, coconut and cocoa are also exported. With the strong dependence of agriculture on weather, and the thrust to cope with fluctuations in yields imposed by climate variations, the need for timely and accurate agrometeorological information has increased. The Ministry of Agriculture produces a quarterly report on comparative estimates of domestic crop production and area reaped.

Additionally, the Pesticides Control Agency produces a farmer calendar. This publication focuses on the planting season, the crops grown and the application of fertilizers and pesticides. The Meteorological Service supplies rainfall data for this publication, which is their only input. Research agencies and the Rural Agriculture Development Agency (RADA) provide support services for the sector. St. Elizabeth, the parish that produces the largest share of domestic crops, is located in the rain shadow zone of the island. Known as the “bread basket” of Jamaica, the parish is sited to the south west of the island. Most of the parish receives less than 100 mm of rainfall per month, (less than 1000 mm annually). Recently two irrigation projects were launched in the parish, funded by the government through funds provided from international agencies. In Jamaica, there is a strong reliance on traditional farming techniques. These methods will have to be revised, and in some cases dispensed, to cope with the challenges of developing and maintaining a more viable and efficient sector.

Recommendations

Following a workshop hosted at the Caribbean Institute of Hydrology and Meteorology (CIMH) held the 3-4 July 2000 in Barbados, the following recommendations for Jamaica were made.

The Meteorological Service should:

- Develop precipitation outlook for Jamaica, using output from CIMH.
- Monitor temperature changes and make temperature forecasts for farmers.
- Determine crop zones for agricultural land-use (with the aid of agricultural agencies and GIS technology).
- Coordinate the work of multidisciplinary teams with representatives from the Meteorological Service, Water Resources Authority, Rural Agricultural Development Agency, the Ministry of Agriculture and other interest groups.
- Produce a 3-5 day agrometeorological forecast for critical districts using farmer-friendly terminologies.
- Formulate soil water balance calculations for Jamaica (aided by Cuba and WMO).

The Agricultural community would:

- Identify periods during which data was most urgently required and the exact data needed.
- Identify sources of agricultural, soil and phenological data and forward it to the Meteorological Service.

Many of these recommendations have not yet been adopted. Various circumstances have prevailed, whereas not the least is a current chronic shortage of staff. A first step to overcoming these obstacles consists in establishing closer relations between the Meteorological Service and the Ministry of Agriculture. However, current links are tenuous.
The Meteorological Services at the Point Salines International Airport in Grenada began operations in October 1994 with the opening of the airport.

The Land Use Division of the Ministry of Agriculture issues monthly agrometeorological bulletins and the Aeronautical Meteorological Service at the international airport issues advisories on flashfloods, mudslides, coastal erosion, etc. as may be necessary. It also reissues the tri-monthly rainfall forecast from the Caribbean Institute for Meteorology and Hydrology (CIMH).

These bulletins contain mainly rainfall data from 47 stations throughout the island but also contain temperature, sunshine and relative humidity data from a few agrometeorological stations and the only Aeronautical Meteorological Service at the airport.

In addition to issuing a copy to every source station, a copy is sent to the Forestry Division, Planning Division, the National Water and Sewage Authority, Grenada Science Council, Caribbean Institute for Meteorology and Hydrology, Pest Management Unit, Taiwanese Agricultural Mission, Government Information Service, the Grenada Banana Cooperative Society, the Grenadian Voice Newspaper, the Government Central Statistical Office, the Food and Nutritional Council and the Marketing and National Importing Board.

Although no real regular effort is being made for the collection of a constant feedback from the users of these bulletins, occasionally comments are received. Remarks about the value or benefits, economic or otherwise, of these bulletins are also received from some users, but no formal assessment is carried out.

Unfortunately, no efforts are being made to issue bulletins of a special nature for addressing extreme events such as drought, floods, forest fires or erosion. Also no simulation models and GIS are used for analysis.

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and preparation of information. The present methods of preparation of these bulletins are somewhat in an old-fashioned way of raw data presentation, with insufficient plain language comparison and histograms for the ordinary non-meteorological user. However, it is planned to improve the preparation, contents and frequency of these bulletins in the near future.
Agrometeorological Bulletins – The Case of St. Lucia

Bernadine Joseph

Introduction

The island of St. Lucia is situated at latitude 13° 53’ North and longitude 60° 68’ West. It forms part of the chain of islands called the Windward Islands. The island covers an area of 618sq km (238 square miles). The general topography of the island is mountainous.

St. Lucia falls within the northeast trade wind belt and is normally under an easterly flow of moist warm air. The island's location in the Atlantic Ocean/Caribbean Sea means that the ambient sea surface temperature average is about 26.7 degrees Celsius at any time.

The island’s weather is influenced by synoptic weather systems, such as the Atlantic high-pressure system (Bermuda and Azores), surface, mid and upper level troughs/lows, the Inter-Tropical Convergence Zone, tropical waves and cyclones and the occasional frontal system. Mesoscale and microscale weather features also affect the island. The rainfall regime of the island can be defined into two seasons, a wet season from June to November and a dry season from January to May.

Agriculture is the main source of export earnings in St Lucia. The importance of the agricultural sector is significant not only from the foreign exchange point of view but also for the island’s employment generation capacity. Banana production, the island’s most important agricultural produce has been on the decline recently. However, some farmers have started to diversify into non-banana crops and other sectors such as livestock and cut flowers.

Though it is an accepted fact that climatic factors are integrally important to agricultural production, for some reason the farmer population of St. Lucia has not been sensitized to understand these relationships.

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Status of Agrometeorological Bulletins

A Hydrometeorological Unit (agrometeorology and hydrology) section forms part of the Agricultural Engineering Services Division of the Ministry of Agriculture. Technicians without any formal training in agrometeorology man this unit. The major focus of this unit as it relates to agrometeorology, is data collection as this unit is also responsible for the hydrometeorological network of St Lucia. This hydrometeorological network consists of six meteorological stations. Two of these stations are managed by the National Meteorological Services, two by private agricultural research agencies and one along with twenty-eight (28) rainfall stations, by the Hydrometeorological Unit of the Ministry of Agriculture.

The monthly and annual publication of agrometeorological bulletins began in 1991 and ended in 1999. These bulletins were made available, among others, to extension officers, agricultural agencies, research officers and the National Water and Sewerage Company. The bulletins were made available to the users by means of mail and hand delivery.

A number of constraints appeared during the years of publication as, late submission of summaries and weather outlook provided by the National Meteorological Services, unreliable data from observers, software problems and inadequate office equipment (photocopies, computer). For example, the software for rainfall data logger was not Year 2000 compliant.

It is hoped therefore, that the new knowledge acquired from this workshop becomes a meaningful contribution towards the continuation of an improved agrometeorological bulletin for St Lucia. Thanks are expressed towards the organizers to have given the opportunity to a representative from St. Lucia to participate in this important workshop.
Agrometeorology - the Trinidad and Tobago experience

Arlene Aaron

Agrometeorology in Trinidad and Tobago is under the auspices of the Climatological Department. Initially, post-graduate training at the Master of Sciences level was sourced and the officer specialized in rice production, training was also sourced at the post-graduate diploma level.

Data sharing arrangements were made with two other State agencies for the use of the rainfall and temperature data on a real time basis. The first was the Water Resources Agency, which has a large network of rain gauges and evaporation stations across the island. Caroni 1975 Ltd, the largest agricultural company in the island has a large database of rainfall and temperature measurements, which are used to increase harvests of sugarcane, rice citrus, etc.

Additionally, the Meteorological Service purchased Automatic Weather Stations to augment data collection in data sparse areas.

Caroni 1975 Ltd., the largest agricultural company, has extensive cultivation of sugarcane, citrus and rice. Additionally there are quite a few individual farmers with large coconut estates, which produce copra used in the manufacture of oils and soaps. There are also many small-scale farmers producing short-term crops for either local consumption or export. Figure 1 shows areas of the large-scale cultivated crops.

In the early 1990’s, in conjunction with the Farmers Training College in Centeno, lectures were given to small-scale farmers on how the weather affects determine local agricultural practices, e.g. what crops to grow and when, irrigation needs, drainage, mulching, windbreakers and pest/disease protection.

It is often stated in Trinidad that the small-scale farmer uses too much pesticide. Therefore, this audience was targeted in 1995 for

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agricultural weather forecast, using the radio as means of dissemination. The forecast included:

- Sky conditions
- Wind direction
- Weather
- Temperature and relative humidity
- Amount of sunshine expected
- Best time to apply chemicals/fertilisers

An example of the agrometeorological forecast is given in Figure 2.

Traditional farming practices in Trinidad and Tobago rely on moon phases in all facets of agriculture. Farmers seemed unwilling or unable to accept the correlation between heat, humidity and the spread of pests and/or diseases. Overuse of chemical pesticides as stated earlier, is a common problem, with the accepted adage “if 100ml is the recommended dosage once every two weeks for the control of a particular pest, then a greater dosage with a higher frequency is better”.
Despite the issuance of the forecast and the lectures to the farmer at the Farmers Training Collage in Centeno, the practice of over dosage of pesticides continues.

There is a need also for greater ties between the Meteorological Service and the university specifically in the field of soil science, to foster a better understanding of the response of the different soil types to floods and dry spells, especially its impacts on irrigation.
The competent staff levels have fallen drastically from 1998 and both members of staff with specialized agrometeorological training have since retired, which forced a curtailment of the agricultural weather forecast in 1999. The software for the automatic weather stations was not Year 2000 compliant, which further exacerbated the problem. There have been subsequent requests from farmers for a re-installation of the forecasts.

The Meteorological Service recognized the importance of agrometeorology to the food security of the nation and the export thrust of the agro-processing industry, whether in food crops or horticulture, therefore, training has been funded to rebuild this vital area. Further, the replacement of the automatic weather stations has been funded and discussions are underway with farmers on their needs related to agricultural weather forecast.

It is hoped during the coming year that the necessary infrastructure and staff will be on stream so that the Agrometeorological section can be fully activated and forecasts once again issued.
The Cuban experience in Developing Agrometeorological Bulletins for the Agricultural Sector


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
tagrometeorological 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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Improving Agrometeorological Bulletins –

Technological Perspectives
Some User-friendly User-interface Computer Techniques for Improving Agrometeorological Bulletins

Zvi Zemel

Abstract

The Agrometeorology department of the Israel Meteorological Service issues a 10-day report and twice-weekly estimates of evapotranspiration based on data collected from several automatic weather stations. Both products make extensive use of the popular Excel spreadsheet software, and in particular, the user-friendly pivot table and input table utilities. These modules are normally used in financial applications, but it is shown that they have great potential in agrometeorology, and are well worth exploring in light of the widespread availability of the necessary low-cost software and desktop computers. As with most spreadsheet applications no programming skills are required even though the two features are quite powerful. The methodology is discussed, and the use and effectiveness of the techniques are demonstrated. Specifically, it is shown that what-if input tables may be easily adapted to analyze relatively complex derived evapotranspiration estimates, and pivot tables may be used to considerably simplify the processing and organization of agrometeorological databases.

Introduction

Spreadsheet techniques have advanced significantly in recent years in tandem with increasing computer power. Microsoft Excel now includes a utility, which generates what-if tables and another, which generates pivot tables. Extensive documentation on these techniques indicates that they are primarily designed for financial applications. Nevertheless, they can easily be adapted to function in scientific applications. In agrometeorology the analysis of potential evapotranspiration as derived from several meteorological inputs serves as a good example to demonstrate the power and use of the what-if utility. The table, which is calculated by this module, may be interpreted as a calculated field in an agrometeorological database. It therefore extends the usefulness of the pivot table utility which enables

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users to design reports, including statistical analyses, based on moderately-sized databases. The techniques are illustrated with the goal of providing useful low-cost tools for processing and improving agrometeorological products.

**What-If Input Tables**

**Test Case - Potential Evapotranspiration**

The usefulness of the *what-if table* Excel utility lies in its ability to reduce a relatively complex set of calculations applied repeatedly to a set of inputs from records in a database without requiring any programming or programming experience. It is therefore particularly suited to the determination of potential evapotranspiration based on the combination method originally developed by Penman (1948), because of its importance as a physically-based model and its relative complexity requiring several meteorological inputs. It is worthwhile therefore giving a brief description of the model, specifically the Penman-Monteith generalization, which estimates the potential evapotranspiration from un-wetted vegetation. Its importance as a tool in estimating crop water requirements as compared with other methods has been well documented (Jensen *et al.* 1990). A general form of the Penman-Monteith equation is given as

\[
PM = \frac{\Delta (R_n - G)}{\Delta + \gamma (1 + \frac{r_s}{r_a})} \tag{1}
\]

where \(R_n\) and \(G\) are the net radiation and soil heat fluxes respectively, with units of \(\text{MJ m}^{-2} \text{day}^{-1}\), \(E_a\) is the aerodynamic component of the potential evapotranspiration \(PM\), both in \(\text{mm day}^{-1}\) and \(L = 2.45 \text{ MJ kg}^{-1}\) (or, equivalently, \(\text{MJ m}^{-2}\)) is the latent heat of vaporization. In eq. (1), \(\Delta\) is the slope of the saturation vapor pressure with temperature and \(\gamma\) is the psychrometric constant, both measured in units of \(\text{kPa °C}^{-1}\), (at sea level, \(\gamma = \text{kPa °C}^{-1}\)); \(r_s\) and \(r_a\) are crop and aerodynamic resistances respectively, in \(\text{s m}^{-1}\). The expression is quite general and physically-based including the crop resistance factor which parameterizes the unsaturated air humidity status adjacent to an un-wetted crop as compared with the saturated status over water or wetted surfaces.

**Reference Potential Evapotranspiration**

Allen *et al.* (1998) provide a detailed guide for calculating crop water requirements, using as a basis the atmospheric water demand,
estimated by the Penman-Monteith combination method, of a hypothetical reference crop. The standard crop is assumed to be a well-watered extended short grass 12 cm high, with 23% albedo and crop resistance \( r_s \) of 70 s m\(^{-1}\). The aerodynamic resistance \( r_a \), modeled from classic turbulent diffusion theory and neutral stability, is given as 208 U\(^{-1}\), where \( U \) is the wind speed in m s\(^{-1}\) at standard 2m screen height. With these aerodynamic and crop specifications, the Penman-Monteith equation becomes with 1-day time steps

\[
\text{PM}_{\text{ref}} = \frac{\Delta (R_n - G) + \gamma \frac{900}{T_k} U (e_s - e_a)}{\Delta + \gamma (1 + 0.34 U)}
\]  

where \( \text{PM}_{\text{ref}} \) is the reference evapotranspiration (mm day\(^{-1}\)), \( R_n \) and \( G \) are now given in equivalent evaporation units (mm day\(^{-1}\)), \( T_k \) is the air temperature at 2m \(^{\circ}\)K\) and \( e_s \) and \( e_a \) are the saturation and actual vapor pressures (kPa).

For the 1-day time step, the soil heat flux may be ignored, and \( \Delta \) is easily calculated as an analytic non-linear function of air temperature. The vapor deficit \( e_s - e_a \) may be calculated from temperature measurements along with a humidity observation, such as wet-bulb temperature, relative humidity or dew-point; \( \gamma \) is proportional to atmospheric pressure, and in the absence of barometric data, it is sufficient to use an average based on the standard pressure corresponding to the station elevation.

The net radiation may be written as

\[
R_n = (1 - \alpha) R_s - R_{nl}
\]

where \( R_s \) is the global radiation, \( \alpha = 0.23 \) is the albedo, and \( R_{nl} \) is the net long-wave radiation. Assuming the latter is not measured directly or calculated from soundings, a suitable semi-empirical expression for \( R_{nl} \) may be used depending on temperature and humidity at screen height, and sunshine duration (e.g. the Brunt formulation), the latter acting effectively as a surrogate for cloud cover. Furthermore, sunshine duration may also be used as surrogate for global radiation \( R_s \) if the latter is not measured directly; for example, the well-known Angstrom expression

\[
R_s / R_s = a + b (n / N)
\]

may be employed where \( a \) and \( b \) are regression coefficients and \( n \) is the sunshine duration. The day-length \( N \) and the daily extraterrestrial daily solar input \( R_{sa} \) may be calculated analytically from astronomical relationships as a function of station latitude and day of the
year. Thus, $PM_{ref}$ may be determined from eq. (2) with observations of temperature, humidity, wind and sunshine duration as a surrogate for radiation observations, which are lacking at many meteorological stations. It is highly recommended that users refer to the paper of Allen et al. (1998) which provides explicit instructions for calculating reference potential evapotranspiration from the available weather data, with useful discussions of data integrity and alternative methods, including various techniques for handling missing data.

One-Input What-If Table

From the previous discussion we note that the daily estimation of $PM_{ref}$ may be obtained from 6 inputs - daily values of maximum and minimum temperatures and humidities, wind run and sunshine duration. As a derived quantity, the calculation of $PM_{ref}$ is straightforward but cumbersome. A computer program written in any high-level language is an easy and logical way to perform the calculations. But this approach is hardly necessary today given the widespread availability of spreadsheet software which obviates the need for programming and which has built-in visual and interactive capabilities and flexible input formats and requirements. Table 1 shows a typical database for making $PM_{ref}$ calculations; the 6 meteorological inputs are given for generic stations $StnA$, $StnB$ etc. on specific dates in the first 8 columns. If the $PM_{ref}$ estimation, which appears as output in the 10$^{th}$ column, were as simple, for example, as calculating the average temperature $T_{avg} = (T_{max} + T_{min}) / 2$, then the formula would be entered into the first record under the database heading $PM_{ref}$ and then propagated downward through the database using the standard Copy procedure. In this case, however, several intermediate calculations are required; an obvious solution would be to introduce several auxiliary columns for these intermediate steps. This is a cumbersome approach, which may also be constrained by memory limitations, especially when the calculations are made for several hundreds or thousands of records.

The Excel Table utility within the Data main menu is a powerful utility which allows the user to carry out repeated $PM_{ref}$ calculations without employing the Copy command; specifically, the calculation is carried out only once with the inputs from the first set of data inputs below the database headings. The repeated calculations for the remaining records are carried out by using pointers to subsequent inputs based on the record number. The counter or index is numbered 2,3,4, etc. in the 9$^{th}$ column with heading $Rec$ in Table 1 and is an essential part of the What-If Excel utility. In a sense, the $Rec$ column is analogous to the “Do Loop” counter or index used in
Field symbols: $T_x$, $T_n$ maximum and minimum temperatures (°C); $U$ windspeed (m s$^{-1}$); $R_{Hn}$, $R_{Hx}$ minimum and maximum relative humidities (%); $SD$ sunshine duration (hr).

<table>
<thead>
<tr>
<th>$T_x$</th>
<th>$T_n$</th>
<th>$U$</th>
<th>$R_{Hn}$</th>
<th>$R_{Hx}$</th>
<th>$SD$</th>
<th>$Stn$</th>
<th>Date</th>
<th>Rec</th>
<th>$PM_{ref}$</th>
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<td>3.0</td>
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<td>2001-01-13</td>
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<td>92</td>
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<td>StnB</td>
<td>2001-01-16</td>
<td>23</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Table 1: Input and output of Penman-Monteith $PM_{ref}$ evapotranspiration calculation.

High-level programming. For convenience, the database, including the headings, is given the name $db$ and the first counter with value 2 below the Rec heading is given the name Rec. Calculations of $PM_{ref}$ are then carried out, preferably in a separate dedicated calculator worksheet, with the 8 data inputs associated with the single index value $Rec=2$. In the calculator area, the maximum temperature $T_x$ for the first record is retrieved using $=Index(db,Rec,1)$, since it is in the 1st column and the Rec or 2nd row. Similarly, $=Index(db,Rec,2)$ points to the minimum temperature $T_n$, and $=Index(db,Rec,3)$ to the wind speed $U$ etc., for the first data record. Time-independent inputs may be inserted into the calculator worksheet using a
separate meta-table. Table 2 is defined as Meta; thus required inputs such as station latitude and elevation may be inserted into the calculator worksheet using expressions such as \( =Vlookup(Index(db,Rec,7),Meta\ 2) \) and \( Vlookup(Index(db,Rec,7),Meta,3) \) respectively.

<table>
<thead>
<tr>
<th>Station</th>
<th>Latitude</th>
<th>Elevation</th>
<th>Anemometer height</th>
<th>Angstrom a</th>
<th>Angstrom b</th>
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<td>StnB</td>
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<td>30</td>
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<td>0.25</td>
<td>0.5</td>
</tr>
<tr>
<td>StnC</td>
<td>31</td>
<td>195</td>
<td>10</td>
<td>0.25</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Coefficients a and b in \( R_s/R_{sa} = a + b(n/N) \) relate global radiation \( R_s \) to \( n \), sunshine Duration to extraterrestrial radiation

**Table 2: Sample metadata for PMref evapotranspiration calculation**

The 8 inputs from the first record are used to calculate various intermediate and auxiliary terms such as the daily terrestrial radiation, vapor pressure, long-wave radiation etc. leading finally to a determination of potential evapotranspiration from eq.(2), and, for convenience, is given the name \( PM_{ref} \).

The one-input Table utility is now applied to the Rec and \( PM_{ref} \) columns in Table 1, and the Rec cell with value 2 is assigned as the utility’s Column Input Cell. The statement \( =PM_{ref} \)’s entered into the first record of \( db \) in the \( PM_{ref} \) output field cell to the right of the \( Rec= 2 \) cell. As with a Copy command the potential evapotranspiration is then immediately propagated downward in the \( PM_{ref} \) output column, but the difference between the two methods is significant. Specifically, changes can be made in the \( PM_{ref} \) calculation, logical expressions included to account for missing data, modules added, and other generalizations may be introduced in the one \( PM_{ref} \) calculation in the calculator sheet without requiring any change in the \( PM_{ref} \) output column in Table 1.

**Two-Input What-If Table**

Another advantage of the one-Input table utility is that with little effort one can easily employ Excel's two-input option. This is particularly convenient in order to examine the sensitivity of \( PM_{ref} \) for example, to some of the inputs in the existing database. If for example, the effect of a change in maximum temperature \( Tx \) on the \( PM_{ref} \) is of interest, then the \( Tx \)
input in the calculator sheet could be generalized to $=\text{Index}(db,\text{Rec},1)+T_{inc}$ where the name $T_{inc}$ is assigned to a cell location with a value of zero. By assigning this cell as the Row-Input Cell of a two-input table, the output as illustrated in Table 3 and Table 4 can easily be obtained. In these tables, actual and relative differences from the $T_{inc}=0$ case are calculated as differences from the PM$_\text{ref}$ output in Table 1, using the output expressions $=\text{PM}_{\text{ref}}-\text{Index}(db,\text{Rec},10)$ and $(\text{PM}_{\text{ref}}-\text{Index}(db,\text{Rec},10)/7)/\text{Index}(db,\text{Rec},10)$, respectively. The essential difference between the two-input tables versus the one-input table is that the output expressions in the former appear in the upper left corner at the intersection of the rows or headings with input values $T_{inc} = -7^\circ \text{C}, -5^\circ \text{C}$ etc. as deviations from the Tx values associated with $\text{Rec}=2,3,4$, etc. pointers; for the one-input table, however, the output expression appears as a sample associated with the first set of input data corresponding to the index counter value $\text{Rec}=2$.

Tables 3 and 4 use actual data from Israel; thus they provide insight into the response of potential evapotranspiration to changes in mid-day temperatures. In the broad sense Table 3 indicates that the evapotranspiration response to $\text{Tx}$ is higher in summer than in winter; the fractional response indicated in Table 4, on the other hand, is higher in winter than in summer.

Pivot Tables

Basic Pivot Tables

A rainfall database given in Table 5 is used to create a simple pivot table given in Table 6. In this example, the database consists of daily rainfall from 2 regions RegA and RegB, each with 3 stations StnA, StnB and StnC. Essentially, the pivot table is a simple and convenient way of organizing the data in a convenient report form, without requiring any programming experience, and includes useful totals and subtotals. Furthermore, the user may select eight report styles, apart from the displayed default standard, and the orientation may be easily changed whereby the stations and dates in this example, which are displayed in columns and rows respectively, may be reversed.

Pivot tables include a standard Page field option, illustrated in Table 7. For example, the region RegB rainfall data are displayed in this design by selecting this region from the RegA and RegB choices within a pick-list box above the pivot table. The Page field option, which is in a convenient drop down box allows the user to focus on regions individually.
Table 3: Sensitivity analysis based on 2-input what-if table describing changes (mm/day) of PM<sub>ref</sub> to changes in daily maximum temperature -7, -5, -3°C, etc.

* = PM<sub>ref</sub> – INDEX(PM<sub>out</sub>,Rec)

<table>
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<tr>
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<th>Date</th>
<th></th>
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<td>0.2</td>
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<td>0.4</td>
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</tr>
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</tr>
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<td>0.2</td>
<td>0.3</td>
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</tr>
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</table>
Table 4: Sensitivity analysis based on 2-input what-if table describing fractional changes (%) of PM\textsubscript{ref} to changes in daily maximum temperature -7, -5, -3°C etc.

* = (PM\textsubscript{ref} – INDEX(PM\textsubscript{out,Rec})) / INDEX(PM\textsubscript{out,Rec})

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<td>20</td>
</tr>
<tr>
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<td>-14</td>
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<td>10</td>
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<td>18</td>
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<td>-3</td>
<td>3</td>
<td>10</td>
<td>17</td>
<td>25</td>
</tr>
</tbody>
</table>
Table 5: Sample database for pivot table analysis.

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<th>Station</th>
<th>Date</th>
<th>Rain</th>
</tr>
</thead>
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</tr>
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<td>0</td>
</tr>
<tr>
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</tr>
<tr>
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<tr>
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<tr>
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</tr>
<tr>
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<td>StnC</td>
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<tr>
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<td>StnC</td>
<td>10/03/01</td>
<td>0</td>
</tr>
</tbody>
</table>

Furthermore, the *Page field* option adds flexibility and prevents the table from growing too large when the user adds more stations and regions into the database.

Another standard pivot table design option which is particularly useful is a grouping option which allows the user to group field items, and includes a special feature which allows users to group time and date fields by regular intervals such as hours, days, months and years. Non-standard time intervals may also be grouped as illustrated in Table 8 in which the rainfall data are grouped into 5-day intervals.
Table 6: Simple pivot table associated with database in Table 5.

Pivot Tables were generally designed for financial applications, which usually involve the *Sum* function. The same principles, however, apply to other statistical functions to calculate maxima, as illustrated in Table 8, minima, means and standard deviations, and are of obvious importance in agrometeorological applications. This includes the *Count* function, which is particularly useful because it retrieves the size of the data sample associated with the statistical operations. The use of this feature will be illustrated in the following discussion, which describes two advanced features – the *GetPivotData* and *Difference* functions.

**Advanced Pivot Tables**

Table 9 is a sample database similar to in structure to the database samples in Table 1 and Table 5, except for a simple addition. Specifically, two additional fields are added – a Cum field to designate seasonal accumulation of rainfall from a specified date until Oct. 10 in the example, and a Base field which contains long-term data and situated for convenience at the top of the database. The associated pivot table in Table 10 contains in the example differences of average maximum temperature in the October 11-20, 2001 dekad period and percent differences of rainfall, both seasonally.
Table 7: Sample use of Page field associated with database in Table 5.

and for the dekad. This advanced feature extends the use of statistical operators by relating them to base fields and items, and is particularly useful on agrometeorological applications.

Perhaps one of the most important and useful pivot table utilities is the GetPivotTable function. It is included within the lookup and reference function category, and consists of two arguments or inputs. The first argument identifies or references the pivot table itself or any part thereof; the second argument is a string expression, (or equivalently, cell references which concatenate to a text expression) associated with one of the values in the pivot table. For example, =GetPivotData (PT, “StnA TDXavg Dekad 2001”) retrieves the average maximum temperature of the Dekad (as opposed to the Normal) for the year 2001, assuming the entire pivot table or an arbitrary cell within is assigned for convenience the name PT.
Table 8: Sample grouping of date field into 5-day periods for pivot table associated with pivot table in Table 5.

The usefulness of this feature can hardly be overestimated as it allows the user to access specific information using simple text expressions. Furthermore, it allows the user to design a dedicated report form in which data entries in its cells would access select pivot table values of interest. This is particularly important because the standard pivot table layout options are only suitable for financial reports and often contain redundant information.

Another important advantage of the GetPivotData function is that it allows the user to select information selectively from a pivot table based on logical criteria considerations. For example, it can easily be combined with the logical If statement to conditionally account for partially missing data in the database. Referring to the pivot table in Table 10 as an example, an expression in a report summarizing average of maximum temperatures in a report may be inserted as follows:

\[
\text{=If(GETPIVOTDATA(PT,"StnA TDXobs Dekad 2001" >6, GetTPIVOTDATA(PT,"StnA TDXavg Dekad 2001", "," ))}
\]

where TDXobs refers to the use of the Count function to retrieve the sample size.

This expression therefore would enter into a report the average of maximum temperatures of StnA for the specific 10-day period only if there are at least 7 observations in the database. Thus, the GetPivotData function

<table>
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<th>Total</th>
<th>RegB</th>
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</thead>
<tbody>
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<td>StnB</td>
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<td>66</td>
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</tr>
</tbody>
</table>

Field symbols: RN rainfall (mm); TD_1 and TD_n maximum and minimum temperatures (°C).

**Table 9:** Sample database to illustrate incorporating seasonal totals and comparisons with normals in pivot tables.
Field and operator symbols: TDX maximum temperature (°C); Dif and Dif% actual (mm or °C) and fractional differences (%); Obs Sample size.

Table 10: Pivot table associated with database in Table 9.

Effectively transforms the pivot table, from one that organizes and statistically summarizes a database, to a system of pointers which links the database and the statistics to a suitably designed and dedicated agrometeorological report. The latter then functions as a template, which updates the report using a simple Refresh command to reflect changes in the original database. It should be noted furthermore, that the Excel 2000 includes a useful chart module linked to pivot tables which simplifies and conveniently links various graphing options.
Conclusions

Two Excel utilities, what-if input tables and pivot tables, were examined as potential tools for processing and design of reports using agrometeorological data.

It has been demonstrated that these modules may be adapted to enhance both routine and operational agrometeorological practices. Both modules, which are linked to databases, do not require any programming experience and yet may be easily adapted as dedicated utilities in agrometeorology. It is of interest therefore to monitor developments and improvements in input and pivot tables, which generally parallel improvements in low-cost computer power.
References


Farmweather - A Case Study in Agrometeorology

Richard N. Whitaker

Abstract

In 1991, meteorological staff from the Australian Bureau of Meteorology toured the cotton growing areas of northern New South Wales, conducting interviews with cotton farmers and other farmers from surrounding areas. The combination of the expertise of the meteorologist and farmer resulted in the formation of the “Farmweather” service, which now provides weather forecast and agronomic advice to a large part of agricultural Australia. In 1996 and 1997, surveys were issued to a wide area of rural Australia to determine the impact of the “Farmweather” service and revealed that the economic benefits based on only the production of four main export crops (wheat, cotton, barley and sorghum) were about six times the cost of producing the services.

Background

Operational and strategic use of weather and climate information is important for agricultural producers for the profitable production of many commodities. Intelligent use of such information, based on advance knowledge of weather events can also contribute towards the goal of sustainable agricultural production through optimal use of chemicals and water.

Advancements in the science of meteorology, and in the development of computer hardware and software, such as supercomputers, satellite and radar technologies have resulted in considerable improvements in global circulation models, the prediction of weather events, and the provision of meteorological and hydrological services such as locality specific weather services. In addition, the use of microcomputers, cable television, phone facsimile and global computer-based Internet information has greatly improved the accessibility of meteorological services, allowing more detail to be included in the forecast, as well as increased frequency of updates.

1 NSW Manager, Special Services Unit, Bureau of Meteorology, P.O. Box 413, DARLINGHURST, N.S.W. 1300, Australia. Tel.: +61 2 92961563, Fax: +61 2 92115287, Email: r.whitaker@bom.gov.au
In Australia, delivery of forecasts to rural areas has, until recent times, relied almost exclusively on the media. Originally, distribution was via the mainstream newspapers, and then radio became important from the 1920's, followed by television after 1956. This system of distribution largely controlled the style and information content of rural forecasts, with media restrictions on broadcast time and newspaper space always of paramount importance.

In November 1991, staff of the Australian Bureau of Meteorology conducted a tour of the cotton growing areas of New South Wales, during which numerous interviews were held with growers and farmers from the surrounding area. The idea was to gain feedback on how the existing rural forecast services could be improved, both in terms of forecast content and also mode of delivery.

The main issues raised in the meetings in priority order were:

1. More detail in the forecasts was requested, especially in the “further outlook” period from 48 to 120 hours ahead. A statement of forecast confidence was also requested, together with a quantitative estimate of precipitation amounts.

2. The preference for a “plain English” in normal conversational style was expressed. Phrases such as “mainly dry” or “becoming unsettled” are of only limited assistance in farm management strategies.

3. A graphic display of prognostic charts and expected rainfall distribution was requested to augment the text description of the forecast.

4. A more flexible method of forecast distribution was also asked for. An “on demand” service was considered ideal, rather than having to fit in with existing media programming schedules.

It was decided that these requests would be incorporated into a new forecasting service for the cotton growing regions of northern NSW, which we called “Cottonfields”. Some additional agronomic advice involving evaporation trends and cotton degree-days was also to be included during the period when cotton was actually in the ground.

The design of the service therefore arose directly from a combination of the expertise of meteorologist and farmer, resulting in an integrated forecast system produced explicitly to assist with short term farm management strategies.
Description of the Service

“Cottonfields” was designed to provide forecasts up to 7 days ahead, and consisted of three pages. These were a recent satellite photograph, a graphics page showing prognostic and rainfall predictions out to 4 days ahead, and a text page providing “expert opinion” commentary on the situation. This text page also contains information on forecast confidence, and quantitative rainfall predictions based on numerical model output.

In addressing the distribution problem, it was decided that this should be a non-media service, and a pollfax system was utilized. No national pollfax system existed at this time, so a local network was organized, centered on the fax machine located at the Namoi Cotton Cooperative offices.

The forecast information was prepared at the Sydney Offices of the Bureau of Meteorology and then faxed to the Namoi Cotton Co-operative machine.

Cotton growers could then poll the information as required, and records of the demand for the service were also available as output from the Namoi fax machine. The service became operational in October 1992, with the demand immediate and heavy, and growers complained of the extensive delays encountered because of line congestion.

Another issue that emerged very early was the way the demand quickly spread beyond the farm gate, with polling requests being received from rural businesses, banks, commodity traders, transport companies, local media and international sources, as well as the local growers it was designed to service. Numerous requests were also received from farmers in adjacent parts of New South Wales to begin a similar service for their area, and it soon became apparent that there was a national demand for this type of service. It was then decided to launch a national fax delivered rural service under the umbrella name of “Farmweather”, and delivery of this was to be achieved through the just developed Infofax system operated by Australia's national telecommunications company, Telstra. “Farmweather” commenced in July 1993, and was subsequently extended to cover 21 agricultural areas around Australia.

Growth of the Service

After about one year of operations, several usage patterns emerged. It became obvious that the demand for “Farmweather” was linked to three main factors, and these in total provided a measure of the level of rural activity around Australia. These factors are:
Significant Weather Events

Whenever significant weather events occur anywhere in Australia, there is immediately a peak in the demand for "Farmweather" services from the affected area. Weather such as tropical cyclones, scattered thunderstorms, or a widespread rain event will trigger such a situation.

Seasonality

Because of the climatic characteristics of Australia, agricultural activity is seasonal in many areas. In Western Australia, the main activity is centered around the winter wheat crop, which is a direct result of the winter maximum/summer minimum rainfall pattern across the area. In Queensland, the situation is reversed, with a summer rainfall maximum resulting in peak agricultural activity between December and March, and a minimum during the winter months. In NSW, dual rainfall peaks occur, one in summer and the other in winter, and this produces two periods of maximum activity in agriculture. These facts show clearly in the call numbers in “Farmweather” with the pattern very pronounced in Western Australia and Queensland, and even the double peak for NSW emerges.

So to a large extent, “Farmweather” call numbers produce a graph similar to the average rainfall pattern for the area in question.

Awareness of the service

For the first 4 years, “Farmweather” call numbers grew steadily, and then peaked during 1999. Typically we now receive about 17,000 to 20,000 calls per month and from survey evidence, awareness of the service is now very high across rural Australia.

Example of a “Farmweather” Service

(a) Sheet 1 contains “expert opinion” text referring to the local weather forecast for the next seven days ahead, percentage probability of rainfall, temperature and wind forecasts, and the last three months Southern Oscillation Index.

(b) Sheet 2 contains forecast temperature and evaporation trends, accumulated cotton degree-days compared with the same period last year and the rainfall across the local area over the previous 24 hours.

(c) Sheet 3 is a graphic representation of the prognostic and rainfall charts out to 4 days ahead based on an Australian numerical weather prediction model.

(d) Sheet 4 is a recent satellite photograph.
Assessment of the Service

During 1996, a detailed survey study of user’s evaluation of the “Cottonfields” weather service and its related benefits to the Australian economy was undertaken (Anaman and Lellyett, 1996a, 1996b). Some of the key results were that the users generally considered the service to be of high quality and useful for both their farming and non-farming activities. The benefits to the Australian economy in terms of aggregate producer benefits (producers surplus) was based on the estimated one percent reduction of costs of producing cotton determined from the survey.

This yielded a societal benefit-cost ratio of about 12:1 based on an increase in production of raw cotton (destined for export) resulting from the use of this service. However, with the advent of the “Farmweather” service, there was an obvious need to evaluate the national economic impact rather than just the effect on the cotton industry via the “Cottonfields” service. Consequently, in 1997, a survey was issued to a wide variety of farmers around Australia containing a large number of questions relating to the “Farmweather” service.

The survey consisted of a questionnaire addressing the following issues:

(a) General farm information
(b) Using weather information from the Cottonfields weather service.
(c) Benefits of the Cottonfields weather information service.
(d) Socio-economic characteristics of respondents.

The objective of this study was to analyse the use of “Farmweather” services and estimate the associated benefits to the Australian economy based on the production of several key export crops. The results of the survey were subject to standard economic regression analysis, and the associated economic theory and mathematical formulae can be found in Appendix 4 of the overall report: Assessment of the Australian Bureau of Meteorology’s “Farmweather” Facsimile Services (Anaman 1997).

Economic Benefits of Service and/or Policy Matters Served

The investigation revealed that the economic benefits of the services based on only the production of four main export crops (wheat, cotton, barley and sorghum) were about six times the cost of producing the services.

“Farmweather” is therefore an economically viable service to the Australian rural economy. However, the actual benefits from “Farmweather” are probably considerably higher, because the survey did not
include input from “beyond the farm gate” users, such as rural businesses, banks, commodity traders, transport companies and the media. It is reasonable to assume that these groups derive benefits similar to the farmers themselves.

**Other Important Issues**

The promulgation of an “expert opinion” weather forecast service, linked to graphically presented forecast information and satellite imagery, and available on demand, was perceived to be a significant step forward by rural Australia, and many appreciative references were received from the users.

(a) One of the first noticeable effects was a reduction in telephone requests from cotton growers to the NSW Regional Forecasting Centre. These calls were originated because farmers had difficulty in building up a coherent weather picture from the traditional media presentations. With "Cottonfields" providing the required level of detail, the demand for personal telephone briefings by a meteorologist fell, thereby allowing the forecasting team to concentrate more on the evolving meteorological situation.

(b) We became aware of the strong educational benefits of the service, with many requests for further information being received from schools. Because of its easy accessibility and user-friendly style, “Farmweather” was used in school projects, and also increased community awareness of the capabilities of a modern weather service. This capability was often obscured in media presentations.

(c) “Farmweather” allowed us to quantify the demand for our rural weather forecast services, which is not possible through media delivery.

(d) Since the beginning of “Farmweather”, the Internet revolution has broken, and “Farmweather” will soon be available through this source, incorporating live radar, satellite photograph “loops”, and output from automatic weather stations. We now regard the fax machine as an intermediate step between the media and the Internet. Although the Internet is growing quickly in rural Australia, it is thought that demand for fax delivery will still be strong for the next two to three years.

(e) A possible advantage of “Farmweather” is that it can be useful in developing countries where Internet delivery is concentrated mainly
in the cities, but which have a fax infrastructure extending to the rural areas. For example, there may be a police station or government office with a fax machine in many rural villages, and these could act as distribution or display points for a “Farmweather” type service. Once again we could view this as an interim step before general provision through the Internet.

(f) There has been considerable speculation in meteorological circles that the provision of such information as live radar, recent satellite photography and automatic weather station information will reduce the demand for the services of a meteorologist, and that user groups will merely attempt their own forecasts. Our experience with “Farmweather” has led us to a different conclusion. We have found that the more information provided, the more the demand for an expert opinion to integrate the data is produced.

**Conclusion**

The provision of a rural weather forecasting service covering the period out to one week ahead, incorporating the expert opinion of a meteorologist, computer graphics depicting model output, updated once per day, and including a recent satellite photograph, all available on demand, produces a quantifiable economic benefit to the rural activities of the host country. Delivery can be through pollfax or Internet.

**References**


Abstract

The *Weekly Weather and Crop Bulletin (WWCB)* provides an invaluable source of information pertinent to regional, national, and international agriculture. Since 1978, the *WWCB* has been produced by the Joint Agricultural Weather Facility (JAWF), a global agricultural weather and information center located within the United States Department of Agriculture (USDA) in Washington, D.C. The JAWF is jointly operated by the Department of Commerce’s Climate Prediction Center (DOC/CPC), and USDA’s World Agricultural Outlook Board (WAOB) and the National Agricultural Statistics Service (NASS). The publication is a shining example of how two major departments within the federal government can mutually cooperate, combining meteorology and agriculture to provide a service that benefits the economic well being of the nation. The *WWCB* highlights weekly meteorological and agricultural developments on a national and international scale. Written summaries of weather and climate conditions affecting agriculture are provided, along with detailed charts and tables of agrometeorological information that are appropriate for the season.

Agrometeorological Service and Success Story

Background

The *Weekly Weather and Crop Bulletin (WWCB)* is deeply rooted in the past. First published in 1872 as the *Weekly Weather Chronicle*, the publication has evolved over the past 129 years into one that provides a vital source of information on weather, climate, and agricultural developments worldwide. A brief history of the *WWCB* can be found in Table 1. Although the major

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2 Agricultural Meteorologist, USDA, WAOB Phone: (202) 720-2397, fax: (202) 690-1805, e-mail: brippey@oce.usda.gov
emphasis of the *WWCB* is on U.S. weather and its impacts on agricultural production, the publication took on an international scope in 1978, with the creation of the Joint Agricultural Weather Facility (JAWF). The JAWF is an operational unit, monitoring worldwide weather conditions and preparing real-time agricultural assessments (Puterbaugh *et al.* 1997; Motha and Heddinghaus 1986). Information on U.S. agriculture is obtained for each state through a network of county extension agents, farmers, and volunteer crop reporters, and summarized at the NASS State Statistical Offices (SSOs). This information is then sent to NASS headquarters in Washington, D.C., and relayed to JAWF. Weather data and information for the United States and international areas are supplied by the National Weather Service (NWS). The international portion contains weather information from over 7,000 global observing stations obtained through the Global Telecommunications Network and managed by the World Meteorological Organization (WMO).

**Regular Features in the *WWCB***

The *WWCB* contains observations of both physical and biological elements that are used to track the cumulative affects of weather on crop growth and development. Although the main emphasis of the *WWCB* is on current growing-season weather conditions and agricultural developments in the United States, summaries and charts for major international areas are included, as well as special articles and charts on episodic weather events. Table 2 lists the descriptive summaries, charts, and tabulations regularly published in the *WWCB*.

**Weekly Text Products**

The *WWCB* begins with a text of U.S. Weather Highlights, a descriptive summary of significant weather events (i.e., droughts, floods, freezes, temperature extremes, snowfall, severe weather, etc.) that affected agriculture during the preceding week (Sunday - Saturday). These highlights provide the framework for the National Agricultural Summary’s section of the bulletin. This national summary contains information on field crop progress and condition that is obtained from detailed weather and crop summaries prepared by the SSOs and transmitted each Monday afternoon to the crop statistician at NASS in Washington, D.C. A shorter version of these individual state reports is published in the “State Summaries of Weather and Agriculture” section of the *WWCB*. The state reports usually discuss crop-weather conditions relating to fieldwork and crop development, pest and disease outbreaks, soil moisture levels, crop progress, and pasture and livestock conditions.
<table>
<thead>
<tr>
<th>Title</th>
<th>Dates</th>
<th>Managing Department</th>
<th>Bureau or Office</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekly Weather</td>
<td>November 1872- April 1881</td>
<td>War</td>
<td>Signal Corps</td>
<td>The Chronicle was a two-page release containing a general weather summary.</td>
</tr>
<tr>
<td>Chronicle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weather Crop</td>
<td>May (?) 1888- June 1891</td>
<td>War</td>
<td>Signal Corps</td>
<td>The Bulletin was Corps issued weekly during the growing season (May to Sept.) and monthly during the other months.</td>
</tr>
<tr>
<td>Bulletin</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weather Crop</td>
<td>July 1891- January 1896</td>
<td>Agriculture</td>
<td>Weather Bureau</td>
<td>The Weather Service of the Signal Corps was transferred from the War Department to the Department of Agriculture (USDA) on Jul. 1, 1891, creating the Weather Bureau.</td>
</tr>
<tr>
<td>Bulletin</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climate and</td>
<td>Feb 1896- August 1904</td>
<td>Agriculture</td>
<td>Weather Bureau</td>
<td>Title Change</td>
</tr>
<tr>
<td>Crop Bulletin</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Weather Crop</td>
<td>August 1904- January 1906</td>
<td>Agriculture</td>
<td>Weather Bureau</td>
<td>Title change.</td>
</tr>
<tr>
<td>Bulletin</td>
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<tr>
<td>Bulletin</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>National Weather</td>
<td>July 1914- December 1921</td>
<td>Agriculture</td>
<td>Weather Bureau</td>
<td>Title change. The Snow and Ice Bulletin, which had been issued</td>
</tr>
<tr>
<td>and Crop Bulletin</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year Range</td>
<td>Frequency</td>
<td>Department</td>
<td>Division</td>
<td>Notes</td>
</tr>
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<td>-------------------------</td>
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<td>----------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>January 1922-December 1923</td>
<td>Weekly</td>
<td>Agriculture Weather Bureau</td>
<td>Weather, Crops, and Markets</td>
<td>The publication was reduced in content and consolidated with Crops and Markets.</td>
</tr>
<tr>
<td>January 1924-June 1940</td>
<td>Weekly</td>
<td>Agriculture Weather Bureau</td>
<td>Weekly Weather and Crop Bulletin</td>
<td>The publications were again separated. The Bulletin had its final name change, acquired much of its present content.</td>
</tr>
<tr>
<td>July 1940-July 1965</td>
<td>Weekly</td>
<td>Commerce Weather Bureau</td>
<td>Weekly Weather and Crop Bulletin</td>
<td>The Weather Bureau was transferred from USDA to the Department of Commerce (DOC) on Jul. 1, 1940.</td>
</tr>
<tr>
<td>July 1965-May 1979</td>
<td>Weekly</td>
<td>Commerce Environment Data Science Administration</td>
<td>Weekly Weather and Crop Bulletin</td>
<td>On Jul. 13, 1965, the Environmental Data Science Administration (ESSA) was created as an agency within DOC. The Environment Data Service (EDS) was established in ESSA. On Oct. 3, 1970, EDS moved into the newly created National Oceanic and Atmospheric Administration.</td>
</tr>
</tbody>
</table>
Administration, and the Weather Bureau became the National Weather Service (NWS). The Climate Analysis Center (CAC) was established within the NWS in May 1979. The JAWF, comprised of NWS/CAC and USDA employees, was created a few months earlier. Under a NWS reorganization in 1995, CAC became the Climate Prediction Center.

<table>
<thead>
<tr>
<th>Weekly Weather and Crop Bulletin</th>
<th>May 1979-present</th>
<th>Commerce Climate Analysis/ Prediction Center</th>
</tr>
</thead>
</table>

The “International Weather and Crop Summary” portion of the WWCB contains information on weather and crop developments in major crop growing areas worldwide. These international summaries provide an early alert of weather conditions that affect yield potential on a regional scale, and ultimately have an impact on United States supplies and prices for agricultural commodities. Areas that are covered in the international section of the WWCB year-round include Europe, Western former USSR, Eastern Asia, Southeast Asia, Australia, and South America. Areas with seasonal coverage include: Northwestern Africa, South Africa, the Middle East, the New Lands region of the former USSR, South Asia, Mexico, and Canada.

**National and International Charts**

High quality weather and climate data serve as the core for the continued success of the WWCB. Most of the various charts (maps) and tables in the WWCB are obtained from the NWS/CPC. For the United States, charts
Table 2. Regular Features in the Weekly Weather and Crop Bulletin

<table>
<thead>
<tr>
<th>Text:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Weather Highlights</td>
<td>w/s</td>
</tr>
<tr>
<td>U.S. Weather and Crop Summary</td>
<td>m</td>
</tr>
<tr>
<td>National Agricultural Summary</td>
<td>w</td>
</tr>
<tr>
<td>Spring Wheat, Oats, and Barley (April - September)</td>
<td>w</td>
</tr>
<tr>
<td>Rice, Sorghum, Corn, Cotton, and Peanuts (April - November)</td>
<td>w</td>
</tr>
<tr>
<td>Soybeans (May - November)</td>
<td>w</td>
</tr>
<tr>
<td>Winter Wheat (September - November and April - August)</td>
<td>w</td>
</tr>
<tr>
<td>Sugar Beets (April - May and September - November)</td>
<td>w</td>
</tr>
<tr>
<td>Sunflowers (May - June and September - November)</td>
<td>w</td>
</tr>
<tr>
<td>U.S. Crop Production Highlights</td>
<td>m</td>
</tr>
<tr>
<td>State Summaries of Weather and Agriculture (April - November)</td>
<td>w</td>
</tr>
<tr>
<td>State Summaries of Weather and Agriculture (December - March)</td>
<td>m</td>
</tr>
<tr>
<td>Water Supply Forecasts for the Western United States (January – March)</td>
<td>m</td>
</tr>
<tr>
<td>International Weather and Crop Summary (major crop areas)</td>
<td>w/m</td>
</tr>
<tr>
<td>Special Articles and Charts</td>
<td>as needed</td>
</tr>
</tbody>
</table>

National Charts:

<table>
<thead>
<tr>
<th>Text:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation</td>
<td>w/m/s</td>
</tr>
<tr>
<td>Percent of Normal Precipitation</td>
<td>m/s</td>
</tr>
<tr>
<td>Average Temperature</td>
<td>m/s</td>
</tr>
<tr>
<td>Departure of Average Temperature from Normal</td>
<td>w/m/s</td>
</tr>
<tr>
<td>Extreme Minimum Temperature (September - April)</td>
<td>w</td>
</tr>
<tr>
<td>Extreme Maximum Temperature (April - September)</td>
<td>w</td>
</tr>
<tr>
<td>Snow Depth (December - March)</td>
<td>w</td>
</tr>
</tbody>
</table>
### Regular Features in the Weekly Weather and Crop Bulletin

(w = weekly, m = monthly, s = seasonal)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Soil Temperature, 4-Inch Depth, Bare Soil (March - June)</td>
<td>w</td>
</tr>
<tr>
<td>Pan Evaporation (May - September)</td>
<td>w</td>
</tr>
<tr>
<td>Growing Degree Days (May - October)</td>
<td>w</td>
</tr>
<tr>
<td>Crop Moisture Index (April - October)</td>
<td>w</td>
</tr>
<tr>
<td>Palmer Drought Severity Index (April - October)</td>
<td>w</td>
</tr>
<tr>
<td>Additional Precipitation Needed to End Drought (April - October)</td>
<td>w</td>
</tr>
<tr>
<td>Drought Monitor</td>
<td>w</td>
</tr>
</tbody>
</table>

**International Charts (major crop areas):**

<table>
<thead>
<tr>
<th>Chart</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation</td>
<td>w/m</td>
</tr>
<tr>
<td>Percent of Normal Precipitation</td>
<td>m</td>
</tr>
<tr>
<td>Average Temperature</td>
<td>m</td>
</tr>
<tr>
<td>Departure of Average Temperature from Normal</td>
<td>m</td>
</tr>
</tbody>
</table>

**National Tabulations:**

<table>
<thead>
<tr>
<th>Tabulation</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather Data for Selected Cities</td>
<td>w</td>
</tr>
<tr>
<td>Weather Data for Selected Locations in the Delta and Bootheel</td>
<td>w</td>
</tr>
<tr>
<td>Precipitation and Temperature</td>
<td>m/s</td>
</tr>
<tr>
<td>Crop Progress: Planting, Development, Harvesting (April-November)</td>
<td>w</td>
</tr>
<tr>
<td>Crop Condition (April - November)</td>
<td>w</td>
</tr>
</tbody>
</table>

**International Tabulation:**

<table>
<thead>
<tr>
<th>Tabulation</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation and Temperature</td>
<td>m</td>
</tr>
</tbody>
</table>

Containing analyzed precipitation and temperature data are published each week, while charts of precipitation, percent of normal precipitation, average temperature, and departure of average temperature from normal are published for each month and season (December - February, March - May, June - August, and September - November). For international areas, charts of precipitation are published each week, while charts of precipitation, percent of normal precipitation, average temperature, and departure of average temperature are published monthly. The weekly charts provide information on weather conditions.
conditions currently affecting crop development. The monthly and seasonal charts provide an indicator of longer-term developments.

The *WWCB* includes agricultural meteorological data and derived parameters, including soil temperature, pan evaporation, growing degree day (GDD) accumulations for corn, Western U.S. snow pack information, the Palmer Drought Severity Index, the Crop Moisture Index, and the Drought Monitor. A map of weekly average soil temperatures at a depth of 4 inches is published during the spring (March - June), providing guidance to farmers on when soil temperatures have reached high enough levels to begin planting field crops such as corn, soybeans, cotton, and sorghum. An U.S. map containing daily pan evaporation measurements averaged over the week from a standardized NWS Class “A” pan device is published for available locations from May - September. Pan evaporation measurements are used to estimate the amount of evaporation from lakes and reservoirs, to compute potential evapotranspiration and crop-water needs, and for irrigation scheduling.

Charts containing cumulative weekly GDDs for U.S. corn are featured during the growing season. Departure from normal GDD maps are also calculated in order to monitor the seasonal progress of the corn crop. The GDD index for corn was first introduced into the bulletin in 1969, as a more accurate measure of corn growth and maturity, instead of the accumulation of a certain number of calendar days. A description of the GDD concept for corn is given by Felch (1972) and Ramirez and Bauer (1974).

Drought monitoring and assessment is of paramount importance when determining the impact of weather on agricultural production. Furthermore, the severity and duration of drought determines the degree to which agricultural production is impacted. Since it takes weeks or months for drought conditions to develop, drought severity not only depends on current conditions, but antecedent weather as well. The Palmer Drought Severity Index (PDSI) was introduced into the *WWCB* in 1961 by Wayne Palmer, as an index of meteorological drought (Palmer, 1965). Today, the PDSI remains a vital portion of the publication, serving as a useful tool in U.S. drought monitoring. Weekly maps of drought severity are generated by computing the PDSI for each of the 344 climate divisions in the continental United States. The PDSI is calculated from long-term records of precipitation and temperature, the available water content of the soil, and the normal climate of an area. The PDSI provides spatial and temporal representations of historical droughts and indicates the availability of water supplies for irrigation, reservoir and pond
levels, range conditions, and potential for wildfires.

While the PDSI evaluates the scope of prolonged periods of abnormally dry weather, it does not evaluate short-term moisture conditions that are needed for agriculture. A period of rain for a couple of weeks could be very beneficial for crops, but would not be nearly enough to replenish depleted soil moisture reserves or restore low reservoirs to a near-normal level. In order to evaluate the short-term moisture conditions for agriculture during the growing season, Palmer (1968) developed a second index called the Crop Moisture Index (CMI). The CMI was first published in the WWCB in the April 15, 1968, issue. Each week, maps containing CMI values for each climate division in the continental United States as well as analyzed values of the CMI are published. The CMI index responds rapidly to changes in temperature and moisture conditions during the growing season. As a result, the CMI is not a good long-term drought-monitoring tool. Furthermore, the CMI is not applicable to germinating and shallow-rooted crops, or for cool season crops when temperatures are averaging below 55 degrees F.

In 1999, representatives from USDA, DOC, and the National Drought Mitigation Center met to discuss the need for a new national drought product. These discussions led to the creation of the U.S. Drought Monitor, which is assembled by a rotating team of nine lead authors, who look at a myriad drought indices, including the PDSI and CMI, to produce a national drought product that incorporates agricultural, hydrological, and wildfire concerns. The Drought Monitor, which is updated weekly, has appeared in the WWCB since March 2000.

**National Tabulations**

Each week during the growing season (April - November), tables containing state and national information on crop progress and condition are published in the WWCB. These tables are compiled at the NASS headquarters in Washington, D.C. and are based on information that is received each week from the SSOs. The crop progress tables contain information on the percentage of crops that were either planted or harvested during the week ending Sunday, and the percentage of crops in various phenological stages, such as silking of corn or heading of wheat. Crop progress tables are provided for each of the major field crops, including winter wheat, spring wheat, corn, sorghum, soybeans, barley, oats, peanuts, sunflowers, sugar beets, cotton, and rice. Each table contains information for only those states where a majority of the crop is
grown. Information on crop progress from the previous week, the previous year, and the 5-year average is included in the table. Each table contains a summary of national crop progress that is weighted by state, and based on either the planted (for planting progress table) or harvested (for harvest progress table) acres for the previous year. Statistics on crop and pasture condition are provided by crop reporters that are instructed to “report the conditions of the crop now, as compared with the normal growth and vitality you would expect at this time, if there had been no damage from unfavorable weather, insects, pests, etc.”. The normal condition of the crop may vary from one location to another due to soil and climate differences, crop varieties, and cultural practices. There are five categories of condition: very poor, poor, fair, good, and excellent. Each table contains a summary of national crop conditions that are weighted by state, and based on planted acres for the previous year.

Each week, a data table containing precipitation (in inches) and temperature (in degrees Fahrenheit) for selected cities in each of the 50 U.S. states is published in the WWCB for the period ending on Saturday. These data are provided by the NWS/CPC. This “Selected Cities” table provides a closer look at weather conditions that are locally affecting agriculture. In addition to temperature and precipitation data, the table contains information on relative humidity and episodic weather events. Around the beginning of each month, tables containing precipitation and temperature data for the previous month are published for selected cities in both the United States and some international locations. For the United States, the data are in English units and consist of calculations of average monthly temperature, departure from normal monthly average temperature, total monthly precipitation, and departure of monthly precipitation from normal. Data for selected cities in international countries are in metric units. The monthly temperature information (in degrees Celsius) consists of calculations of average maximum temperature, average minimum temperature, extreme maximum and minimum temperatures, monthly average temperature, and the departure from normal monthly average temperature. Precipitation data (in millimeters) includes the total observed monthly precipitation and its departure from normal (based on 1961-1990 data).

While the information contained in the “Selected Cities” table is highly useful, these sites do not provide satisfactory coverage for some agricultural areas. Such areas are found in the Mississippi Delta and the Missouri Bootheel region, where agricultural weather data collection sites exist, but are beyond
the responsibility of the current NWS basic reporting network. In order to establish a linkage between these two networks, a table containing “Weather Data for Selected Locations in the Delta” was added to the WWCB in February 1999. Additional data for the Missouri Bootheel region was added in August 2000. Data contained in the table is provided weekly by the Mississippi State Delta Research and Extension Center, the Southern Regional Climate Center, and the University of Missouri. The table contains weather data similar to that found in the NWS “Selected Cities” table, except values of soil temperature (at the 4-inch depth in degrees F) are substituted for the relative humidity values.

**Economic Benefits**

Meteorological conditions influence important farming operations such as planting and harvesting, and greatly influence yield at critical stages of crop development. As a result, the statistics contained in the WWCB keep crop and livestock producers, farm organizations, agribusinesses, state and national farm policy-makers, government agencies, and foreign buyers of agricultural products apprized of worldwide weather-related developments and their effects on crops and livestock. The WWCB provides critical information to decision-makers formulating crop production forecasts and trade policy. Furthermore, tracking weather and crop developments in countries that are either major exporters or importers of agricultural commodities keeps the agricultural sector informed on potential competitors. The bulletin also provides timely weather and crop information between the monthly *Crop Production* and *World Supply and Demand Estimate* reports, issued by NASS and WAOB, respectively.

Crop and weather reports are especially important in farming areas. A wet planting season may prompt farmers to switch to another crop. A poor grain harvest may affect livestock feeding patterns. A regional drought can boost planted acres elsewhere to offset the expected production decline, and government policymakers may adjust farm programs to accommodate changing conditions. Thus, agricultural statistics contained in the WWCB keep farmers, consultants, public agencies, and private organizations aware of changing crop developments within each state and across the nation. Another important user of agricultural statistics is the analyst. The analyst uses statistics on crop progress and crop condition to make crop-yield projections, and to determine the local and national economic impacts of changes in crop developments, including their potential impacts on U.S. agricultural commodity prices.
Other Important Issues

The main emphasis of the WWCB is on macro-scale (regional) applications of agricultural meteorology, as opposed to micro-scale field applications. While the WWCB was originally designed to maintain a current awareness of weather and crop conditions both nationally and internationally, the long history of the publication makes it an excellent climatological record. This extensive history provides a reference source that is rich in climate and agricultural information, which is essential for episodic-events monitoring and analog-year comparisons. The value of information provided to data users depends on the speed of delivery. Although the WWCB is available by subscription, quicker access to the information can be obtained through the JAWF Web site at http://www.usda.gov/agency/oce/waob/jawf/wwcb.html. Both NASS and WAOB maintain an archive of reports and databases on the Internet at http://usda.mannlib.cornell.edu.

Conclusion

For over a century, the Weekly Weather and Crop Bulletin has provided a current and reliable source of information on meteorological and agricultural developments within the United States. The expansion of coverage into international areas in the 1970's, along with the creation of the Joint Agricultural Weather Facility in 1978, made the WWCB an invaluable source of information on global weather and agriculture, further increasing the economic benefit of the publication.

References


Agrometeorological Bulletins – The Case of Canada

Abdoulaye Harou

Introduction

In Canada, agrometeorological services are provided by two federal departments: the Department of Environment (through the Meteorological Service of Canada (MSC) and the Department of Agriculture and Agri-food (AAFC). The MSC is responsible for the provision of meteorological information applicable to the agricultural sector. AAFC conducts agricultural research and development (R&D) and provides information on plant diseases, pest infestations, pasture and dugout using inputs from various sources, including from Environment Canada.

The Department of Environment, commonly known as Environment Canada (EC) is organized into five more or less independent regions that provide various agrometeorological information and products to respond to their clients’ needs. Consultation services and special products are provided on a cost recovery basis.

The private sector is slowly gearing up to provide value-added products for the agricultural sector. Some organizations have their own network and provide specialized information to their clients. In all cases EC (MSC) works in partnerships with the private sector facilitating its development.

Meteorological Service of Canada - MSC

Agrometeorological Bulletins and Contents

There are no standard agrometeorological bulletins issued by the MSC. Some regions produce bulletins while others do not. Agricultural information is usually included in the body of the public forecast bulletin during the growing season. Information on relative humidity, drying index and precipitation amounts are usually included for free for the first two days.

1 Senior Sector Development Specialist Services, Clients and Partners Directorate, Meteorological Service of Canada, 10 Wellington Street, 4th Floor, North Tower, Les Terrasses de la Chaudière, HULL, QUEBEC K1A OH3, Canada
Tel.: +819 997 3845, Fax: +819 994 8864, E-mail: abdoulaye.harou@ec.gc.ca
of the forecast. Frost warnings and special weather statements such as for dry weather and heavy precipitation are provided free of charge.

The Regions have commercial services for consultation and specialized user designed products. Information such as 5 day forecast, amounts of precipitation, growing degree-days and corn heat units are usually charged to clients. To illustrate please see figure 1, a regular farm forecast issued by Ontario Region and figure 2, a specialized forecast issued in co-operation with the provincial department of Agriculture of Prince Edward Island to assist potato growers with decision-making on the spraying of pesticides.

**Figure 1. Agrometeorological Bulletin issued by Ontario Region, August 2001**

**Middlesex-Oxford**
Today..Sunny With Cloudy Periods.
Winds Southwest 30 km/h.
High Near 34. Minimum Humidity 50 Percent.
Drying Index Very High at 79.
Tonight..30 Percent Chance of Showers. Risk of a Thunderstorm Overnight.
Winds Southwest 20 km/h.
Low Near 22. Maximum Humidity 95 Percent.
Friday..30 Percent Chance of Showers. Risk of a Thunderstorm in the Morning.
Winds Northwest 20 km/h.
High Near 27. Minimum Humidity 50 Percent.
Drying Index High At 54.

**Southwestern Ontario**
Latest Observations on Aug 9, 2001 Edt

<table>
<thead>
<tr>
<th>Station</th>
<th>Time</th>
<th>Weather</th>
<th>Tmp</th>
<th>Dew</th>
<th>Wind (Km/H)</th>
<th>Rh (%)</th>
<th>Pres (Kpa)</th>
<th>Wind Chill or Lcl</th>
<th>Humidex (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>London</td>
<td>0900</td>
<td>Sunny</td>
<td>29</td>
<td>20</td>
<td>W 17</td>
<td>58</td>
<td>101.30</td>
<td></td>
<td>37 (Hum)</td>
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</table>

Climate Data for Wednesday August 08.

<table>
<thead>
<tr>
<th>Station</th>
<th>High (C)</th>
<th>Low (C)</th>
<th>Mean (C)</th>
<th>Precip (mm)</th>
<th>Chu</th>
<th>Gdd (Base 5 C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>London</td>
<td>37.0</td>
<td>18.5</td>
<td>27.8</td>
<td>Nil</td>
<td>27</td>
<td>23</td>
</tr>
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</table>

Seasonal Accumulations For London

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Period</th>
<th>Year</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growing Degree Day (Base 5; Celcius)</td>
<td>Apr 1 To Aug 7</td>
<td>2001</td>
<td>1398</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2000</td>
<td>1310</td>
</tr>
<tr>
<td>Corn Heat Unit</td>
<td>Apr 23 To Aug 7</td>
<td>2001</td>
<td>2151</td>
</tr>
<tr>
<td></td>
<td>May 6 To Aug 7</td>
<td>2000</td>
<td>1970</td>
</tr>
<tr>
<td>Precipitation</td>
<td>Apr 1 To Aug 7</td>
<td>2001</td>
<td>169 Mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2000</td>
<td>564 Mm</td>
</tr>
</tbody>
</table>

The Accumulation of Corn Heat Units (CHUs) Starts on the Third Day of Three Consecutive Days of Mean Temperatures of 12.8 °C or Greater

Data Sources

Data used for public forecast bulletins are also used to derive agricultural information. These data come from the regular MSC surface observing network, model output and form the basic database used in the forecast production system. Where available, data from the farming communities, other levels of government and the private sector are also used in deriving agrometeorological information.

Each region is responsible for observing sites in its area of responsibility and collates the observations before sending them to the Canadian Meteorological Centre (CMC) for analysis and use in the atmospheric models. Analyzed data are sent back to the regions for their use in forecast production. (See figure 3)
Figure 2: Special bulletin for Potato Growers – Atlantic Region
Target Audience and Dissemination Methods

The main users of MSC agrometeorological products are farmers, extension agencies, provincial Ministries of Agriculture, agricultural research facilities, agricultural engineers, and commodity experts. Chemical companies also use MSC information (mainly climate information) for the planning of production and dispatch of their products. Various means are used to distribute the information: Internet, FTP, media wire, ATADs (Automatic Telephone Answering Devices), weather radio and e-mail.

Feedback from Users and Economic Values of Agrometeorological Bulletins

Although there is no organized way of obtaining feedback from users, most of the products are available on the Internet and effort is being made to allow users to make comments via this medium. As to the economic value of agrometeorological bulletins, very little has been done but some global studies on the impacts of MSC environmental predictions (e.g.
temperature, winds, precipitation, humidity) on agriculture were conducted. The following is a summary of findings:

“Day-to-day weather associated with temperature, precipitation, and winds has the potential to disrupt decision-making, thereby adding to the "cost of doing business". Thus accurate weather and climate information can make an important contribution in ensuring the economic efficiency and competitiveness of weather sensitive industries in Canada (Agriculture, public and recreation, construction, forestry, utilities, transport and fisheries). The benefit/cost ratio of short-term weather information for weather sensitive Canadian industries has been estimated (to be in excess of 10 to 1. “ (The DPA Group Inc, 1985).

Findings from other studies include:

- A University of Guelph Masters thesis in 1996 estimated that the value of the EC precipitation forecast information to hay and winter wheat farmers in Southern Ontario to be in the range of over $50 to $85/ha. Gross values for hay farmers were estimated at over $56M per year in 1994 and 1995.
- Improved use of current forecasts has been shown to have economic and environmental benefits through increased efficiency of fertilizer applications. A 1997 study suggests that 15% of all fertilizer used is wasted when washed away by heavy rains, with $22M annual potential saving with more effective use of precipitation forecasts. Environmental benefits of better-forecast utilization include reduced nitrogen pollution in the soil and water.
- Cost of recent prairie droughts have been less than expected due to improved climate forecasting, which permits drought-prevention strategies such as piling snow to enable more water to enter the soil.
- A 1992 study on the use of weather information in spraying fungicide on tomato crops in southern Ontario determined that timing the spraying based on weather information (temperature and dew point) resulted in $500K savings in a 10,000 hectare. Benefits include labor and cost savings for growers; reduced likelihood that target disease organisms will become chemical-resistant due to over-use; and decreased chemical load on the environment.

Note: Values quoted in Canadian dollars
Agriculture and Agri-Food Canada (AAFC)

Agriculture and Agri-Food Canada provides information, research and technology, policies and programs to achieve security of the food system, health of the environment and innovation for growth.

In addition to regular weather information provided by Environment Canada, a branch of AAFC, the Prairie Farm Rehabilitation Administration (PFRA) provides special agrometeorological support to the Canadian Prairie which represents about 80% of Canadian farm lands. Dugout, drought condition maps and precipitation and temperature anomaly maps are made available on the Internet. Data from Environment Canada, the Timely Climate Monitoring Network (TCMN) and other agencies are used to derived these maps. Examples of these maps are provided in figure 4. TCMN data are climate data gathered on a timely basis (every day or on a weekly basis) by volunteers on a contractual basis ($1500/year) for the period February to October of each year. Environment Canada provides training. TCMN data are quality assured by Environment Canada and managed by a private company, Agrometeorological Centre of Excellence (ACE) which sells the quality assured data to subscribers such as the PFRA.

AAFC, through its research directorate and in coordination with Environment Canada, issue bulletins on Diamond back moth infestation potential for all Canadian farmlands. Environment Canada trajectory models are used to infer potential area for infestation.

Shortcomings and Limitations for the Preparation of Agrometeorological Bulletins

The lack of resources to develop and implement standard agrometeorological bulletins tailored to user needs is a major issue the MSC is addressing. The present situation of adding some agrometeorological information to public bulletins does not usefully target the agricultural sector. The advent of Internet provides MSC and AAFC with an excellent dissemination vehicle but this technology is not yet widely used by farmers.
Suggestions for Improved Agrometeorological Bulletins

Figure 4: Examples of AAFC (PFRA) Products
Suggestions for Improved Agrometeorological Bulletins

In order for the agrometeorological bulletins to be useful and effective it is suggested that separate, stand-alone agrometeorological bulletins be issued with the following content:

- A warning section: (Frost, Heavy rain, Hail)
- Basic contents - Forecasts (up to 48h): Sky conditions, Temperature, winds, precipitation amount, Relative Humidity, drying index.
- Additional information:
  - Growing degree days to date versus last year
  - Total precipitation amount to date versus last year amount for the same period
  - Corn Heat Unit (CHU)
  - Any other relevant information
- Outlook section: Day 3, 4 and 5 with the following information:
  Sky condition, max and min temperatures and average wind speed.

It is also suggested that MSC commercial services be limited to consultation services only. Data packaging and specialized products should be left to the private sector, thus contributing to its development

References


Abstract: The major requirement of this study is to estimate the current value of short-range weather forecasts to the entire Canadian economy. For this study, a pragmatic, empirical and descriptive approach was adopted. The study describes how, when and why weather information is used by individual companies and estimates the economic value of observations and short-range forecasts to each company. These empirical estimates have been extrapolated to each industry sub-sector and aggregated to provide an estimate of the economic value of short-range weather forecasts to the Canadian economy as a whole.

Interviews were held with users of weather information from each of the major economic sectors and climate regions of Canada. The application of weather information was examined for each major weather sensitive activity and estimates obtained of the costs and value of taking modified
actions based on short-range weather forecasts. The calculated net value for each user interviewed is the net value allowing for all of the costs involved, including the costs of taking action when forecasts prove to be either correct or incorrect and the costs incurred by lost value when a non-forecast threat event occurred.

Net estimates of the value of weather information were related to the total value of output for each user interviewed in order to obtain a coefficient showing the value of short-term forecasts as a proportion of total output. The individual estimates most often provided a narrow range of value coefficients, for example from 4% to 11% of total output. Considering the frequency of consistent responses, a conservative (average) estimate of the value coefficient for each economic sub-sector was then made and applied to the entire sub-sector.

**Conclusions:** The estimates of the approximate first order (direct) economic value of short-term weather forecasts are as follows:

<table>
<thead>
<tr>
<th>Sector</th>
<th>$ Millions</th>
</tr>
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<tbody>
<tr>
<td>Agriculture</td>
<td>685-785</td>
</tr>
<tr>
<td>Public and Recreation</td>
<td>300-400</td>
</tr>
<tr>
<td>Construction</td>
<td>100-200</td>
</tr>
<tr>
<td>Forestry</td>
<td>90-100</td>
</tr>
<tr>
<td>Utilities</td>
<td>80- 85</td>
</tr>
<tr>
<td>Transport</td>
<td>55- 60</td>
</tr>
<tr>
<td>Fisheries</td>
<td>20- 50</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$1330-1680m</strong></td>
</tr>
</tbody>
</table>

The budget for the MSC Weather Services program sub-activity was approximately $124 million in 1983/84. Thus, the benefit/cost ratio of short-term weather information would be in excess of 10 to 1. Considering that the quantified value of short-term forecasts calculated in this study underestimate the total value involved (since non-quantifiable benefits such as safety were left out and other important industries such as defense, which benefit from weather information and are included in the budget, were not included), the actual benefit/cost ratio would be much higher than 10 to 1.
Abstract: A framework for estimating the value of weather forecast information in agricultural production was developed. Certainty equivalent profit models were developed to estimate weather forecast information value for dry hay and winter wheat harvest using 1994 and 1995 forecast data from Windsor, London and Waterloo weather office. Values for Environment Canada, improved and perfect forecast methods were estimated. Impact of producer risk preference on forecast value was investigated. Average value of the Environment Canada, improved and perfect forecast was $53.74/ha/yr, $65.79/ha/yr and $90.46/ha/yr respectively for dry hay harvest. Risk preference had no impact on the value of forecast information for dry hay production. Average value of the Environment Canada forecast for winter wheat harvest ranged from $84.72/ha/yr to $161.08/ha/yr for Arrow-Pratt coefficient values of 0.01 to 0.00001 respectively. Perfect forecast average value ranged from $161.08/ha/yr to $174.03/ha/yr for Arrow-Pratt coefficient values of 0.00001 to 0.01 respectively.

http://www.weatheroffice.ec.gc.ca: weather website of Environment Canada

http://www.agr.ca: Agriculture and Agrifood Canada website
### Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC</td>
<td>Environment Canada (Department of Environment)</td>
</tr>
<tr>
<td>MSC</td>
<td>Meteorological Service of Canada</td>
</tr>
<tr>
<td>CMC</td>
<td>Canadian Meteorological Centre</td>
</tr>
<tr>
<td>WAN</td>
<td>Wide Area Network</td>
</tr>
<tr>
<td>GTS</td>
<td>Global Telecommunication System</td>
</tr>
<tr>
<td>SATNET</td>
<td>SATellite NETwork</td>
</tr>
<tr>
<td>AAFC</td>
<td>Agriculture and Agri-Food Canada (Federal Department of Agriculture)</td>
</tr>
<tr>
<td>PFRA</td>
<td>Prairie Farm Rehabilitation Administration</td>
</tr>
<tr>
<td>FTP</td>
<td>File Transfer Protocol</td>
</tr>
<tr>
<td>WMO</td>
<td>World Meteorological Organization</td>
</tr>
<tr>
<td>ATAD</td>
<td>Automatic Telephone Answering Device</td>
</tr>
<tr>
<td>TCMN</td>
<td>Timely Climate Monitoring Network</td>
</tr>
<tr>
<td>ACE</td>
<td>Agrometeorological Centre of Excellence</td>
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</tbody>
</table>
Presentation of Drought Information in Agrometeorological Bulletins

M.V.K. Sivakumar

Abstract

Drought is an insidious natural hazard with serious implications for the economic well being of the farming community. The overall goal of providing drought information in agrometeorological bulletins is to enable and persuade people and organisations to take action to maximise the probability of successful production in agriculture, forestry and fisheries and/or minimise the potential damage to established crops, forests and other assets. A number of components can be considered essential in the presentation of a comprehensive picture of droughts in a given region. These include information on timing of droughts, drought intensity, drought duration, spatial extent of a specific drought episode and analysis of the risk of the phenomenon and its likely effect on agricultural production. Information on drought intensity can be presented in a number of different ways including the use of drought indices such as the Deciles, the Palmer Drought Severity Index, the Crop Moisture Index and the Standardized Precipitation Index. A brief description of each of these indices is presented. To provide effective drought information, there should be improved collaboration among scientists and managers to enhance the effectiveness of observation networks, drought monitoring, prediction, information delivery, and applied research. Such a collaboration could help foster public understanding of and preparedness for drought.

Introduction

Of all the extreme meteorological events affecting agriculture and forestry, drought is perhaps the most important hazard with serious implications for the economic well being of the farming community. Drought disrupts cropping programs, reduces breeding stock, and threatens

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1 Chief, Agricultural Meteorology Division, World Climate Programme Department, World Meteorological Organization, 7bis Avenue de la Paix, Case postale 2300, Ch-1211 GENEVA 2, Switzerland
Tel.: +41 22 730 8380, Fax: +41 22 730 8420, Email: msivakumar@wmo.int
permanent erosion of the capital and resource base of farming enterprises. Continuous droughts stretching over several years in different parts of the world in the past significantly affected productivity and national economies. In addition, the risk of serious environmental damage, particularly through vegetation loss and soil erosion, as has happened in the Sahel during the 70s, has long term implications for the sustainability of agriculture. Bushfires and dust storms often increase during the dry period.

Since there are a large number of direct and indirect economic, environmental and social impacts of droughts, there is a clear necessity to convey information on droughts in a timely and useful manner in the agrometeorological bulletins that are routinely issued by the National Meteorological and Hydrological Services (NMHSs). Some of the key issues in the presentation of drought information and the different methods and tools available to prepare such information are presented here.

**Drought - the concept**

In any discussion on the preparation and presentation of information concerning a natural hazard, it is necessary to understand first the basic concepts underlying the hazard under discussion. Hence, a brief discussion of the concept of droughts is presented here.

Drought is considered by many to be the most complex but least understood of all natural hazards, affecting more people than any other hazard (Hagman, 1984). However, there remains much confusion within the scientific and policy communities about its characteristics. It is precisely this confusion that explains, to some extent, the lack of progress in drought preparedness in most parts of the world.

Drought is an insidious hazard of nature. Although it has scores of definitions, it originates from a deficiency of precipitation over an extended period of time, usually a season or more. This deficiency results in a water shortage for some activity, group, or environmental sector. Drought should be considered relative to some long-term average condition of balance between precipitation and evapotranspiration in a particular area, a condition often perceived as "normal".

Drought is a slow-onset, creeping natural hazard that is a normal part of climate for virtually all regions of the world; it results in serious economic, social, and environmental impacts (Wilhite, 2000). Drought onset and end are often difficult to determine, as is its severity. Drought severity is dependent not only on the duration, intensity and spatial extent of
a specific drought episode, but also on the demands made by human activities and vegetation on a specific region’s water supply.

The impacts of drought are largely nonstructural and spread over a larger geographical area than are damages from other natural hazards. The nonstructural characteristic of drought impacts has certainly hindered the development of accurate, reliable, and timely estimates of severity and, ultimately, the formulation of drought preparedness plans by most governments.

**Goals and objectives for presentation of drought information**

The overall goal of providing drought information in agrometeorological bulletins is to enable and persuade people and organisations to take action to maximise the probability of successful production in agriculture, forestry and fisheries and/or minimise the potential damage to established crops, forests and other assets.

Accomplishment of this goal requires not only precipitation data on a temporal and spatial scale suitable for effective interpretation of the nature and extent of droughts, but also information on the stage of crop/forest growth and the degree of sensitivity of crops/forests to droughts that are currently occurring and to droughts that may prolong into the future. Hence it is important that NMHSs establish a strong liaison with the agricultural research and extension agencies in the country to provide comprehensive information that could be useful to the user community in their applications.

The ultimate objective of presenting drought information in the agrometeorological bulletins is to enable governments and organizations to develop a pro-active response to droughts. The traditional approach to drought management has been reactive, relying largely on crisis management. This approach has been ineffective because response is untimely, poorly coordinated, and poorly targeted to drought stricken groups or areas. In addition, drought response is post-impact and relief tends to reinforce existing resource management methods. It is precisely these existing resource management practices that have often increased societal vulnerability to drought. The provision of drought relief only serves to reinforce the status quo in terms of resource management. Many governments and others now understand the fallacy of crisis management and are striving to learn how to employ proper risk management techniques to reduce societal vulnerability to drought and, therefore, lessen the impacts associated with future drought events.
As vulnerability to drought has increased globally, greater attention has been directed to reducing risks associated with its occurrence through the introduction of planning to improve operational capabilities (i.e., climate and water supply monitoring, building institutional capacity) and mitigation measures that are aimed at reducing drought impacts. In the past, when a natural hazard event and resultant disaster has occurred, governments have followed with impact assessment, response, recovery, and reconstruction activities to return the region or locality to a pre-disaster state. Little attention has been given to preparedness, mitigation, and prediction/early warning actions (i.e., risk management) that could reduce future impacts and lessen the need for government intervention in the future. It is precisely these actions which are targeted by comprehensive drought information presented in agrometeorological bulletins.

Components of drought information

There are a number of components that can be considered essential in the presentation of a comprehensive picture of droughts in a given region. These include information on:

- Timing of droughts
- Drought intensity
- Drought duration
- Spatial extent of a specific drought episode
- Analysis of the risk of the phenomenon and its likely effect on agricultural production.

A short description of each of these components is presented below.

Timing of droughts

As mentioned earlier, it is difficult to define the onset of droughts as it is a creeping phenomenon. However, some attempts have been made to define the onset of droughts. According to the British Meteorological Office (Crowe 1971), an absolute drought begins when at least 15 consecutive days have gone by with less than 0.25 mm of rainfall on all days and a “dry spell” is a period of at least 15 consecutive days none of which has received 1 mm or more. Other definitions of the onset of droughts have been developed using drought indices, which are described in the next section.

In addition to precipitation data, it is important to take into account the soil type, soil water holding capacity, and the specific cropping situation to which the information is to be applied.
**Drought intensity**

There are a number of ways to provide information on the drought intensity:

**a) Presentation of current rainfall data along with long-term average rainfall**

This is the most simple means of presenting information on drought intensity and is used frequently in many agrometeorological bulletins around the world. Information is presented in either a tabular form or a graphic format. Presentation of monthly totals of rainfall along with long-term average rainfall at representative locations is quite common to describe the drought intensity. While the information presented provides a bird's eye view of drought intensity, it is difficult to understand the spatial nature of droughts from the information provided. Also, when monthly rainfall totals are used, it is difficult to clearly discern the exact nature of the dry spell within the month.

**b) Presentation of current rainfall as a percentage of long-term average rainfall**

The percent of normal precipitation is one of the simplest measurements of rainfall for a location and is calculated by dividing actual precipitation by normal precipitation -- typically considered to be a 30-year mean -- and multiplying by 100%. Depending upon the need, it can be computed for either a single month or number of months or a whole year. Ideally, one should be able to compute this for the cropping season (taking into account the dates of sowing and harvesting of crops), but the computation of long-term normal in this case could be a bit cumbersome, especially if there are missing data of daily rainfall.

As Hayes (1999) explained, one of the disadvantages of using the percent of normal precipitation is that the mean, or average, precipitation is often not the same as the median precipitation, which is the value exceeded by 50% of the precipitation occurrences in a long-term climate record. The reason for this is that precipitation on monthly or seasonal scales does not have a normal distribution. Use of the percent of normal comparison implies a normal distribution where the mean and median are considered to be the same.
c) Using different thresholds of current rainfall as a percentage of long-term average rainfall

Based on experience with previous droughts and the impacts caused by rainfall deficiency exceeding certain thresholds, some countries such as India use different thresholds of current rainfall as a percentage of long-term average rainfall to delineate the intensity of drought in different parts of the country. If the current rainfall in a given meteorological subdivision exceeds the Long-Period Average (LPA) by 20%, the subdivision is deemed to have received excess rainfall. Threshold values of +19 to -19% of LPA are considered as normal while current rainfall falling within -20 to -59% of LPA would categorize a subdivision as "deficient". When the threshold value falls below -60% of LPA, rainfall in a subdivision is considered "scanty".

For example, in 1999, rainfall for India as a whole was 95.5% of the Long Period Average (LPA) rainfall, but seven out of the 35 meteorological subdivisions in the country received deficient rainfall i.e., 20% to 59% below the normal rainfall. In other words, some 8.1% of the country was affected by droughts in 1999. Rainfall in 2000 was 92% of the LPA and again seven meteorological subdivisions received deficient rainfall.

d) Computing drought indices and using the indices in a comparative mode to depict drought intensities

Drought indices have been developed from known values of selected parameters to present a quantitative description of droughts. Following are some of the most commonly used drought indices around the world.

- The decile approach (Coughlan, 1987) used in Australia
- Palmer Drought Severity Index (Palmer, 1965) used in the United States
- Crop Moisture Index (Palmer, 1968) used in the United States
- The Standardized Precipitation Index (McKee et al. 1993) which is now gaining increasing popularity and is being used in several countries

The decile approach: The decile approach (Gibbs and Maher, 1967) is a non parametric method to describe the distribution of rainfall totals. Annual rainfall totals for a long series of years are arranged in an ascending
order (from lowest to highest) and are then split into 10 equal groups. The first group would be in decile range one, the second group in decile range two etc., In other words, deciles are used to give an element a ranking. It is possible in a decile rainfall map to show whether the rainfall is above average, average or below average for the time period and for the area chosen.

The drought maps highlight areas considered to be suffering from a serious or severe rainfall deficiency. In Australia, these classes are assigned by first examining rainfall periods of three months or more for selected places to see whether they lie below the 10th percentile (lowest 10% of records). The terms serious and severe are defined by:

- Serious rainfall deficiency:- rainfall lies above the lowest five per cent of recorded rainfall but below the lowest ten per cent (decile 1 value) for the period in question,

- Severe rainfall deficiency:- rainfall is among the lowest five per cent for the period in question.

Once an area has been classified, it remains in the severe/serious deficiency category of the review until the deficiency is removed. Rainfall deficiency is considered removed if it exceeds the third decile and is less than the seventh decile.

**Palmer Drought Severity Index:** The Palmer Drought Severity Index (PDSI), based on the concept of a hydrological accounting system, relates drought severity to the accumulated weighted differences between actual precipitation and the precipitation requirement of evapotranspiration (Palmer 1965). The PDSI is calculated based on precipitation and temperature data, as well as the available soil water content. From the inputs, all the basic terms of the water balance equation can be determined, including evapotranspiration, soil recharge, runoff, and moisture loss from the surface layer. The objective of this index was to provide measurements of moisture conditions that were standardized so that comparisons using the index could be made between locations and between months (Palmer 1965). Drought conditions indicated by different PDSI values are as follows:

<table>
<thead>
<tr>
<th>PDSI</th>
<th>Indicated drought condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0 or more</td>
<td>extremely wet</td>
</tr>
<tr>
<td>3.0 to 3.99</td>
<td>very wet</td>
</tr>
<tr>
<td>2.0 to 2.99</td>
<td>moderately wet</td>
</tr>
<tr>
<td>1.0 to 1.99</td>
<td>slightly wet</td>
</tr>
<tr>
<td>Range</td>
<td>Description</td>
</tr>
<tr>
<td>---------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>0.5 to 0.99</td>
<td>incipient wet spell</td>
</tr>
<tr>
<td>0.49 to -0.49</td>
<td>near normal</td>
</tr>
<tr>
<td>-0.5 to -0.99</td>
<td>incipient dry spell</td>
</tr>
<tr>
<td>-1.0 to -1.99</td>
<td>mild drought</td>
</tr>
<tr>
<td>-2.0 to -2.99</td>
<td>moderate drought</td>
</tr>
<tr>
<td>-3.0 to -3.99</td>
<td>severe drought</td>
</tr>
<tr>
<td>-4.0 or less</td>
<td>extreme drought</td>
</tr>
</tbody>
</table>

The Palmer Index is most effective in determining long term drought—a matter of several months—and is not as good with short-term forecasts (a matter of weeks). The Palmer Index is popular and has been widely used for a variety of applications across the United States. It is most effective measuring impacts sensitive to soil moisture conditions, such as agriculture (Willeke et al. 1994). It has also been useful as a drought monitoring tool and has been used to trigger actions associated with drought contingency plans (Willeke et al. 1994). Alley (1984) identified three positive characteristics of the Palmer Index that contribute to its popularity:

- it provides decision makers with a measurement of the abnormality of recent weather for a region
- it provides an opportunity to place current conditions in historical perspective; and
- it provides spatial and temporal representations of historical droughts.

**Crop Moisture Index:** The Crop Moisture Index (CMI), developed by Palmer (1968) subsequent to his development of the PDSI, uses a meteorological approach to monitor week-to-week crop conditions. CMI defined drought in terms of the magnitude of computed abnormal ET deficit which is the difference between actual and expected weekly ET. The expected weekly ET is the normal value, adjusted up or down according to the departure of the week's temperature from normal. The CMI responds more rapidly than the Palmer Index and can change considerably from week to week, so it is more effective in calculating short-term abnormal dryness or wetness affecting agriculture. It differs from the Palmer Index in that the formula places less weight on the data from previous weeks and more weight on the recent week. CMI is weighted by location and time so that maps, which commonly display the weekly CMI across the United States, can be used to compare moisture conditions at different locations.
Because it is designed to monitor short-term moisture conditions affecting a developing crop, the CMI is not a good long-term drought monitoring tool (Hayes, 1999). The CMI's rapid response to changing short-term conditions may provide misleading information about long-term conditions. For example, a beneficial rainfall during a drought may allow the CMI value to indicate adequate moisture conditions, while the long-term drought at that location persists. Another characteristic of the CMI that limits its use as a long-term drought monitoring tool is that the CMI typically begins and ends each growing season near zero. This limitation prevents the CMI from being used to monitor moisture conditions outside the general growing season, especially in droughts that extend over several years. The CMI also may not be applicable during seed germination at the beginning of a specific crop's growing season.

**Standardized precipitation index:** McKee et al. (1993) developed the Standardized Precipitation Index (SPI) to quantify the precipitation deficit for multiple time scales. In SPI calculations, the long-term precipitation record for a desired period is fitted to a probability distribution. If a particular rainfall event gives a low probability on the cumulative probability function, then this is indicative of a likely drought event. The cumulative probability gamma function is transformed into a standard normal random variable Z with mean of zero and standard deviation of one so that the mean SPI for the location and desired period is zero (Edwards and McKee 1997). Transformation of all probability functions fitted for different rainfall station data results in transformed variate in the same units. Because the SPI is normalized, wetter and drier climates can be represented in the same way, and wet periods can also be monitored using the SPI. Positive SPI values indicate greater than median precipitation, while negative values indicate less than median precipitation.

SPI represents the amount of rainfall over a given time scale, with the advantage that it also gives an indication of what this amount is in relation to the normal, thus leading to the definition of whether a station is experiencing drought or not. Plotting a time series of year against SPI gives a good indication of the drought history of a particular station. Rainfall of two areas with different rainfall characteristics can be compared in terms of how badly they are experiencing drought conditions since the comparison is in terms of their normal rainfall.

McKee et al. (1993) used the classification system shown below to define drought intensities resulting from the SPI.
<table>
<thead>
<tr>
<th>SPI Values</th>
<th>Drought intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0 +</td>
<td>extremely wet</td>
</tr>
<tr>
<td>1.5 to 1.99</td>
<td>very wet</td>
</tr>
<tr>
<td>1.0 to 1.49</td>
<td>moderately wet</td>
</tr>
<tr>
<td>.99 to -.99</td>
<td>near normal</td>
</tr>
<tr>
<td>-1.0 to -1.49</td>
<td>moderately dry</td>
</tr>
<tr>
<td>-1.5 to -1.99</td>
<td>severely dry</td>
</tr>
<tr>
<td>-2 and less</td>
<td>extremely dry</td>
</tr>
</tbody>
</table>

McKee et al. (1993) also defined the criteria for a "drought event" for any of the time scales. A drought event occurs any time the SPI is continuously negative and reaches an intensity where the SPI is -1.0 or less. The event ends when the SPI becomes positive. Each drought event, therefore, has a duration defined by its beginning and end, and an intensity for each month that the event continues. The accumulated magnitude of drought can also be drought magnitude, and it is the positive sum of the SPI for all the months within a drought event.

**Drought duration**

Information on drought duration depends not only on the onset of drought, but equally on when exactly the droughts end. In some years, it might appear that drought had been relieved through a light shower, but in effect the drought could persist because of a subsequently long dry period. Hence it is important to evaluate carefully conditions that could clearly signal the end of droughts e.g., rainfall above a given threshold, soil moisture recharge that would enable crops to recover etc.,

It is important to document the exact duration of droughts as part of the drought records along with other details such as timing of droughts, intensity of droughts, drought impacts etc., because the length of the time the drought persisted is a good indicator of the nature of the problem and relates quite well to the damage suffered by crops, livestock etc.,

**Spatial Extent of a Specific Drought Episode**

The Spatial extent of specific drought episodes is best described using mapping tools. One of the good examples is the Drought Monitor which was developed for the United States and represents a weekly snapshot of current drought conditions. The Drought Monitor is a synthesis of several different climate indices and parameters.
One of the useful ways to represent the spatial extent of droughts is to map the average frequencies of dry spells which can be computed from the dry spell lengths:

\[ F = \frac{N(D_i) \times 100}{m} \]

where \( N(D_i) \) is the number of occurrences of dry spells \( D \) for a prescribed period \( i \)

\( m \) is the number of years of data

**Analysis of the risk of the phenomenon and its likely effect on agricultural production.**

As the drought information presented in the bulletins is primarily to assist the farming community in making operational decisions regarding the management of their farming systems, it is very important to provide a short analysis of the risk of the ongoing drought phenomenon and how it is likely to affect the agricultural activities. Any suggestions made for changes in operational activities must take into account the availability of inputs (where needed) and give sufficient lead time for farmers to take corrective action. In this regard, it would be useful to interact closely with the extension agencies active in the region. It is equally important to bring to the attention of planning agencies any important aspects of ongoing droughts and their likely impacts to assist them in making appropriate adjustments in their regional/national plans.

**Conclusions**

Given the improved tools and technologies available today, it is possible to provide drought information that enables action to maximise the probability of successful crop production and/or minimise the potential damage to established crops and other assets. To this end, information should be provided on the timing, intensity and duration and the spatial extent of droughts. An equally important element of drought early warning systems is the timely and effective delivery of this information to decision makers. To provide effective drought information, there should be improved collaboration among scientists and managers to enhance the effectiveness of observation networks, drought monitoring, prediction, information delivery, and applied research. Such a collaboration could help foster public understanding of and preparedness for drought.
References


Application of GIS Technology for Agrometeorological Bulletins

Harlan D. Shannon¹ and Raymond P. Motha²

Abstract

U.S. Department of Agriculture World Agricultural Outlook Board meteorologists recently implemented a geographic information system to analyze the impact of weather on domestic and international crop progress and conditions. Sample products are presented demonstrating the effectiveness of this system in preparing agrometeorological analyses. A significant capability of this system is the ability to develop customized applications that automate data processing and display. Staff meteorologists are currently developing an application to automatically generate black and white contour maps for the U.S. Department of Agriculture Weekly Weather and Crop Bulletin.

Introduction

The U.S. Department of Agriculture (USDA), World Agricultural Outlook Board (WAOB) provides official government forecasts of agricultural commodities. These forecasts are prepared by staff economists, which are responsible for estimating domestic and international crop production, supply, and trade. The impact of weather on crop progress, condition, and ultimately production is well documented. For example, timely rainfall and seasonable temperatures can significantly enhance crop production. In contrast, untimely precipitation and temperature extremes can significantly reduce crop production. Given the influence of weather on crop progress and conditions, WAOB meteorologists monitor weather conditions worldwide to help staff economists to improve forecasts of changes in agricultural commodities.

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WAOB meteorologists employ various techniques to monitor and analyze global weather conditions. Time series analyses are used frequently to diagnose the timing and cumulative affects of weather through the various stages of crop development. These analyses help analysts determine the vulnerability of crops to weather extremes at point locations or within small regions. Analog comparisons are used often to identify similarities among recent and historical weather data. These analyses enable meteorologists to estimate the likely impact of weather on current crop production based on crop production figures from those years when similar weather patterns were observed. Spatial analyses are employed regularly to plot and analyze meteorological data relative to geographically important features. Such features may include political boundaries, terrain, or crop growing regions. Recently, WAOB meteorologists implemented operationally a geographic information system to monitor changes in the weather relative to major crop producing regions worldwide. Several applications were developed to facilitate and automate data processing and display, improving meteorologist capabilities to identify and delineate crop areas of concern. Following is a brief introduction to geographic information systems and a description of how WAOB meteorologists are implementing such a system to prepare agrometeorological products.

**Geographic Information Systems**

**Definition**

Geographic Information Systems (GIS) are used to display and overlay layers of spatial data. In contrast to basic computer programs that can be used to draw simple maps or import static images, GIS import, manage, and display raw spatial data. This GIS capability is significant, enabling users to develop accurate and precise maps based on quantitative data. Because quantitative data are incorporated into GIS the associated maps can be modified easily, changing with changes in the underlying spatial data. Furthermore, this quantitative data handling capability enables users to overlay numerous spatial data sets and statistically analyze these data, developing quantitative relationships not achievable using simple map drawing or graphics display programs.

**Components**

A GIS consists of three key components: hardware, software, and data. A simple GIS can be developed by loading basic GIS software on a desktop personal computer and using it to display and analyze any spatial data accessible through that computer. A more robust GIS can be developed by loading advanced GIS software on multiple desktop computers, linking
these computers through local area networks (LAN), and using a database management system (DBMS) to archive spatial data. Although the second GIS described offers the most options and flexibility in performing agrometeorological analyses, quality analyses can still be achieved using the first GIS described. Furthermore, the former often requires much less maintenance than the latter, and is therefore much easier to manage.

**WAOB GIS**

**Hardware and software**

WAOB meteorologists developed an agency GIS using Environmental Systems Research Institute (ESRI) Inc. ArcView 3.2 software installed on desktop personal computers and the WAOB LAN. Each desktop computer has a Pentium III processor, a processing speed between 450 and 900 MHz, between 256 and 512 MB of RAM, and is equipped with the Microsoft Windows 98 operating system. ESRI’s Spatial Analyst 2.0 extension is installed on several desktop computers and the LAN, enhancing the functionality of the ArcView 3.2 software. Given this configuration, multiple people within WAOB have access to the GIS. Nevertheless, the majority of the GIS products regularly produced by WAOB are created using just one computer, demonstrating that advanced systems and networks are not necessary to produce quality products.

**Data**

Several meteorological data sets are examined regularly to assess the impact of weather on global crop production. International crop progress and conditions are estimated using World Meteorological Organization (WMO) temperature and precipitation data. Similarly, domestic crop development is monitored using synoptic and cooperative observer data obtained from the U.S. National Oceanic and Atmospheric Administration (NOAA). All of these data are archived in the WAOB agricultural weather DBMS. Other meteorological data sets are examined less frequently, however, these data often play a significant role in assessing crop progress and conditions when extreme or severe weather is observed. Such data includes tropical cyclone coordinate data and data from various mesonetworks. Because these data are used irregularly, these data are not typically stored in the WAOB DBMS.

Another important group of data examined by WAOB meteorologists is various agricultural data. International and domestic crop production data are used to identify major and minor crop producing areas worldwide. These data help meteorologists focus crop weather monitoring efforts on only those regions that are agriculturally important. Additionally,
domestic crop progress and condition data obtained from the USDA National Agricultural Statistics Service (NASS) are often examined to help augment these assessments.

**Sample Analyses**

Following are examples of how WAOB meteorologists have used GIS to display and analyze agrometeorological data.

**Analysis of WMO data**

Figure 1 shows a sample text file containing comma-delimited WMO temperature and precipitation data. Note that information on the latitude and longitude of each reporting station is included in this file. Such data are necessary for the GIS to plot the weather observations in the correct locations. Figure 2 depicts these data after they have been imported into ArcView 3.2. This data table looks similar to those seen in spreadsheets, however, unlike spreadsheets; GIS are designed specifically to display and analyze spatial data. Figure 3 illustrates how ArcView 3.2 can be used to display the raw meteorological data and overlay these data on other data such as political boundaries. This map was created using the graphical user interface (GUI), commanding the software to generate a map of maximum temperatures at point locations. Finally, figure 4 shows how GIS can be used to further analyze spatial data. A shaded contour map of maximum temperatures was created using the ArcView Spatial Analyst extension to interpolate among point values. In addition to serving as an effective tool for displaying and analyzing meteorological data, GIS is also an effective tool for displaying and analyzing crop data.

**Analysis of crop production data**

Figure 5 shows U.S. county-level crop production data for corn as viewed on the USDA NASS web site. Data tables for a variety of crops, including corn, cotton, soybeans, wheat, and barley, were downloaded from this web site to a desktop computer. Similar to the WMO data, the downloaded data were imported into ArcView 3.2 and displayed, as demonstrated in figure 6. Major and minor crop production areas in the United States are delineated based on the underlying quantitative crop production data imported into the GIS. Note that latitude and longitude data are not included in the crop data table. In this case, crop production data were mapped by joining the crop data file to a county data file that contained the necessary spatial data to map county locations. These examples combined demonstrate how GIS can be used to display and analyze a wide variety of data. Significantly, these data layers can be overlaid and analyzed simultaneously to obtain even more information.
Figure 1. Sample text file containing WMO temperature and precipitation data.

Figure 2. WMO data imported into ArcView.
Figure 3. Raw WMO maximum temperature data plotted in ArcView.

Figure 4. Interpolated analysis of maximum temperatures in ArcView.
Figure 5. County-level corn production data on the USDA NASS web site.

Figure 6. Corn data imported into ArcView and displayed.
WMO data overlaid crop production data

In September 2000 tropical storm Gordon made landfall in the southeastern U.S., producing heavy rain in major cotton-producing areas. WAOB meteorologists were requested to assess the likely impact of the heavy rain on cotton production in this area. This task was accomplished by overlaying numerous data sets in the WAOB GIS. Figure 7 depicts the major and minor cotton-producing areas in the southeastern U.S. as shown in ArcView. Tropical storm coordinate data were downloaded from the Internet and imported into ArcView to show the track of the storm, as shown in figure 8. Similarly, rainfall data were obtained from NOAA and imported into the GIS. These data were contoured and overlaid the other data layers for further analysis, as shown in figure 9. Finally, the percent of cotton in each state that was in the critical open-boll stage of development was plotted on the map to identify the fraction of the crop most susceptible to heavy rainfall. The final map, shown in figure 10, was exported as a JPEG image and distributed to WAOB economists to assist them in preparing commodities estimates. Similar products have been prepared to assess the temporal and spatial extent of flooding rains during summer crop harvesting, to analyze the likely impact of drought on corn production, and to determine the impact of freezing temperatures on citrus production.

Figure 7. Cotton-producing areas in the southeastern U.S. displayed in ArcView.
Figure 8. Tropical storm coordinate data imported into ArcView and overlaid crop data.

Figure 9. Rainfall data contoured and overlaid crop and tropical cyclone data.
Fig. 10. Final product resulting from several data layers overlaid in GIS.

**Customization and Automation**

Similar to other commercially available Windows products, ArcView 3.2 has a user-friendly, menu-driven architecture that simplifies user interactions with the GIS. Nevertheless, creating several similar, but relatively simple maps, or one map with numerous data layers, can be time consuming. An important feature of ArcView 3.2 that has significantly benefited WAOB meteorologists is the ability to customize and automate ArcView processes using the Avenue programming (i.e., scripting) language. WAOB meteorologists produce hundreds of maps each month using the WAOB GIS. Such maps include daily and weekly plots of maximum and minimum temperatures and precipitation for approximately 20 regions worldwide and crop progress and condition maps for several major domestic crops. Producing these maps without automation capabilities would be enormously labor intensive and time consuming. For these reasons, Avenue scripts were developed to automate numerous tasks, including importing data, processing and analyzing data, and exporting maps.
The Avenue programming language is an object-oriented programming language that is similar to Visual Basic or Visual Basic for Applications. The language is considered object-oriented because the code interacts with windows, menus, buttons, text boxes, and other objects within ArcView. For example, GIS users can develop routines that respond to such actions as button pushes or menu clicks. Conversely, code can be written that causes points to be plotted, text to be written, or maps to be exported automatically. Using Avenue, WAOB meteorologists have significantly improved operational efficiency by creating custom menus, buttons, and tools that are tailored to specific user needs and automate numerous time consuming and redundant tasks. If such programming capabilities were not available, many of the maps produced by WAOB could not be produced operationally.

Weekly Weather and Crop Bulleting maps

WAOB meteorologists developed several scripts that automatically produce color maps using the WAOB GIS. Although color maps are often easier to interpret, printing and copying costs prevent distribution of these maps via the Weekly Weather and Crop Bulletin publication. As a result, WAOB meteorologists recently began developing scripts to produce black and white versions of these maps for publication. Given that these maps must be produced in black and white, these maps necessitate the use of labels to delineate temperature and precipitation gradients. Figure 11 shows sample code developed for this project. This code is similar in structure to that of the Visual Basic programming language. Figure 12 shows a sample map generated using this code. Note that many of the properties of this map are controlled through this code. Such features include, but are not limited to, contour spacing, label size and spacing, line thickness, shaded areas, and the map projection.

Discussion

These examples show that GIS is a convenient method for displaying and analyzing agrometeorological and other data sets. An important feature of GIS, however, is the ability to overlay and analyze data sets simultaneously. This capability enables users to statistically evaluate and quantify relationships, such as the percentage of a corn-producing area that is experiencing severe drought. Another important feature of ArcView GIS is the ability to customize and automate tasks by programming in Avenue. This programming language enables users to automate repetitive tasks and thereby improve operational efficiency. Such automation is necessary to create rapidly multiple maps. Given that a wide variety of dissimilar data
sets can be displayed and analyzed in GIS, and that quality maps can be produced using this technology, GIS offers an attractive means for producing maps for agrometeorological bulletins.

**Figure 11.** Sample Avenue code that creates black and white contour maps.

**Figure 12.** Example black and white contour map generated from the above code.
European Agrometeorological Applications

Giampiero Maracchi¹, Zoltan Dunkel² and Simone Orlandini³

Abstract

Agrometeorology can represent an important tool for the improvement of agricultural producer activity. The development of agrometeorological application, also by using World Wide Web, can produce and disseminate elaborated information to the users, representing an important decisions support system. In this paper the results of a survey of agrometeorological applications in Europe are presented, showing several examples collected on different countries. An important activity is also performed by COST Action 718, Meteorological Applications for Agriculture. The main objective is to improve the meteorological applications to agriculture and environment protection identifying and defining the requirement in terms of scale and time resolution and end-users' needs.

Introduction

Even in developed countries, the availability of weather/climate based information can represent the basis for the improving production methods, so making the notion of precision farming a real possibility. Accordingly, economical and environmental benefits can be obtained, realising “sustainable agricultural systems which optimise inputs, conserve resources and are environmentally friendly, socially acceptable, profitable and competitive in a global economy” (Seeley, 1994). On this basis, there is often expressed a commitment to improve the contribution of agrometeorology to the agricultural production and so a particular attention should be addressed to the areas of research, education and service. At present, research and education in academic setting have been the major focal points. Services constitute the most neglected area (Hollinger, 1994).

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They have been left to the national or local structures, but generally in a non-agricultural oriented organisation. As a result weather/climate information for agricultural purposes have not been a high priority except for high value horticultural crops or irrigated regions.

It is then crucial that agrometeorological services will be improved and their activity increased. Many authors discussed the future of challenges and opportunities for serving agriculture with real time and forecast weather data, as well as with products concerning tactical and strategic management of the farm (Seeley, 1994; Maracchi, 2002). In future, important improvement will be obtained by the availability in real time of high resolution weather data, elaborated by the numerical weather forecast models. The major challenge to agrometeorologist is to educate producers to use weather data and elaboration in various management decisions. Several examples of how these data can be used by farmers are described by many authors, concerning when to plant spring crop (Huda, 1994), the risk of nitrogen leaching losses (Shaffer et al., 1994), the timing of pesticide application (Rosa et al., 1995), the assessment of crop yield and quality (Bindi et al., 1997).

At present efforts of the agrometeorological community to provide weather/climate information service to agriculture are shaped by tradition, transition and technology (Seeley, 1994). The perspective of many agrometeorologists are based upon long standing traditions about the types of information expected by their agricultural users. The potential for expanding services to agriculture is growing as a result of changes which are presently underway in developed countries (farm number has declined, farm size has increased, manager has become more educated, the environmental regulation is increased, etc.). Finally advances in electronics, especially in computers, communication and measurements technologies have a major impact which are strongly related to the progress of collection of weather data and elaboration and dissemination to the agricultural producers (Orlandini, 1998).

On these bases a survey of the European agrometeorological applications is presented in this paper, describing several examples per each country based on World Wide Web (WWW). This represents a very important tool for disseminating real time information among the farmers, and an increasing number of services base their activity on this network. In the second part of the paper, the structure and activity of COST Action 718 “Meteorological Applications for Agriculture” is reported, focussing on the general objectives and the activity of the three Working Groups.
Survey of European Country Applications

Reports of agrometeorological activity were found in many countries. So only one example per country was described, also taking into account the wide range of possible applications (pest and disease, irrigation, phenology, crop monitoring, etc.).

In Austria, the Universität für Bodenkultur in Wien performed a comparison of airborne and ground measurements of surface temperature and surface soil water content in field crops. This is based on the investigation of the agreement of ground based measurements with data of soil surface temperatures and soil water content (upper layers) recorded from a helicopter. Also additionally information concerning the characteristics of surface area is necessary. In Austria the European Pollen Information is also active, which produces forecast about the pollen distribution in Europe both in maps and charts format sorted by pollen-type. The same activity focused on the Mediterranean area is realised by the MedAeroNet network. This provides information about the allergenic risk due to pollen, with a weekly time step. The participants to this activity are Spain, France, Italy, Greece, Israel and Albania.

In France an important activity is organised to improve the control of potato late blight (*Phytophthora infestans*) by Cimel Electronique. The system simulates the pathogen infection and determines the theoretical dates for the first treatment and the following ones. Fungicide efficiency and variety sensitivity are also taken into account. IRRISOFT system is available in Germany, providing information on irrigation of many crops. It contains metalinks to servers with information on the software packages and further data, as well as it forms a broad base for efficient information exchange and discussion. Other models are part of a complex Agrometeorological model toolbox of the German Weather Service. AMBAV calculates the potential and real evapotranspiration, soil water balance under different crop covers. Recommendation for irrigation amounts scheduling are disseminated by fax. ASCHORF can be used to improve the control of apple scab (*Venturia inaequalis*) (Fig. 1), while PERO is a model developed for the primary and secondary infections of grapevine downy mildew (*Plasmopara viticola*). The biological cycle of the latter is simulated by PLASMO (Plasmopara Simulation Model) developed by the Italian National Research Council (CNR-IATA) and Department of Agronomy (DISAT-UNIFI). This model allows a better identification of the suitable periods for spraying fungicides, increasing their efficacy. In Italy a wide range of activities are also realised by the Regional Agrometeorological Service of Sardinia. It provides
agrometeorological information to the farmers, along with weather forecast to any interested users. Model running and available information updating are performed online (Fig. 2).

Figure 1. ASCHORF model has been proposed for the simulation of apple scab.

Figure 2. SAR output for the control of Lobesia botrana attacks.
The Wageningen University in The Netherlands is the Centre of the European Phenology Network. Correlation of the timing of phenophases with climate characteristics are available, and they represent an important early warning mechanism. The SWAP model (Soil – Water – Atmosphere – Plant) is the successor of the agrohydrological model Swatrer (Fig. 3). The model addresses both research and practical questions in the field of agriculture, water management and environmental protection. Different types of input are required, concerning meteorological variables, crop, irrigation, soil, heat flow, solute transport and transformation. The model generates water and salt balance over a flexible time period. Water balance terms include evaporation by intercepted rainfall, bare soil and crop, irrigated gift, runoff, infiltration and drainage. Other examples of output are water contents, pressure heads, leaf area index, soil temperature, and they can be generated in form of ASCII output files. They can be directly used as input for pesticide and nutrient models.

![Figure 3. SWAP (Soil – Water – Atmosphere - Plant) model structure for the water balance.](image)

The Institute of Arable Crops Research in United Kingdom realised a site containing a scheme for forecasting the severity of light leaf spot of winter oilseed rape crops (*Pyrenopeziza brassicae*) (Fig. 4).
Provided in Autumn of the ongoing year, it is constantly updated and foresees the situation for the next Spring. This system is based on crop and weather factors. At the start of the season, prediction for each region taking into account of the average weather conditions expected for that region are disseminated. During the season periodical update to take into account deviations in actual weather away from expected values are elaborated. Several parameters are taken into account, such as the amount of pod disease the previous summer, summer temperature, the number of winter rainy days above the regional average and the susceptibility of variety.

Figure 4. Light leaf spot forecast in United Kingdom.

IRRIFIB is a computerised model applied in Slovenia giving soil water balance and available water around rooting system. Together with the weather forecast parameters it estimates the soil water consumption for the next three days. The model is characterised by several input variables (ET0, phenology, root depth, crop coefficients, etc.) and optional parameters (synoptic weather forecast, soil water depletion, type of irrigation, etc.). Planning and management of irrigation are also possible applying CROPWAT decision support system developed by the Land and Water Development Division of FAO. A global Agrometeorological Integrated Information System is available in Bulgaria for the management of crop protection, irrigation, etc. (Fig. 5).
Figure 5. Agrometeorological services developed in the National Institute of Meteorology and Hydrology of Bulgaria

COST Action

Founded in 1971, COST is an intergovernmental framework for European Co-operation in the field of Scientific and Technical Research, allowing the co-ordination of nationally funded research on a European level. COST Actions cover basic and pre-competitive research as well as activities of public utility. The goal of COST is to ensure that Europe holds a strong position in the field of scientific and technical research for peaceful purposes, by increasing European co-operation and interaction in this field. COST has clearly shown its strength in non-competitive research, in pre-normative co-operation and in solving environmental and cross-border problems and problems of public utility. It has been successfully used to maximise European synergy and added value in research co-operation and it is a useful tool to further European integration, in particular concerning Central and Eastern European countries. Ease of access for institutions from non-member countries also makes COST a very interesting and successful tool for tackling topics of a truly global nature. To emphasise that the initiative came from the scientists and technical experts themselves and from those with a direct interest in furthering international collaboration, the
founding fathers of COST opted for a flexible and pragmatic approach. COST activities have in the past paved the way for Community activities and its flexibility allows COST Actions to be used as a testing and exploratory field for emerging topics. The member countries participate on an "à la carte" principle and activities are launched on a "bottom-up" approach. One of its main features is its built-in flexibility. This concept clearly meets a growing demand and in addition, it complements the Community programmes. COST has a geographical scope beyond the EU and most of the Central and Eastern European countries are members.

COST also welcomes the participation of interested institutions from non-COST member states without any geographical restriction. COST has developed into one of the largest frameworks for research co-operation in Europe and is a valuable mechanism co-ordinating national research activities in Europe. Today it has almost 200 Actions and involves nearly 30,000 scientists from 32 European member countries and more than 46 participating institutions from 11 non-member countries and Non Governmental Organisations. This and other information can be found in the Web site: http://cost.cordis.lu/src/home.cfm.

COST Action 718

On these bases, the Memorandum of Understanding for the implementation of a European Concerted Research Action designated as COST Action 718 "Meteorological Applications for Agriculture" was proposed. The main objective of the Action is to improve the meteorological applications to agriculture and environment protection identifying and defining the requirement in terms of scale and time resolution and end-users' needs.

In general terms, the project seeks to see what the current use of weather data is in agrometeorological products with a review of current methods and how they are used. This ought to help fix objectives and to provide verification. The weather input data to such schemes should be reviewed together with the uses of such information. The following tasks cover such topics as how the weather data can be improved (aerial coverage, timeliness, etc.) and if remote-sensing data can make an impact. Improvements can be made then a pilot trial could be done to verify the practicalities of such improvements and if the uptake by the users has increased. A bespoke database of agreed surface and remotely sensed data to a common European standard and to an agreed protocol would have value. This database could be made available to each member country to allow the
running and possibly integration of the largely empirical models - pest, disease, water quality.

In particular these are the main objectives of the Action:

1. obtain detailed information on the all end-user’s needs for data inputs, outputs and interpreted information and knowledge;
2. compile a meta-database of all available data and appropriate ancillary information;
3. identify omissions in the available data and methods such as remote sensing data of obtaining additional data to remove the omissions;
4. select models with outputs that satisfy the exacting needs of users; in the absence of any such models consider how best to provide them and at what scale.

In addition, the project will demonstrate the practicality of such applications to management and planning of agriculture sector at the national/regional/local level. Regional models are often successful, but local models are notoriously hard to define - local topography, microclimate and crop development all have an influence here. How are these problems to be addressed will have a great bearing on the types of exploitation of the data. Both spatial and temporal resolutions at which the meteorological data are available don't correspond to the specific needs of applications in agriculture and represent one of the main constraint for certain operational applications. One of the main objectives of this Action is to write down protocols for the validation, implementation and use of models, bearing in mind user requirements and operational constraints related to the data and the information currently available. The scientific community defining the content and goals of the protocols will make an organised attempt in this topic.

An estimation of the benefits arising from the utilisation of agrometeorological models can be made with a strict collaboration with the end-users. This kind of approach would be extremely beneficial to advance and strengthen the presence of the meteorological community in the field of agriculture and the related environment. The beneficiaries of this COST action will be the agricultural extension services and the planners for agricultural sector. This kind of end-users that will be involved in the Action will benefit from the existence of common procedures for data collection, archiving and spatialising and for model utilisation in co-operation with the meteorological services.
All the sequences of operations will be analysed from data acquired in the requested format from meteorological network, numerical weather predictions, satellite and airborne sensors up to the use of models at local, regional and national scale. A specific evaluation will be done concerning the ancillary information such as phenology, soils characteristics and methodologies for computing derived data as evapotranspiration, beginning of the growing season, degree days, etc., collecting and comparing methodologies for their calculation and estimation in order to establish a standardised approach and a harmonisation of methodologies useful in this field throughout Europe.

The problem of spatialisation will deal with the availability of surface data at a scale of time and space useful for the input in the models. The aim of the project will be to investigate whether data can be produced in good time with the requested format and accuracy useful for operational models in order to provide an enhanced service to meet growers needs. Requirements and availability of climatological data will be investigated considering different sources (classical weather network, satellite images, grid data produced by high-resolution climate models, by building spatial weather generators, in short-term forecast from high-resolution weather models).

A special attention will be paid to define rules and procedures of scientific validation of some selected models to establish a common protocol. The following aspects of validation will be investigated in terms of statistical methodologies and sensitivity of the models to the different meteorological parameters. One of the main goals of this issue would be to establish a common protocol in the European framework for the validation and application of models in the field of crop management, including the effect of adverse weather, at national/regional/local level.

The results of the action should be the improvement of the application of meteorology to agriculture and environmental protection and in particular:

1. provide climate model community with characteristic sizes (time frequency and ground resolution) of weather data needed by agriculture at regional and national level, identifying a compromise between feasibility and needs.
2. Identify needs for and promote development of some paradigms of models adapted to large spatial domains (models for crops, pests and diseases, effluents, consumption), eventually useful for regional monitoring (of crop production, of environmental costs) and
management (scenarios of changing, agricultural systems, dimensioning of environmental taxes or subsidies).

3. Integration between ground-based and remotely-sensed data to improve the accuracy of the model performance.

4. Estimate the cost-effectiveness of such a methodology (cost of model development plus cost of inputs - climate and remote sensing).

The Memorandum of Understanding has been signed by 21 countries: Austria, Belgium, Bulgaria, Cyprus, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, The Netherlands, Norway, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and United Kingdom.

The activity of COST 718 Action is organised in three Working Groups and one Sub Working Group (Fig. 6). These are their general objectives:

1. WG1: Identification of meteorological data requirement for agrometeorological models and the analysis of their availability, at a scale of time and space useful for the inputs in the models.

2. WG1.1: 1.Comparison of satellite data accuracy in space and time with the accuracy of surface meteo data. 2.Differentiation and separation of the remote sensing data that are used as weather variables from the data that are used into crop and pest and disease models.

3. WG2: 1.To study ability of crop and pest-and-disease models to fit a domain (landscape, region or country). 2.To check off components of models and their resilience to upscaling. 3.To check their ability to receive regionalized weather data. 4.To perform validation study of crop and pest-and-disease models (test and check their ability to predict and forecast short and long-term outputs).

4. WG3: 1.To identify with a selection of current and future end-users needs with respect to selected applications or models. 2.Usefulness and delivery of agrometeorological information to those who can make best use of it in planning operation. 3.To encourage exploitation of advances in technology transfer and visualisation techniques. 4.Harmonise model application where possible.
A specific WEB site has been realised to present the activity of the COST Action 718 at the following address: http://agromet-cost.istea.bo.cnr.it/ (Fig. 7).

**Conclusions**

In Europe there is an intense activity in the field of agrometeorology. Many applications have been proposed to support the decision activity of agricultural producers, disseminating a wide range of information in the field of crop protection against pests and diseases, water balance and
irrigation management, crop growth and development monitoring. There is an increasing use of WWW applications, allowing a real time dissemination of information, the interaction with the end users, a reduction of cost bulletin elaboration and distribution.

In this ambit, the activity of COST Action 718 can represent a fundamental element to co-ordinate the different activities performed in the European countries. The most important topics are considered from data collection, data elaboration and model running, elaboration of bulletins and dissemination of information to the end users.

It is very important that co-ordinated activities in this field are realised, particularly with an interdisciplinary approach, so that all the involved experts (biologists, agronomists, agrometeorologists, etc.) can cooperate to a single goal. Only in this way, important tools can be realised to support the decision activity of farmers, with real benefits in terms of income and environment.
References


The Agrometeorological Information System – AgIS

Giampiero Maracchi

Introduction

In the last decades several changes occurred in the field of agriculture and forestry. In the industrialized countries a specific attention has been devoted to the quality of products and to the environmental safety. On the other hand, in developing countries, due to the huge population increase, a strong need of food commodities exists along with a concern to maintain the sustainability of the system and reduce the danger of desertification and land degradation. In any case, the perspectives of climatic changes due to the global processes highlight the issues of forecasting the impacts of agricultural practices and on the environment (Maracchi and Sivakumar 2000). At present, sensible changes in the general circulation pattern have occurred, both atmospheric and oceanic, as well as in the energy balance of the surface and in the increase of extreme events in temperate areas.

In the meantime the world policy and economy changed to a more global perspective and relevant efforts have been made in the research of new technologies. Earth observation from space, progress in the field of computer science, information technology via the Internet system, development of electronic devices for monitoring environmental parameters, numerical meteorological models, crop models and seasonal climatological models for climate prediction, improved substantially our ability to measure, compute and control the natural processes (Maracchi et al. 1997).

Despite such improvements, our capacities did not develop at the same rate because of several reasons, i.e. difficulties in adapting to such rapid changes both in terms of mentality and of professional skills, lack of innovative organisation and the poor capability to face new situations and possibilities (Rijks et al. 1996). The last argument applies specially in the public sector where any change of the established structure means a risk in terms of employment or impacts on relevant economic interests.

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In particular in the agrometeorological sector, it is now time to shift from a philosophy of "agrometeorological bulletin" to a more innovative concept of "Meteoinformation System for Agriculture".

**The Role of Bulletins**

The meteorological bulletins for agriculture were thought, since the fifties, to give information concerning the main meteorological parameters such as sunshine, temperature, wind, rainfall and evaporation for a better crop management to the farmers and/or extension services. But since then, some indications have come from international agencies, such as WMO and FAO, to integrate this information with biological data on crops, on the related pests etc.

The guide to agricultural meteorological practices (WMO 1981) prepared by the WMO Commission for Agricultural Meteorology (CAgM), underlines in each chapter how agricultural meteorology depends on the combination of meteorological and biological data as well as on the agricultural practices. In the annex 1E (Outline of a general syllabus), soil science, plant physiology, plant pathology and biometeorological interrelationships are mentioned as crucial parts of the skills of an agrometeorologist.

Although a division of agricultural meteorology has been established in the majority of the meteorological services around the world, the products of this division deal in many cases only with meteorological or climatological data. The bulletin, once printed, is the product with the largest diffusion and is now often available on the web-pages.

In general, 90 % of the extents of the bulletin consists of tables of meteorological data and only 10 % of the bulletin provides some qualitative estimates of the progress of agricultural season, on the pests occurring or on some similar qualitative information.

Unfortunately on many web-sites (more than 50% of the observed cases), the information on the predicted and monitored status of the growing season is published critically late. In another 20% of the web-sites, the information is updated with a delay of two days, which can often make the same information totally useless. Table 1 below is given as an example.

To improve the production and the dissemination of information to agriculture in a useful manner, the following questions should be addressed:

- To whom is the information directed?
<table>
<thead>
<tr>
<th>Update</th>
<th>% of countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Every 1/2 days</td>
<td>30 %</td>
</tr>
<tr>
<td>Every month</td>
<td>15 %</td>
</tr>
<tr>
<td>Not updated</td>
<td>55 %</td>
</tr>
</tbody>
</table>

Table 1: Update of agrometeorological information on web-sites

- What is the utility of the information in relation to the decisions to be taken?
- Is the time of delivery coherent with the time for the adoption of decisions?
- Is the way of information diffusion adequate to convey it at the right time to the users?
- Is the language adopted understandable by the relevant category of users to whom the information is directed?
- Is it correct to produce a bulletin or is it better to think about an "agrometeorological information system"?

Each person responsible for the agrometeorological division in a meteorological service should ask himself this kind of question to plan the preparation of a bulletin or to check whether the current one is efficient enough.

**The Agrometeorological Information System**

The term ‘agrometeorological bulletin’ should be changed for two main reasons:

- The users of a bulletin could be various groups with different information needs; hence there should be the opportunity to prepare various kinds of “bulletins”. Therefore it is more appropriate to talk about an Agrometeorological Information System;

- The bulletin evokes the idea of a printed document, but in many cases the use of other means are necessary to reach the targeted group, such as radio broadcasting or television.
The first step is to define the targeted group to be reached. The main groups identified are the following:

- Decision makers and the extension services for agriculture and environment
- Farmers
- Businessmen

**Decision makers**

The decision-makers are interested in monitoring the agricultural season to help the farmers in adverse years and to provide agroclimatological information for agricultural planning (WMO 2000). Concerning the first item, the information is required some time in advance, concerning the production of the main crops, generally at a level of aggregation corresponding to the administrative subdivisions of the country. The preparation of this type of information needs the conversion of meteorological data into crop yields in a format comparable with the statistical data of historic series. In a certain way, it is possible to state the departure from the average yields of each area as well as the evaluation of the acreage of the crop to compute the production.

Another important information for the decision makers is on extreme events causing damages to the agricultural system or to the environment, as in the case of hurricanes, extreme droughts, floods, frosts, strong winds, very intense rainfall etc. In that case, the users need to know the area affected and the intensity of the phenomena.

**Farmers**

The farmers are interested:

a) Before the beginning of the season, to know the characteristics of the season in order to plan, where possible, which crops to grow. This was completely beyond the forecast possibilities in the past. Nowadays, progress in the seasonal climatology combined with the earth observation from space of the sea surface temperature, brings the time closer when this will be possible operationally for many areas;

b) During the season, the farmers require information which allows them to take decisions in terms of crop management, whether to sow or not, to spray or not, to irrigate or not and if the decision is made to irrigate what should be, the amount of irrigation etc.
The information to be delivered to the farmers should be punctual, sufficiently precise in space, coherent with the available options and already in an agricultural technical language. For example, it is less important to indicate the temperature or the amount of rainfall, but it is essential to communicate whether the farmers should sow or not.

In preparing the advice, the agrometeorologists should keep in mind the following issues:

- which options the farmers have in relation to the information delivered;
- the required accuracy in time and space of the information;
- how to translate the meteorological or climatological information into a crop management information;
- how to estimate the value of the advice.

**Businessmen**

The businessmen are interested mainly in the prices. The prices of the main commodities are related to the production on a regional and international level in such a way, that the balance among various markets would lead to an adjustment of the local market. Nevertheless, their focus is on comparing the current year production with the past years and the information has to be available some time in advance of the harvest.

Examples of the Agrometeorological Information System for different end users are shown in figures 1 and 2.

**The Golden Rules for Establishing an Agrometeorological Information System**

The problems faced by agrometeorologists are often related to the fact that the resources available for this sector are rather limited. It could be argued that the system should be drawn assuming that all the resources are available as in a theoretical situation. This approach, which is usually followed, is not realistic and it is advisable indeed to organise the system keeping the real situation in mind, with its constraints and possibilities, trying to adapt to such situation in the best way.

The work of an agrometeorologist is often very difficult because he is alone, he has no indications on how to operate, and he has to take his own decisions without any technical help. Furthermore, the background of knowledge in meteorology and climatology, in crop science and in computer science has to be very large and comprehensive to achieve any practical result.
Figure 1. Scheme of hydrological and water balance information distributed with an Agrometeorological Information System to three final users: farmers, local and national administration.
Agrometeorological Previsional Service
for the next 10 days (Example for the irrigated zone of Benimellal – Morocco)

Water Balance and Irrigation Planning - Decision Support System

Cereals: Durum Wheat – irrigation YES in the case of shortage or stress (min. 170 m³ ha⁻¹)

Other crops: No irrigation for olive and citrus.

Workability: (50 cm of depth)

Trafficability: low level of risk for the whole area

Hydrology: Water balance into the basin: NEGATIVE

Difference with the reference values (last 10 years):

Observation:

Forecasting: No rainfall for the next week. Negative Hydrologic Balance (Reduction of Water Reserve)

→ Reduce the consumption where possible

Figure 2. Example of a possible informative document for farmers or local agronomic agencies (distributed by fax). The data and the information used for the example were collected in the project SEM 04/204/028 between DMN/Morocco and FMA/Italy. The bulletin’s structure is currently under evaluation.
Fortunately today the technologies can help substantially in solving problems which once were impossible to solve. However, to tackle with these technologies, a modern agrometeorologist needs greater skills than before.

The steps to prepare the Agrometeorological System would be:

1. Definition of users and their needs;
2. Division of the country in units coherent with the needs of the users (administrative etc.);
3. Choice of the crops relevant for the users;
4. Determination of the appropriate information for the users in relation to the available options;
5. Division of the units in climatological homogeneous sub-units;
6. Establishment of the method to convert the climatological and meteorological data;
7. Evaluation of the data available concerning weather, climate, ancillary data, crops, etc. and their accuracy in time and space;
8. Establishment of the methods to convert the data at the requested scale of time and space (spatialisation);
9. Preparation of the software to make the chain of data processing more automatic;
10. Definition of the way to deliver the information (E-mail, radio, TV, World Wide Web, etc.).

Despite the common approach, the contents of each step, as it is understandable, depend from each country.

**How to Approach Each Step of an Agrometeorological Information System**

**Data collection**

An Agrometeorological Information System needs real time meteorological data in every application, especially in the case of advice to the farmers. This is a problem because in many countries the meteorological stations connected to the headquarters are quite few. The use of the numerical forecast on rainfall and temperature values to fill the gaps of the meteorological network is a compromise becoming increasingly accessible. Subsequently, the station data available will be utilized as control and validation of the forecast information.
Some products are already available on the web-sites, as for instance from the National Climatic Data Center (NDCD) of NOAA concerning rainfall for Africa (Fig. 3). Another kind of information available on the Internet is remotely sensed data from satellites, like from NOAA or METEOSAT (Fig. 4).

Moreover, to use these data a software has to be prepared, including an automatic software to download data daily at the same time, a geographic base of the country to overlay the meteorological data, a software to spatialise the data taking into account the country’s morphology, and a system to archive the daily data in a format compatible with the input to the agrometeorological models. The final output of this exercise should be a grid map of the main parameters (e.g. rainfall, temperature and wind) at a resolution compatible with the agricultural applications (Fig. 5). This is variable in relation to the climatic zone; it would be 10 km in temperate zones with a rough morphology and 50 km in the plains.

Remotely sensed data will be useful to compute some missing parameters such as solar radiation, which can be derived from the cloudiness, or to estimate the rainfall from the cloud top temperature. This data can be used in combination with the forecasted data to improve the estimation. Another possible estimation of remotely sensed data is in an integrated way, by means of the reply of the vegetation to the rainfall,
Figure 5.  Example of an Agrometeorological Information System

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Figure 6. Linear regressions between final crop yield and NDVI values obtained for Morocco by the “leave-one-out procedure” during the 1982-1994 period (** = correlation significant at the 99% confidence level).

Comparing the total amount of the rainfall in a specific point of the grid with the Normalized Vegetation Index (NDVI) curve or the final crop yield with the NDVI values as shown is Fig. 6 (Maselli et al. 2000; Maselli and Rembold 2001).

The software to be used for these processes are, a database (DB), a Geographical Information System (GIS) and an image processing software. In any case, commercial software is the most reliable for these kinds of applications (Access for the DB and IDRISSI for the GIS and Image processing software).

A climatic database

An important tool for the agrometeorologist is the climatic database for a representative number of years. A climatic database of the daily data of rainfall and temperature can be used for two main purposes, which are the classification of homogeneous areas and the comparison of the i-year with the statistical series.
Moreover, it is convenient to couple the climatic DB with the geography of the country to facilitate at a later stage the comparison with the data of the year analysed (AGRHYMET 2001).

The climatic classification can be done using a matrix of temperature and rainfall with the average/total monthly data for 30 years (if possible) and a cluster analysis programme in order to group the zones with similar values (Le Houérou et al. 1993).

The identification of homogeneous areas is useful to divide the administrative units in sub-units with a similar climate. This applies particularly where the administrative units are very large and heterogeneous in terms of physical parameters (Bacci et al. 2000).

Once the system for crop monitoring has been built, the climatic indices concerning the growing season can be compared for the entire season with the statistical data (average and standard deviation) contained in the historic series (Di Chiara et al. 1994).

**Crop monitoring**

Crop monitoring can be carried out for two main reasons, namely for early forecasting of crop yields, and providing advice to the farmers in order to help them in decision-making.

All these systems, from the simple ones to the more complex, require a good knowledge of the ecophysiology of the crop, i.e. the response of the crop, as well as the ecophysiology of the variety of each crop. A good knowledge of the common agricultural practices in the area and of the environmental factors is also required.

To analyze the relationships between the crops and the environmental factors, consideration of the following questions could be useful:

- How long is the growing season?
- In which period the sowing date does occur?
- What should be the temperature and soil moisture thresholds for germination?
- How many phenophases are there along the growing periods?
- Which phenophase is more sensitive to the meteorological parameters?
- Which are the more frequent adverse events (droughts, high temperatures, storms, strong winds, pests and diseases, cold, frosts, floods)?
- How much water does the crop need for each phenophase?
- What is the average evapotranspiration during each phenophase?
- Which are the most important factors affecting the yield and the production?
- How much is the variation in yield between years? What is the absolute minimum and maximum?
- How can the minimum year and the maximum year be characterized from a climatic point of view?
- Can the principal causes of the variation be identified? What is the coefficient of reduction of the maximum possible yield for each phenophase?
- Which kind of management practices do the farmers use?
- How many possible options do they have during the growth periods (i.e. date of sowing, varieties, timing and amount of fertilizers, spraying for pests and diseases, timing of weeding, amount and scheduling of irrigation, timing of harvest etc.)?
- What are the possibilities for delivering agrometeorological information useful for decision-making? If yes, which kind of decision?
- Are the meteorological forecasts useful to take some decision?
- How much time is required before the decision based on the information is delivered?
- Which should be the accuracy of the information on a spatial basis?

The replies to these questions allow building a reasonably efficient AgIS. The way to compute the final yield or the advice concerning the management techniques can vary from very complex deterministic models to simple evaluations of the relationships between the meteorological parameters and the final yield. While the first approach is quite complex and asks for scientific competency, the second one is more related to the practice and to the knowledge of local situations.
Information delivery

The question to be asked in the evaluation of a bulletin’s performance is whether the information is delivered in a timely manner to allow the user to make the appropriate decision. In many situations the output of an agrometeorological division is more related to the need to demonstrate that the salary of the personnel is well spent rather than providing a real service to the farmers or others users.

The printed bulletin, issued on a decadal basis as is most common in the traditional agrometeorological services, can be a useful tool for the monitoring of the agricultural season and whether problems for the final production are foreseen. However, it is generally of poor value to the farmers (Maracchi 2000) for two reasons, first because it will arrive after the decisions are taken and secondly because the information is aggregated at the level of large administrative units. If the activity of the farmers has to be really supported, the focus should be more on the various features of the territory and on using different methods than the printed bulletin. In the industrialized countries where the Internet has become a widespread tool, this would be a good solution, at least for a number of farmers. The possibility to deliver the information timely is also facilitated in this case, because the entire chain of data processing, including the use of images, is coherent with the delivery system and allows tailoring the information in space and for various categories of farmers and crops. In addition, there is the possibility to build an interactive system in which the farmers themselves can provide some local information to improve the preparation of advise.

In less developed countries with regard to the information technologies, another approach to reach the farmers should be researched. One possibility is to reach the local agricultural services through the Internet and then identify jointly the way to reach the farmers in the field. In most situations, the only possibility is through the local broadcasting. Where even this possibility is not available in the organisation of local extension services, the only available means is the national radio broadcasting.

In this case, as the radio has to be paid for the service, the information would be delivered in a very synthetic and efficient way. A specific exercise to convert the agrometeorological information in a useful tool will be done. The information to be delivered should be formulated more like "in the district of x starting from the next Thursday farmers can sow the maize" or "in the district of y farmers should spray the fruits against z".
Conclusions

The development of an efficient agrometeorological information system is crucial in many countries where agriculture is the basis of the economy. Nowadays, even if the available resources are quite limited, building a good service and delivering useful products to a variety of users is possible. To achieve this, the main condition is a proactive attitude of the agrometeorologists to tailor the information to the real user needs. We should shift from a simple collection of tables of meteorological data to information helping the users to decide.

The professional capacities of the agrometeorologist are the key to changing attitude. He should know thoroughly the user needs, be able to use the computer possibilities, reinforce the collaboration with the experts of the Ministry of Agriculture to build a joint system, ask for the various information (geographical, biological, climatological etc.) to make the puzzle complete. In many cases he should demonstrate to its service the utility of the products he can deliver and the benefits for the service itself to deliver information appreciated by the rural communities.

In this context, there is a need of further actors helping the local services to organise a well-shaped agrometeorological service, as the international agencies and the research institutions. The entire chain of data processing software, from the data acquisition from Internet to the application of simple models for crop monitoring, is in most cases out of reach of the single agrometeorologist. Therefore, the co-operation between the international agencies as WMO and the research institutions can lead to the preparation of the tools of the chain as well as testing and adapting them to the various situations. In this connection, the preparation of training activities and even of self training software can be very helpful to promote the establishment of an efficient system with very important results for the users, the service and for the individuals in the service.

Acknowledgements

The scientific support provided by M. Paganini for the collection and analysis of the agrometeorological bulletins on the Internet, G. Pini for the compared analysis of the climatic predictions with the observed data, and B. Rapi for the contribution given in the selection of applications is gratefully acknowledged.
References


Improving Agrometeorological Bulletins –

Brainstorming on Issues and Prioritization

Conclusions and Recommendations of the Workshop
Improving Agrometeorological Bulletins:
Brainstorming on Issues and Prioritization

M.V.K. Sivakumar¹

Participants in the workshop were engaged in a brainstorming session on the main problems faced in improving agrometeorological bulletins in different Regions. Participants were divided into four groups to get the divergent views from each of the groups and then through common discussion a consensus view was reached.

Main problems in improving agrometeorological bulletins

The workshop identified the main problems in improving agrometeorological bulletins as follows:

1. Lack of clarity regarding users and their needs
2. Lack of adequate data (quantity, quality) and timely availability
3. Lack of resources (expertise, financial, infrastructure), tools and methodologies
4. Lack of systematic feedback and evaluation
5. Inappropriate style (user friendliness) in the preparation of products and their timely dissemination and lack of standards
6. Lack of cooperation between relevant agencies
7. Lack of training (staff and users)

The group then constructed cause-effect tables for each of the above categories as follows:

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Category 1. Lack of clarity regarding users and their needs

Lack of clarity regarding users and their needs

- Insufficient communication between producers and users
- Insufficient knowledge regarding who the users are
  - Insufficient expertise in agrometeorology
  - Lack of knowledge of farming communities

Category 2. Lack of adequate data (quantity, quality) and timely availability

Lack of adequate data & timely availability

- Insufficient network in crop areas
- Inadequate telecommunication systems
- Lack of standardized quality control and quality assurance
- Lack of adherence to established procedures for data collection and station maintenance
- Inadequate access to new technologies for data collection and handling (NWP forecasts, remote sensing, internet etc., )
- Lack of access to agricultural data
Category 3. Lack of resources (expertise, financial, infrastructure), tools and methodologies

- Lack of resources
  - Inadequate access & knowledge of available technologies
    - Inability to seek internal and external resources
      - Lack of motivation
        - Low national priority
        - Lack of sensibilization of policy makers of the value of agrometeorological potential
Category 4. Lack of systematic feedback and evaluation

Lack of systematic feedback

Lack of interest and motivation

Poor response from users

Cultural differences in agricultural communities

Difficulties in handling the various steps in the feedback process

Lack of time and manpower to implement feedback mechanism

Inadequate communication and networking between users and producers

Lack of awareness of the importance of feedback in many cases
Category 5. Inappropriate style (user friendliness) in the preparation of products and their timely dissemination, lack of standards

- Inappropriate style (user friendliness) in the preparation of products
  - Higher costs to prepare products in appropriate style
    - Timeliness of the of data to be incorporated into bulletins
      - Preparation without consideration of user requirements
        - Lack of skill and expertise in product preparation (various stages and their communication)
        - Inappropriate balance between meteorological and agricultural information
        - Poor writing skills
Prioritization of problems in improving agrometeorological bulletins

The participants were asked to prioritize the problems identified and convey their views regarding the prioritization by voting on the problems. Following the voting, the following problems emerged as the priorities:

1. Lack of Resources (expertise, financial, infrastructure), tools and methodologies
2. Lack of clarity regarding users and their needs
3. Lack of adequate data (quantity, quality) and timely availability
4. Lack of cooperation between relevant agencies
5. Lack of training (staff and users)
6. Lack of systematic feedback and evaluation

Strategies to address the priority problems in improving agrometeorological bulletins

Considering the above prioritization, participants were asked to suggest appropriate strategies to address the particular problem. After exchange of views, all the members agreed on the following priority strategies to address the main problems (identified in bold characters):

Lack of Resources

- Pool resources at a central regional/national location to create a technological infrastructure for agromet information for value added products at the national level.
- Improve the efficient use of existing resources through international and regional cooperation
- Form partnerships with national and international interests to share and exchange resources and technology
- Mobilize resources

Lack of Awareness of User Needs

- Conduct regular surveys and open forums with users
- Increase knowledge of agriculture and user needs in agrometeorological units
Lack of Data

- Improve agrometeorological networks in crop areas
- Use additional non-conventional sources of data (Remote Sensing, Numerical Weather Products, Geographical Information Systems)
- Improve skills in database management
- Improve the skills of instrumentation personnel

Lack of Cooperation

- Create partnerships between relevant agencies through effective dialog and education
- Enhance cooperation through administrative mechanisms (establish MOUs)
- Form inter-institutional working group on agrometeorological products

Lack of Training

- Request WMO to organize more roving seminars
- Develop mechanisms for more formal and informal self-training
- Establish training programs for providers and users of agrometeorological bulletins using workshops/seminars
- Give high priority to training

Lack of Feedback and Evaluation

- Provide contact details (e-mail, fax, telephone.) and encourage user feedback (comments, complaints, suggestions)
- Organize user forums and user pay systems (cost recovery)
- Establish working programs with extension services to facilitate feedback and evaluation
- Maintain dedicated and sustained liaison with end users

General Strategy

- Establish a server on the World Wide Web (WWW. Agromet.com) for all Agrometeorological bulletins issued from different countries.
Conclusions of the Workshop

• Considering the growing need for food to meet the demands of rising population, especially in developing countries, it is important that agrometeorological information is made available in a timely fashion to the users. Hence, it is concluded that every effort should be made to improve and make available good quality agrometeorological products in a timely fashion with the full involvement of the users.

• Recognizing that agrometeorological products must continue to be produced by members, the common problem of a lack of knowledge of users needs must be addressed.

• Noting the usefulness of this workshop in initiating the process to improve national agrometeorological products, it is suggested that another workshop be organized to evaluate the progress in the implementation of the workshop recommendations in two years time.

• Capitalizing on existing resources, especially on the latest technologies, the following recommendations of the Workshop should be adopted by countries as much as possible.

Recommendations of the Workshop

The workshop recommends that:

• A common web server be created to share experiences in the preparation of agrometeorological products and also to facilitate exchange of new ideas. The server will be a location where all countries would routinely post their agrometeorological products;

• WMO and other relevant agencies help countries improve their agrometeorological services;

• Each country prepares products to best meet the needs of users, taking into consideration the availability of data, tools and methodology;

• A task force be created at the national level to assess the quality, relevant acquisition and dissemination of data;
• Although timely availability of good quality data for producing and disseminating agrometeorological products and strengthening agrometeorological networks in cropping areas are essential, non-conventional sources of data, such as Numerical Weather Prediction Products (NWP) and Remote Sensing (RS) data must be considered;

• National Meteorological Services make a concerted effort to sensitize the policy makers and Governments on the economic benefits of their agrometeorological services and on the necessity of operating a core network of agrometeorological stations;

• In order to make efficient use of existing resources, partnerships with national and international stakeholders be established to share and exchange resources and technology to improve agrometeorological products;

• Each country identifies training needs for producers and users of agrometeorological products and actively seeks funds to provide the training, especially in developing countries like in the Caribbean region.
Workshop Evaluation

M.V.K. Sivakumar

Introduction

The Inter-Regional Workshop on Improving Agrometeorological Bulletins was co-sponsored by the World Meteorological Organization, the National Oceanic and Atmospheric Administration (NOAA) and the Caribbean Institute of Meteorology and Hydrology. The purpose of this meeting was to assess the current status of preparation of agrometeorological bulletins in the six Regions of WMO and determine the different ways and means to improve the contents of these bulletins to facilitate timely and efficient on-farm operational decision-making that relies on agrometeorological information.

The specific objectives of the Workshop were to:

1. Evaluate how the NMHSs in six Regions of WMO determine the contents and methods of presentation of information in the agrometeorological bulletins that are issued in their countries;

2. Identify the shortcomings and limitations in the current methods of preparing agrometeorological bulletins;

3. Review the different improved methods and tools to improve the contents and presentation of information in the agrometeorological bulletins and their delivery to decision-makers in a timely fashion;

4. Formulate an effective training strategy to build the capacity of the NMHSs in the different WMO Regions to rapidly implement improved systems of preparing and disseminating agrometeorological bulletins.

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Format for the Workshop

The Workshop was designed in such a way as to allow time for:

- Presentations by participants from each of the six WMO Regional Associations describing the current procedures being followed by them to provide agrometeorological information to the user community.

- Presentations from invited experts outlining the technological perspectives in improving agrometeorological bulletins.

- Brainstorming and analysis of different issues mentioned under the objectives of the Workshop in order to seek the divergent views from the participants, engage the participants in discussion and arrive at a consensus view on future approaches to improve agrometeorological bulletins.

Participant Interaction

The Workshop was interactive with emphasis on active participation. The participants were encouraged to exchange ideas and evolve concepts, particularly in the brainstorming and analysis sessions, to address the specific issues of the workshop outlined above. The interaction helped the participants appreciate the problems in improving agrometeorological bulletins and develop appropriate recommendations for future action by the Members.

Workshop Evaluation

In order to facilitate the evaluation of the Workshop and help obtain feedback from the participants, an evaluation form was circulated on the final day. A summary of the participant evaluation of the Workshop is shown in Table 1. All the participants rated the workshop as good to very good.

Overall the workshop has been a success. It was held in an atmosphere of free discussion and friendly exchanges. The recommendations of the workshop should help generate strong interest among the Member countries to review the current procedures being used in the preparation of agrometeorological bulletins and take adequate improve them.
Table 1. Summary of workshop evaluation
(Responses given in percentage of the total participants (22) responding to the evaluation form)

<table>
<thead>
<tr>
<th>Question</th>
<th>Very well met/ Very relevant/ Very good</th>
<th>Fully met/ Relevant/ Good</th>
<th>Nearly met/ Adequate</th>
<th>Yes</th>
<th>No/ Poor</th>
<th>No response</th>
</tr>
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<tbody>
<tr>
<td>1. Did the workshop meet all its objectives?</td>
<td>64</td>
<td>27</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>2. Will the knowledge acquired help you contribute more effectively in your work?</td>
<td>23</td>
<td>27</td>
<td>-</td>
<td>50</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3. Relevance of programme to your work?</td>
<td>37</td>
<td>46</td>
<td>-</td>
<td>17</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4. Did you receive advice relevant to work?</td>
<td>14</td>
<td>23</td>
<td>8</td>
<td>41</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>5. Did you have language difficulties?</td>
<td>5</td>
<td>5</td>
<td>9</td>
<td>8</td>
<td>73</td>
<td>-</td>
</tr>
<tr>
<td>6. Quality of workshop programme?</td>
<td>73</td>
<td>27</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7. Quality of papers presented in different sessions?</td>
<td>45</td>
<td>55</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8. Did you find the discussions during the workshop productive?</td>
<td>32</td>
<td>18</td>
<td>-</td>
<td>46</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Question</td>
<td>Yes</td>
<td>No</td>
<td>N/A</td>
<td>91</td>
<td>5</td>
</tr>
<tr>
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<td>-----</td>
<td>----</td>
<td>-----</td>
<td>----</td>
<td>---</td>
</tr>
<tr>
<td>9</td>
<td>Did you find the brainstorming session useful?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Was the duration of the workshop adequate?</td>
<td>18</td>
<td>27</td>
<td>18</td>
<td>27</td>
<td>5</td>
</tr>
<tr>
<td>11</td>
<td>Quality of pre-workshop information</td>
<td>37</td>
<td>37</td>
<td>9</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>12</td>
<td>Quality of service received from WMO/UNDP regarding travel arrangements</td>
<td>37</td>
<td>28</td>
<td>5</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>13</td>
<td>Assistance received from CIMH</td>
<td>55</td>
<td>28</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Do you have suggestions for future workshops of this nature?</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>78</td>
</tr>
<tr>
<td>15</td>
<td>How do you rate the workshop?</td>
<td>82</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
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</table>

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