Meteorol. Appl. (Supplement), 21–30 (2006) doi:10.1017/S1350482706002520

Dissemination and communication of agrometeorological information—global perspectives

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Agrometeorological information and services from the National Meteorological and Hydrological Services (NMHSs) are increasingly being demanded by the farming community to cope more efficiently with climate variability and the increasing incidence of extreme meteorological events such as droughts, floods, frosts and wind erosion. While considerable advances have been made in the collection, archiving and analysis of weather and climate data, their transformation into information that can be readily used by the farm sector has lagged behind, especially in developing countries where such information needs are the greatest. One of the important reasons is the lack of adequate interaction with the user community in assessing the appropriate dissemination and communication procedures that can enhance the value of the agrometeorological information and services. A brief review of the present status of dissemination and communication of agrometeorological information by the NMHSs and associated agencies in different regions around the world is presented. A description of the user communities for agrometeorological information and their varying needs is also presented. Opportunities and challenges in the dissemination and communication of agrometeorological information by the NMHSs are described with suitable examples which emphasize that continued improvements are necessary to make agrometeorological information more accessible and useful to the user community.

Keywords: agrometeorological information and services, status in different regions.

1. Introduction

Agriculture is a major sector of the economy in most countries, especially in the developing world. Inter- and intra-seasonal variations in weather/climate carry considerable impact on the timing as well as efficiency of routine agricultural operations such as planting, weeding and harvesting, and they also determine the efficacy of application of inputs such as fertilisers, insecticides and pesticides. In many parts of the world, it is of paramount interest to know in detail the climatological conditions in order to make the best possible use of land available for agriculture (Berggren 1978). Extreme meteorological events such as droughts and floods, with their potential to increase pest and disease infestations, can cause significant economic losses depending on the stage of crop growth during which they occur. Early forecasts of such events have the potential to help farmers take appropriate remedial measures that could help avoid or reduce economic losses. Timely availability of agrometeorological information and services could facilitate both strategic and tactical decisions in increasing and sustaining agricultural production. The main strategic decisions for which the information is needed include assessment of crop production potential and identification of appropriate regions for a specific crop, choice of crops/cropping systems, management practices and marketing of agricultural products. The tactical decisions incorporate a wide range of day-to-day operational decisions concerning soil, crop and water management such as sowing, cultivation, spraying and irrigation scheduling.

The main objective of this paper is to present a brief perspective on the current needs for agrometeorological information and services and compare the needs with the current practices in the dissemination and communication of agrometeorological information by the National Meteorological and Hydrological Services (NMHSs) in different regions of the world. This evaluation leads to a short discussion on the opportunities and challenges to improve the communication of agrometeorological information by the NMHSs. No attempt is made here to present a comprehensive overview, but it is hoped that the examples presented will be adequate to throw light on the major issues in the dissemination and communication of agrometeorological information and how to address them.

2. Agrometeorological information and services

As Weiss et al. (2000) explained, information can be identified as the cornerstone to successful farming in the twenty-first century. Agrometeorological information and services can be viewed as beginning with data that are generated through various sensing and measurement techniques. Meteorological data are collected on a daily or hourly basis depending upon the type (conventional or automatic) of agrometeorological station. Agricultural data, on the other hand, are collected in the crop fields by agricultural personnel or extension agents. The distinction between agrometeorological data and information that is useful for decision-making is an appropriate one that has also been made by other authors (Doraiswamy et al. 2000; Weiss et al. 2000). The information service itself can be viewed as the output of a production process that incorporates data, the different forecasts of weather and climate that are available, observations of various components of agricultural systems that are impacted by weather and climate variations and the anticipated uses of associated outputs from the system in economic and social activities. Recent advances in technology for communicating data and information electronically have opened up new avenues of opportunity to communicate agrometeorological information in a timely and effective manner, but there are varied capabilities between the developed and developing countries. A short-listing of different categories of agrometeorological information and services are given below. These include the five major types of agrometeorological services identified by Stigter et al. (2000):

2.1. Past or historical data and derivations

Long-term climatic data in their raw form as well as derived data and indices emanating from them serve a variety of purposes. Data and derived information include the following:

- Raw and quality-controlled observational data. Derivations from observations including averages, normals, frequency distributions, extremes, drought indices, soil moisture deficits, degree days, downtimes, commodity weighted climate indices, comfort and biometeorological indices.
- Time sequences of agrometeorological data, comparisons with earlier periods and anomalies.
- Spatial analyses (including model analyses, gridded data sets and maps) of agrometeorological variables and derivations.
- Regressions or associations of agrometeorological measurements with various yields, quality indices, demands, productivity, incidences (including pests and diseases).

The above types of information may be supplied directly as a result of ad hoc enquiries or as part of a consultancy service, or routinely through bulletins or publications, many monthly but some daily, weekly, fortnightly or annual. These can be divided into general agrometeorological bulletins (e.g. climate systems monitoring) or publications (e.g. atlases) or market sector specific bulletins (often provided on a commercial basis).

2.2. Climate prediction/forecasts for agriculture

Year-to-year variability of climate significantly affects the agricultural fortunes of most farmers. For example, the all-Australian crop value has been shown to fluctuate by as much as six billion dollars from year to year, and these fluctuations are highly correlated with seasonal ocean temperature changes (Nicholls 1985). Farmers have to take a number of crucial land and water management decisions during the season, which are based on the climatic conditions, and sometimes these decisions have to be taken several weeks in advance. One of the persistent demands from the agriculturists is to have reliable forecasts of seasonal weather and climate patterns as it could help them take appropriate decisions as to which crops/cropping systems should be chosen well ahead of the sowing rains so that undue risks could be avoided, or conversely, opportunities could be identified. Farmer demands can vary from multi-year to seasonal to within-season forecasts. The activity for each of these forecasts is needed and the scale of forecasts varies, but their utility is unique, and hence, the demand is consistent.

Even after the crop is sown, favourable weather conditions during critical stages of crop growth can greatly enhance crop productivity, and hence availability of reliable weather and climate forecasts can assist the farmers in scheduling farm operations and in adoption of appropriate tactics to reduce the impact of unfavourable weather conditions. However, quantitative forecasts of the amount and temporal distribution of rainfall during the growing season are difficult to make. Climate forecast and impact assessment needs include the following:

- long lead climate forecasts (e.g. for a season starting 1–13 months ahead),
- climate forecasts for the next month and the next season,
- decadal and climate change forecasts,
- statistics of predicted climate,
- impact and response assessments,
- assessments of savings and costs associated with impacts and response strategies.

2.3. Medium- and short-range weather forecasts

Predictions 5–10 days ahead of those weather variables, which have an established agrometeorological correlation with the growth and development of crops and animals, are often quite useful to make tactical management decisions. A number of crucial operational decisions on crop management during the growing season such as planting, intercultivation, spraying, top dressing and irrigation require information on the expected amount of rainfall. In addition, for irrigation, scheduling estimates of potential evapotranspiration are required.

For most crops, decisions on when to apply the first dose of nitrogen fertiliser are also linked to the timing of rainfall as farmers often apply the fertiliser following a weeding operation in order to maximise the efficiency of use of fertiliser by the crop. Small rain showers of 5–10 mm facilitate these operations while heavy rains following the application of nitrogen fertiliser can induce losses through ammonia volatilisation, and hence, considerable loss of investment.

While expected rainfall information is most crucial for most farming operations, certain other decisions require information on dry weather and wind. These include, for example, operations for pasture and fodder management involving hay making and silage and crop spraying.

For crops such as groundnut which need to be pulled out for the harvest, small showers before the harvest can render the operation faster and much easier. On the other hand, farmers tend to 'field dry' the produce of most dryland crops after harvest and heavy rains at this time could cause considerable economic losses.

2.4. Services to help reduce the impact of natural disasters, including pests and diseases

Natural disasters play a major role in agricultural development and the economic cost associated with all natural disasters has increased 14-fold since the 1950s. During 1993–2002, hydro-meteorological disasters caused an estimated damage of US$ 41.3 billion per year on average (UNEP 2004). According to Johnson (2003), in a survey of the impacts of extreme weather and climate events on agriculture, the events which were reported by most of the 57 countries around the world which responded included drought (91%), local severe storms (83%), floods (79%), frost (74%) and high winds (72%). The Plan of Implementation of the World Summit on Sustainable Development (WSSD) held in Johannesburg in 2002 highlighted the need to mitigate the effects of droughts and floods through such measures as improved use of climate and weather information and forecasts, early warning systems, land and natural resource management, agricultural practices and ecosystem conservation in order to reverse the current trends and minimize degradation of land and water resources. WSSD noted the need to promote the access and transfer of technology related to early warning systems and to mitigation programmes to developing countries affected by natural disasters.

In addition to the specific information and services listed above, information on threshold values of certain meteorological variables that favour the incidence of pests and diseases is also often sought. Simulation models are being increasingly used to forecast the onset and severity of pests and diseases and in most developed countries, this information is being provided on-line.

2.5. Agrometeorological advisory services

According to Gommes (1998), important contributions to improve agricultural production and food security in developing countries can be achieved by more efficient agrometeorological advisory services to farmers to stabilise their yields through management of agroclimatic resources as well as other inputs (fertiliser, pesticides).

2.6. Services to help reduce the contributions of agricultural production to global warming

Through agricultural activities (e.g. land clearing, cultivation of annual crops, irrigation, grazing of domesticated animals), humans have extensively altered the land cover and its properties. The changes affect both physiological (leaf area, rooting depth, stomatal resistance) and physical characteristics (surface reflectivity and roughness) (Raddatz 2006). Forest clearing, in particular slash and burn farming techniques, has resulted in a reduction of global area of forests by almost 20% during the last 140 years (IPCC 2000). This has led to a net release of about 120 Gt C which has contributed significantly to the GHG increase in the atmosphere. Between 1972 and 1992, the world's consumption of chemical fertilisers increased from 73.8 million tonnes to 132.7 million tonnes of nitrogen, P_2O_5 and K_2O (Hopper 1995). It is estimated that the contribution of agriculture to the global loss of nitrogen gases released to the atmosphere is 35% of the approximate 20 Mt released annually. Animal production contributes to the greenhouse gas increase in the atmosphere with the release of CH_4 coming from the enteric fermentation in ruminants, and CH_4 and N_2O from manure.

Desertification is a process of land degradation that affects especially the arid, semi-arid and sub-humid dryland regions around the world (Sivakumar 2007). This process increases the frequency and severity of dust storms: for example, more than 100 Mt of sand is blown every year from the Sahara Desert towards Europe and the Atlantic Ocean. Dust has an effect on climate, both directly through reflection and absorption of solar energy and indirectly by changing the optical properties and persistence of clouds.

Agrometeorological services are needed not only to monitor the above-mentioned changes, but also to develop mitigation strategies to reduce the contribution of agriculture to global warming.

3. Communication of agrometeorological information—status in different regions of the world

In order to assess the current status of preparation of agrometeorological information in different parts of the world and to determine different ways and means to improve the preparation and dissemination of agrometeorological information, the World Meteorological Organization, 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 Barbados from 15 to 19 October 2001 (Sivakumar 2002). Papers were presented at this workshop based on surveys carried out on the current status of the communication of agrometeorological information in different regions of the world. In addition, the Working Group on Communication of Agrometeorological Information of the Commission for Agricultural Meteorology of WMO also presented information on this issue in different regions (WMO 2004). A summary from these two reports on the communication of agrometeorological information by NMHSs in different regions of the world is presented below.

3.1. Africa

In Africa, most of the NMHSs have been in existence for over 20 years except in a few cases where the services are just a few years old. Based on the responses received from 29 NMHSs and four institutions in Africa to a questionnaire, Akeh and Muchinda (2002) reported that all respondents issued agrometeorological bulletins and advisories. The majority of the respondents (75%) issued agrometeorological bulletins on a ten-day (decadal) basis while one quarter stated that they issued monthly bulletins as well. Less than 1% of the respondents issued seasonal bulletins.

More than 95% of the agrometeorological units present their data in the form of text, tables and graphics. 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. The majority of the agrometeorological units (80%) informed that their bulletins are targeted at government agencies, non-governmental organizations, regional and international organizations, whilst the remainder (just 20%) said that their target audience is the research community, farmers, agencies responsible for early warning systems and the general public. It is important to note that 80% of the respondents have not made any effort in obtaining feedback from users. Even for those that have done so, the process of obtaining feedback is not carried out on a regular or systematic basis. In his analysis of the problems faced by the clientele for agrometeorological services in Africa, Isabirye (2004) attributed them to lack of ability to understand raw data and its interpretation for the relevant action, language technicalities, lack of awareness of the importance of the agromet information and lack of timeliness to meet the early warning aspects.

A large majority of the NMHSs in Africa (90%) have not made any efforts to assess the economic value and benefit of the use of information provided in the agrometeorological bulletins. 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 and forest fires.

Besides the NMHSs, the African Centre for Meteorological Application and Development (ACMAD), a regional institution, also disseminates a variety of products to various users. One example is the climate prediction for Western Africa, Chad and Cameroon which is disseminated through its website. The IGAD Climate Prediction and Applications Centre (ICPAC) in Nairobi, a specialised Regional Institution serving Burundi, Djibouti, Ethiopia, Eritrea, Kenya, Rwanda, Somalia, Sudan, Tanzania and Uganda in the Greater Horn of Africa (GHA) region contributes to climate monitoring and prediction services for early warning and mitigation of the adverse impacts of extreme climate events on various socio-economic sectors in the region such as agricultural production and food security, water resources, energy and health among others. The Drought Monitoring Centre (DMC) in Harare serves the SADC countries and is responsible for preparing and disseminating advisories on impending drought and other adverse regional weather patterns to member countries, international and regional institutions. These advisories include 10-day and monthly bulletins as well as seasonal forecasts.

3.2. Asia

There are 34 NMHSs in Asia and based on responses received from 14 NMHSs to a questionnaire, Kamali and Lee (2002) reported that, with the exception of two NMHSs, all respondents issue agrometeorological bulletins and advisories. In most cases, products are targeted at government agencies, large farming and industry companies. Some provide information to farmers.

As in the case of Africa, no systematic effort is made by the Asian NMHSs to obtain feedback from users. Some limited efforts are made to assess the economic value and benefit of the use of information provided (Kamali & Lee 2002). Early warnings are given and distributed to the authorities.

3.3. South America

Information on the communication of agrometeorological information by the NMHSs in South America was collected by Carvajal and da Anunciação (2002) through the administration of a questionnaire sent to different NMHSs in South America. Based on the analysis of information received from eight countries in the region, Carvajal & da Anunciação (2002) concluded that with the exception of two NMHSs in South America, all respondents issue agrometeorological bulletins and advisories. Early warnings are given and distributed to the authorities and farmers. In most cases, products are targeted at the general public, farmers, association of producers, technicians, authorities and commercial companies.

No systematic effort is made by the NMHSs in South America either to obtain feedback from users or to assess the economic value and benefit of the use of information provided.

3.4. North and Central America and the Caribbean

Based on information collected through questionnaires, Solano and Frutos (2002) concluded that in the North and Central America and the Caribbean region, very few NMHSs have independent agrometeorological services. Only Canada, Colombia, Cuba and USA have such services. Few NMHSs issue agrometeorological bulletins and advisories. In most cases, products are targeted at farmers, association of producers, technicians, authorities and commercial companies. No systematic effort is made by the NMHSs to obtain feedback from users. Yearly evaluation is conducted on the cost of preparing the bulletins. Early warnings are given and distributed to the authorities and farmers.

Based on responses received from about 24 contributors in eight different countries, Bootsma (2004) concluded that decisions on the types of agrometeorological information and products that are communicated to users in North/Central America are generally based on knowledge of the principal agricultural production systems that are in place in each region and of the most weather sensitive activities/problems associated with each of these production systems. In the United States, agricultural droughts can be a significant factor affecting crop production, particularly in the mid-west, and operational drought monitoring products have been developed as a result. However, agrometeorological information is also frequently disseminated for decisions in programs to control weather-sensitive insect pests and diseases, particularly in the more humid regions of the country. For Canada, Bootsma (2004) provided a number of examples showing how agrometeorological information is communicated to users and how the user feedback is obtained. In central American countries, agrometeorological products and services seem to be most often in response to needs for information on moisture supply, either its excess or deficits, and the services are typically linked with hydrometeorology programs or national weather services (Bootsma 2004).

3.5. South-West Pacific

Responses received from the NMHSs in seven countries in the South-West Pacific to a questionnaire indicated that, generally agrometeorological services by the NMHSs are provided together with other services (Chan & Whitaker 2002). Only one country has an independent service.

With the exception of Australia and New Zealand, generally, agricultural research and extension agencies are not involved in issuing agrometeorological bulletins and advisories in the South-West Pacific. The Australian Government has continued to invest explicitly in climate variability research and development in recognition of the threats and opportunities that climate variability presents to farmers and resource managers (http://www.managingclimate.gov.au). There has also been substantial investment by state governments, industrial organisations and other research and development corporations (Hassal and Associates 2002). Mullen (2003) provided an excellent description of case studies in Australia where several web sites provide a combination of climate monitoring products as well as outlook information that can be used by those in agriculture—notably, the Australian Bureau of Meteorology web site (www.bom.gov.au), SILO (www.bom.gov.au/silo), Queensland Department of Primary Industry (QDPI) Long Paddock (www.dnr.qld.gov.au/longpdk/) among others. In most cases, products are targeted at farmers, land users, agricultural researchers, extension workers, land development personnel and foresters.

With the exception of Australia and New Zealand, no systematic effort is made by the NMHSs in the region to obtain feedback from users. Developing countries do not assess the economic value of the information provided.

3.6. Europe

Dunkel (2002) obtained responses from the NMHSs in 30 countries and one agency in Europe. His analysis showed that 17 of the 30 respondent countries have independent agrometeorological units. In 19 countries, agricultural research and extension agencies are involved in the preparation of the agrometeorological bulletins and advisories. According to Pérarnaud (2004), the way in which agrometeorological information is developed and distributed in Europe depends on the way in which different actors in the agricultural sector involved in agrometeorology are organized in each country and the interest that the national meteorological service has within this area (and on its relations with agricultural actors). There is also a number of private sector initiatives in providing agrometeorological information (Pérarnaud 2004), which are increasingly becoming important. For example, in Great Britain, the Agricultural Development and Advisory Service (ADAS) in partnership with United Kingdom Met Office (UKMO) produces a specific bulletin every week, which is distributed using different means (post, fax, e-mail).

Elsewhere in Europe, nine NMHSs target farmers in their agrometeorological bulletins and advisories. In seven countries, the target is the government while in 12 countries extension services or private companies were mentioned as the target. Regarding the feedback from the users, some limited efforts have been made. For example, the French Ministry of Agriculture conducted a survey of farmers and advisory technicians in 1996 and 1997. It showed that farmers increasingly want to receive information by fax (Pérarnaud 2004). Most countries do not assess the economic value of the information provided.

4. Need for greater user feedback in improving the dissemination and communication of agrometeorological information

From the overview of the current status of communication of agrometeorological information by the NMHSs in different regions of the world, it is evident that there is an urgent need for greater feedback from the users in improving the dissemination and communication of agrometeorological information. Agrometeorological information can only be useful if it is timely and relevant to actions, which potential users can incorporate into production decisions to improve potential outcomes. Hence, it is important that both the users and providers of agrometeorological information are able to anticipate outcomes associated with each decision option under different agrometeorological conditions. Investment in the provision of agrometeorological information will not achieve the desired outcomes unless the information products are effectively and more broadly adopted by the agricultural sector.

For example, early assumptions about the value of climate forecasts were often exaggerated due to a lack of understanding of the variety of user decision-making environments. An important lesson learned from the past decade of activities in the application of climate forecasts is that users are diverse and cannot be lumped into an homogeneous set (Phillips et al. 2000). The user community for agrometeorological information can be understood in its broadest sense to cover the spectrum from institutions and governments to farmers at the subsistence level. The different categories of users include the farming community, the research community, governmental bodies, private sector, public sector and international agencies.

It is important for the NMHSs to recognize that the content of information varies with the end user. Depending on its purpose, the content of information can be related to special advisories provided to farmers through the national or state extension services, general advisories accessed by farmers directly through the electronic media, early warning advice to prevent famine crisis and the development of agricultural planning policies. Most often, agrometeorological information provided by the NMHSs is not comprehensive. In many cases, it refers only to the 'meteorological' component (i.e. weather conditions, forecasts of future weather events, analyses of past weather). It neglects the 'agricultural' part, which is the linkage between physical and biological parameters. This linkage is required by farmers to make informed agricultural decisions.

Primary producers use agrometeorological information to assist with many decisions on a range of scales varying from days to the entire cropping season to interannual time periods. The decisions relate to crop choice (e.g. wheat if suitable pre-season and seasonal rainfall is expected; sorghum for warmer or drier regimes); choice of cultivar (early or late flowering); mix of crops; fertiliser use; pest and disease control; timing of the harvest; irrigation scheduling; the area planted to a given crop (and/or rotation of fields); timing and amount of tillage; and stocking rates. Strategic planning and marketing decisions mostly use climate information for the next year.

It must be understood that the needs of agribusinesses such as seed suppliers and grain traders vary distinctly from farmers at the local level. Even at the farm level, the goals of subsistence farmers, i.e. self-sufficiency or survival are quite distinct from the profit maximisation goals of commercial farmers. Large farmers mostly have the capacity to invest in costly inputs, labour and equipment and the ability to respond quickly to recommendations on the land allocation and cropping patterns based on agrometeorological information. On the other hand, the small-holder farmers may have many limitations to invest in inputs and need close guidance in implementing recommendations on changing cropping patterns since they usually follow time-honoured cropping strategies that have stood them well in times of extreme climate variability, albeit with low crop productivity. It is equally important to carefully assess the degree of flexibility with which different groups operate in the application of agrometeorological information. As Phillips et al. (2000) explained, family farms potentially have somewhat greater flexibility in shifting the dates for critical activities than those who have to plan their labour needs much in advance or meet production deadlines.

It is equally important to consider the agrometeorological applications to industry as well as primary processors of agricultural produce. It will be necessary to develop a comprehensive profile of these different users including socio-economic data, education status, agroecological characteristics of the regions (with emphasis on the quantitative understanding of the climate risk) where they operate, the nature of climate risk-management strategies they currently use, their access to inputs and information on the nature of climate forecast information they need for on-farm management decisions. Such comprehensive profiles could help categorise the users into different groups based on their vulnerability to impacts of climate variability, develop suitable information products targeted to those who are in a position to benefit from them and decide on the kind of feedback mechanisms that should be put in place to evaluate the products provided to them. It is important to include social scientists right from the beginning in developing these profiles.

To enhance agrometeorological information applications in future, it is important to target the needs of particular primary production and food sectors—where appropriate—at a regional level.

5. Opportunities and challenges in the communication of agrometeorological information

In the past, data were manually observed and manually checked and printed in tables or displayed on maps by the meteorological service. Indices and simple empirical models were used to provide added value to the data. With the advent of computers, data were often punched on cards or typed into a computer data file. Development of software programmes such as CLICOM from WMO made it easy to manipulate the data on the personal computers (PCs) through facilities for data entry, quality control, data management as well as statistical and graphical outputs. Examples of agrometeorological applications based on these data included land use planning and agrometeorological zoning, protection against adverse weather factors, weather information for plant protection, application of meteorological information for fertiliser application, irrigation scheduling, transportation and storage of crop produce, forestry management, animal husbandry and yield forecasting.

Recent developments focussed on Automatic Weather Station networks with automated data retrieval, and analysis. Transfer of climate and weather data in near real-time is frequently done by using telephone lines to connect to data loggers, but satellite transmission is also becoming popular, particularly where commercial services are involved (Bootsma 2004). Data and information are accessed with PCs using computer to computer links. Advances in user-friendly software for PCs contributed to advances in data management, interpretation and information formulation. New relational database management systems have made it easy to store large amounts of data efficiently in an accessible format. Advances in geographical information systems (GIS) have contributed to the analysis of layers of spatial information and facilitated in their interpretation and application. Expert Systems software has advanced to a point where it can provide useful advice for farm management decisions. Decision support systems have been developed that incorporated a range of crop simulation models for decision support. Multiprocess models that combine many individual processes to address agricultural production systems are now available for the PCs.

Information and Communication Technologies (ICTs) and especially Internet communication tools can be effectively used to reach farming communities with agrometeorological information for appropriate decision making (Weiss et al. 2000). Internet provides special opportunities for reports with graphics and allows three-dimensional views and even animation which is not possible with graphics on printed pages. For example, FAO web pages present an animation of Graphic Interchange File (GIF) images depicting 10-day averaged cold cloud duration during West African and Sahelian rainy season. Some organizations provide access to climatic databases online. Webpages devoted to agrometeorology combine diverse and sophisticated information. One example is a cooperative agreement between the National Aeronautics and Space Administration (NASA) and the University of Wisconsin wherein satellite products, numerical weather prediction and crop models are combined to aid agricultural decision making (Diak et al. 1998).

Revolutionary changes in audio-video media in the past two decades make it easy to take the information to users. Changes in radio technology also are having an important impact on the dissemination of information. One of the good examples is the Radio and Internet for the Communication of Hydro-Meteorological and Climate Related Information (RANET) implemented in Africa (Boulahya et al. 2005). Considering the potential that drought monitoring and prediction technologies hold for improving the quality of life in rural Africa, the African Centre of Meteorological Applications for Development (ACMAD) worked with herders and farmers to design the RANET system. RANET is an information and communications support network based on the needs of remote communities and the realities of rural living in Africa (Boulahya et al. 2005). RANET combines data from global climate data banks in the United States, seasonal rainfall predictions from the international scientific community, data and forecasts generated in Africa, along with food security and agricultural information, to disseminate a comprehensive information package via a network of digital satellite receiving stations, computers, radio and oral intermediaries.

5.1. Future challenges for communication of agrometeorological information

While all the above advances made the task of data manipulation, analysis, interpretation and preparation of information easier, the challenge of communicating the right kind of information to meet the user needs remains, even today. User awareness of what information is available, where it can be found and how it can be used in agricultural management decisions needs to be enhanced. Various means can be employed to foster better awareness (Bootsma 2004). Seminars and workshops need to be conducted for educating users. Catalogues of products and services need to be made more readily available. News media need to be made aware of the types of information that the public needs on a timely basis. Much of the agrometeorological information, despite the rapid technological advances, does not reach small farmers with limited means. As was evident from the discussion on the status of communication of agrometeorological information in different regions of the world, one main gap that remains to be addressed is the issue of obtaining user feedback. While agrometeorological information is expected to be used by the farmers, many NMHSs around the world have no adequate mechanisms in place to obtain user feedback as was evident from the discussion presented earlier on the status of communication of agrometeorological information in different regions. It is imperative that this issue be addressed quickly to make sure that agrometeorological information provided to the farming community meets their perceived needs.

There is also a need to integrate the diverse types of agrometeorological data into information useful for the farming communities. The challenge is to produce information that is of relevance and value to the users and deliver it in a timely and appropriate manner so as to assist in the operational decisions of the user. Given the complexity of abiotic and biotic factors that affect crops/cropping systems, it is important to collect diverse types of agrometeorological data and integrated them into usable information. Bootsma (2004) argues that more 'added-value' information is needed in some cases, such as interpretations of data in graphs, charts and map forms and by processing data through models. In other cases where the steps involved in accessing and using the information are too complex, the process needs to be simplified.

An important challenge is the choice of an appropriate medium for communication of information in a rapid and efficient manner. While the Internet is recognized as the most efficient medium of communicating information, problems of access and training for its use still remain as the major stumbling blocks for its use in many developing countries around the world. While ICTs are undergoing rapid changes, the pace of their implementation around the world is quite variable. Strategies for communication of agrometeorological information must take into account the implementation aspect of ICTs and the appropriate medium for communication. A large majority of farmers in the developing countries do not yet have ready access to the Internet, and consequently, there is a continuing need to provide information through more traditional means such as radio, television and newspapers. Greater acceptance of computer technology and the Internet needs to be developed to deliver more information in a timely fashion to the user and so that more 'added value' can be derived from data products. Specialised target communication efforts that utilize local media such as radio are needed, as demonstrated by the success of RANET in Africa.

Given the costs of dissemination and communication of agrometeorological information to the end users, it will be important to investigate the potential of public/private partnerships to provide different details of agrometeorological information at different prices to a range of end users (Kruger & Dommermuth 1999).

6. Conclusions

The growing world population and the pressing need to increase and stabilise agricultural production to meet the increasing demands for food emphasise the necessity to make more efficient use of natural resources while ensuring at the same time the conservation of environment. NMHSs have much to contribute in addressing this priority and their timely availability could facilitate both strategic and tactical decisions in increasing and sustaining agricultural production. A better understanding by the NMHSs of the user needs is needed to provide agrometeorological information in a timely and useful manner. Sophisticated and effective climate prediction procedures are now emerging rapidly, and through the Regional Climate Outlook Fora, they are finding increasingly greater use and applications in different parts of the world. Availability of crop simulation models in a decision systems framework is making it possible to generate alternative decisions for field applications. Comprehensive profiling of the user community in collaboration with social scientists and regular dialogue with the users could help identify the opportunities for better communication of agrometeorological information. Active collaboration between NMHSs, agricultural research and extension agencies and non-governmental organizations in developing appropriate products and processes and more effective communication processes for the user community is essential.

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