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Status of Agrometeorological Information and Dissemination Networks

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농업기상 정보 및 배분 네트워크 현황

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ABSTRACT

There is a growing demand for agrometeorological information that end-users can use and not just interesting information. To achieve this, each region/community needs to develop and provide localized climate and weather information for growers. Additionally, provide tools to help local users interpret climate forecasts issued by the National Weather Service in the country. Real time information should be provided for farmers, including some basic data. An ideal agrometeorological information system includes several components: an efficient data measuring and collection system; a modern telecommunication system; a standard data management, processing and analysis system; and an advanced technological information dissemination system. While it is conventional wisdom that, Internet is and will play a major role in the delivery and dissemination of agrometeorological information, there are large gaps between the "information rich" and the "information poor" countries. Rural communities represent the "last mile of connectivity". For some time to come, TV broadcast, radio, phone, newspaper and fax will be used in many countries for communication. The differences in achieving this among countries arise from the human and financial resources available to implement this information and the methods of information dissemination. These differences must be considered in designing any information dissemination system. Experience shows that easy access to information more tailored to user needs would substantially increase use of climate information. Opportunities remain unexplored for applications of geographical information systems and remote sensing in agro meteorology.

Key words **: agrometeorological information system, Internet, information dissemination, operational agriculture, Information network, EWS**

I. INTRODUCTION

Given that livelihood of most rural households, in most parts of our world, depends on rainfed farming it is hardly surprising that agricultural communities always express strong interest in agrometeorological information (AMI). AMI is part of a continuum that begins with scientific knowledge and understanding, collection of data, changing data into useful information, dissemination of information, and ends with products that are used and evaluated by end-users. While scientific knowledge and understanding transcends national borders, the remaining components of this continuum may differ from developed and developing worlds. The reasons for these differences are mainly a function of human, financial, and natural

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resources. In order for this information to be useful, it must be accurate, timely, and cost effective; i.e., the benefit to be gained from implementing the information is greater than the cost to obtain the information. In this paper we present examples from a few countries as case studies to illustrate the type of the efforts several nations have made to create and disseminate agrometeorological information (AMI) to assist agricultural communities to manage climatic variability, a major source of risk in many human endeavors. These examples illustrate the different approaches that can be used to generate and communicate agrometeorological information. It is not an exhaustive list and we understand that this is an area of rapid change.

Attention to differences and similarities between nations can help nations improve their current AMI systems. There have been significant and increasing efforts devoted in various parts of the world to applying agrometeorological information to improve agricultural systems. The successful efforts call for a concerted research effort, integrated across the physical, biological and social sciences, to bridge the gap between available agrometeorological information and the information needs of stakeholders. Our examination of patterns of use of AMI indicates constraints and suggests opportunities for the useful application of AMI in the future. It is impossible to discuss AMI services around the globe. We have rather chosen few (based on our limited knowledge) as candidate to explain what they do and do not. Several meteorological and climatological databases can be easily accessed from the Internet. An extensive list can be found at: http://dss.ucar.edu/other_resources/

1.1. Nature of operational agriculture

Agricultural production is for a large part still dependent on weather and climate despite the impressive advances in agricultural technology over the last half a century. More than ever, agrometeorological services have become essential because of the challenges provided to many forms of agricultural production by increasing climate variability and associated extreme events as well as climate change, all of which affecting the socio-economic conditions, especially of developing countries. Detailed observ ations/monitoring and real-time dissemination of meteorological information, quantification by remote sensing (radar and satellites) and derived indices and operational services are important for tactical Agrometeorological decisions in short term planning of agricultural operations at different growth stages. A well organized, where possible automatic production and a co-coordinated dissemination of this information and related advisories and services are essential. Operational decisions include timing of cultural practices, such as ploughing, sowing/planting, mulching, weeding, thinning, pruning and harvesting. They also include decisions such as the application of water, extensive chemicals and the operation of costly crop protection measures.

Regardless of the type of decision, an ever improving understanding of the effects of weather and climate on soils, plants, animals, trees and related production in farming systems, is necessary for decision makers (farmers and managers), to make timely and efficient use of meteorological and climatological information and of agrometeorological services for agriculture. To these ends choices have to be made of the right mixture and blending of traditional adaptation strategies, contemporary knowledge in science and technology and appropriate policy environments.

1.2. Where agriculture is heading?

We started to think of this topic by raising a question. How well prepared are meteorologists to provide agricultural weather services for the future? Before we try to answer the questions, lets consider where agriculture is headed. Most parts of the world, relatively speaking, the number of farmers is shrinking. Growing concerns for food quality protection and water rights disputes are raising the cost of agricultural production. Concerns about agricultural production have gone through several phases: starting with quantity, quality, and now, efficiency. Technology, including specialized weather support, has helped farmers in developed countries overcome many hurdles, and "efficiency" is the most recent concern of farmers. To operate more efficiently, more farmers are turning to "precision farming" practices. Precision farming is a data intensive practice which almost continuously monitors and analyses both the physical and environmental factors affecting crop production. It is accomplished at such a scale that no data pertaining to a significant piece of farmland would be overlooked. The results of this monitoring and analysis are used as management tools to produce the highest quality crop possible on every piece of ground. The scale of monitoring and management define how "precise" the farming will be.

So what does this mean to the agricultural weather forecaster? There will be an increased need for monitoring of weather data and transmission of same back to analysis programs. Farmers shifting into precision farming may acquire blossoming data networks where heretofore there was a dearth of observations. Such information may swamp current data collection techniques by weather forecasters. In addition, this will likely also require that forecast resolution match the observations. A network for a small grower (few 10s acres), may require a finer-than-mesoscale forecast. Obviously, precision farming will bring many challenges and opportunities to those involved in agricultural weather prediction.

1.3. Information needs: critical Issues

We need information that people are willing to listen and not just interesting information. The practical application of agro-meteorological knowledge is linked to the availability and accuracy of weather and climate forecasts or expected weather and climate patterns, depending on the time scale. The requirements range from accurate details of short-range weather forecasts (less than two days), medium range forecasts (less than ten days) at certain critical times to seasonal predictions of climate patterns. To ensure that development plans are not rendered meaningless by a significant change in weather and climate behavior, indications of possible climatic variability, and of increasingly frequent and serious extreme events in the context of global climate change, are necessary as agrometeorological services in addition to the application of other Agrometeorological information. Continued improvement in communicating agrometeorological information to farming communities requires addressing several critical questions.

1. **How can diverse types of agrometeorological data be integrated into useful information that responds to the often-dissimilar application needs of farming communities?**
   In the strict sense of the word, data and information are two kinds of things. Real time information should be provided for farmers, including some basic data. But national meteorological services should put increasing emphasis on how to change data into diverse useful information, i.e., further analysis of basic data needs to be undertaken to meet different end-users need. Agrometeorologists change data into information through whatever tools are available, currently through the use of computer-based technologies. In addressing the first question, we must begin by considering the training of agrometeorologists. Training in this area should include an appreciation of the complex interactions of biotic and abiotic factors as plants and animals develop and grow. This addition to the traditional training of agrometeorologists is necessary to provide a larger perspective to the transformation of data into useful information. An ideal agrometeorological information system includes several components: an efficient data measuring and collection system; a modern telecommunication system; a standard data management, processing and analysis system; and an advanced technological information dissemination system. In other words, data management, processing and analysis system is the key of whole system, data collection and transmission is the foundation, information dissemination is the final goal. Therefore, we must further enhance the data analysis level and information delivery technology (Weiss *et al.* in 2000).
2. **What types of information are needed by diverse groups of end-users and, given their different farming, socio-economic and cultural systems, which are the appropriate communication technologies to reach them?**
   The information needed for diverse groups of end-users growing crops or raising animals is basically the same. The differences arise from the human and financial resources available to implement this information and the methods of information dissemination. These differences must be considered in designing any information dissemination system.
3. **How to enhanced capacity to forecast and timely deliver of weather that could negatively affect crop yields in order to allow producers to take preventive actions?**
   Producing more in a favorable year may lead to lower market price and reduced profit in todays global economy. To achieve this, each region/community needs to develop and provide localized climate and weather information to growers. Our thinking on this is to develop climate statistics for available weather stations using historical data classified by ENSO phase (or any other proven trigger) so an advisory can be

generated. Another possibility is to translate the climate forecasts from a regional/global center and produce statistics for use at local scales. Additionally, provide tools to help local users interpret climate forecasts issued by the National Weather Service in the country.

4. **Practical approaches for pesticide and fertilization to reduce inputs, increase efficiency of input use, and decrease risk to environment.**
Develop methods for reducing influence of weather and climate variability on nutrient losses from intensively managed crops. For this objective, a close collaboration should be developed between faculties of agriculture, environment, climatology, and hydrology to document if and how rainfall events can cause large losses of nutrients from the soil. This information can be used to analyze potential for climate forecasts to aid in managing fertilizers.

5. **Develop and improve techniques for planning, breeding, etc. that addresses production challenges associated with year to year and regional variations in climate.**
Develop a risk assessment tool for several crops for use by farmers and their advisors in planning production decisions. Such tools could use web-based crop simulation models that will allow users to address production related decisions. This tool will provide information, before the season (using historical or forecast data), within season (using a combination of real and historical or forecast data) about production risks associated with climate variability. The questions to be addressed by such a tool may vary from region to region as the issues change. Few examples may include, should a farmer withdraw land from production/irrigation and what is the cost of making this decision? Or should management practices be modified to reduce risk under rainfed conditions, or should a different crop be planted? 3) What are the risks of using climate forecasts for guiding these decisions relative to use of climatology?

6. **Given diminishing public support for agricultural advisory services, what alternatives exist for the communication of agrometeorological information and under which circumstances can it be provided on a fee basis?**
First, as much as possible, agricultural advisory services must accurately document the added value and impacts of these services. This should be done as a proactive rather than a reactive position. The documentation should include the monetary value of the information, if used properly. Just because accurate information is disseminated doesn't mean that it will be used or used properly. Included in this documentation should be detailed descriptions on changes in positive behavior (impacts). This documentation may positively influence government funding or funding from other sources. The information must be prepared by agrometeorologists in a way that the majority of users will easily understand. Then it can be adapted and sent to key communication outlets such as radio, television, newspapers, bulletins, specialized information networks and web sites for broad-scale as well as targeted dissemination. From the perspective of these media outlets, the information must also have a value, a different value than intended for the end users. Various types of users may buy the products advertised by the different media outlets or subscribe to information services.

7. **What are the training needs of end-users and of the various intermediaries that provide them with advisory services?**
Before the training needs of end-users and intermediaries can be addressed, the question of motivation for users to access and use the information should be discussed. Farming is a long-term business, and like any business, its practitioners want to be successful. Given this perspective, what information is needed? What information is already available? What information needs to be provided? Of the information that needs to be provided, what information is of primary importance, secondary importance, etc? Addressing these questions requires assessments of the information needs and resources of specific groups within the diverse user community. In order to facilitate the communication of information to the user community, social scientists should interact with agrometeorologists to provide a

structure for the information that is suited to the target audience.

II. AGROMETEOROLOGICAL INFORMATION NETWORKS

There are different levels of agrometeorological networks in the world. Generally speaking, national is the highest and its information is provided for all the public and departments of government and management. State or provincial is the second in most countries, such as in America and China, their services are to local government and farms. Most of agrometeorological information delivery is under the meteorological services. But other information providers exist and have a great influence, i.e. many universities and research institutions are also involved in this field, especially in North American and Europe.

No matter whether its a developed or developing country, many agrometeorological websites are established and are widely used. But there is some difference in using efficiency among different countries. Because of economic problem, the users are mainly government and management department in developing countries, farmers only a small part of end-user community. For developed countries, most of end-users are farmers. In reality, the selection of information transferring channel has an influence on the efficiency of the use of information products. In developing countries, radio broadcasts of agrometeorological information to end-user farmers have a great effect for providing timely suggestions at the local level.

2.1. Information content and kinds

Rijks *et al.* (2000) divided the possible agro meteorological products into three groups: Basic data; Basic data together with an analysis and/or an advisory message for specific applications, possibly combined with non-meteorological data, such as those derived from remote sensing. These products cater information that is either generic or special. The generic information is used as a common way to public service, for instance, daily weather forecast and meteorological elements information (i.e. high and lows of temperature and humidity, etc). Most people turn to weather reports to help plan their days. If rain is predicted, you take along your umbrella. If a warm, sunny day is expected, you feel safe leaving the umbrella at home. But accurate, local weather data has many more far-reaching applications. Many users need special information services for special purpose, such as agrometeorological hazards mitigation or pest, disease and irrigation advisories to farmers. We found many examples of such services on the internet. For example an apple grower needs to know the degr‐e days, to determine when the cottling moths are layi‐ their eggs and may start feeding on the apple leaves. nchecked they can devastate an apple crop. Growe‐ ‐se degree days information to plan when and how c‐ ‐ to spray the apple crop to make the chemicals mo‐e effective and makes sense both economically and environmentally. In areas where crops have to survive through winter, farmers rely on knowing early the wind direction and speed data which gives them time to get protection ready and fired up.

In most agrometeorological web sites we visited, the information for users is real time, basic meteorological factors determining the atmospheric environment. This information, in fact, is only data, not information. Data and information are two different things for end-users. Some information services give detail information, not only meteorological data, but agrometeorological information (analyzed meteorological and agro meteorological products) also, such as suggestions for future weather, crop growth and development condition and analysis of weather impact on crops. In addition to these, few developing countries provide information on vegetation (crop) growth condition and soil moisture condition. State-of-the-art monitoring and information technologies will help farmers make more-informed decisions. Better decisions can result in higher yields; reduced production costs; more-efficient use of resources, such as water; and less pollution.

2.2. Global networks

FAO's Global Information and Early Warning System on Food and Agriculture (GIEWS) - In many countries, particularly in Africa, FAO has helped governments establish specialized units for food security monitoring. These units act as focal points within governments for collecting, processing, and communicating information on all the key variables that influence food security. These units are basically an international mechanism to avoid famine situations, and are therefore mainly situated in sub-Saharan Africa, where food insecurity is endemic. The methodology followed by GIEWS is a well-established methodology of food security assessment, which is based on crop condition monitoring at regional and national levels and monitoring of food security at global, national, and sub national levels. The crop condition monitoring relies on agrometeorological models, fed by data from meteorological networks, and supplemented, in data-sparse areas by low-resolution satellite imagery products, particularly cold cloud duration, as a proxy for rainfall, obtained from Meteosat, and the Normalized Difference Vegetation Index (NDVI), as an indicator of crop stage and condition, obtained from NOAA. At the national level, GIEWS monitors in particular a group of some 80 "Low-Income Food-Deficit Countries" (LIFDCs), in which food security is particularly vulnerable to crop failure or high international cereal prices. The main focus of this analysis is on cereals because unto-date information on other types of food is often weak in many countries. At the sub national level, the system focuses on vulnerable population segments and monitors indicators of food crisis such as local market food supplies, retail price rises, and evidence of individual and community responses to food insecurity. Such responses are sometimes referred to as "coping strategies" and include unusual sales of livestock or other assets, migration in search of food, consumption of wild foods that are not part of the normal diet, and a reduction in the number and size of meals. When they are available, data on malnutrition indicators are also monitored. The GIEWS produces a wide range of regular reports, which cover global and national food security outlooks and are frequently updated. Some of these reports focus on particular regions, such as sub-Saharan Africa and the Sahel. Special reports and alerts are issued when food security emergencies arise in particular countries.

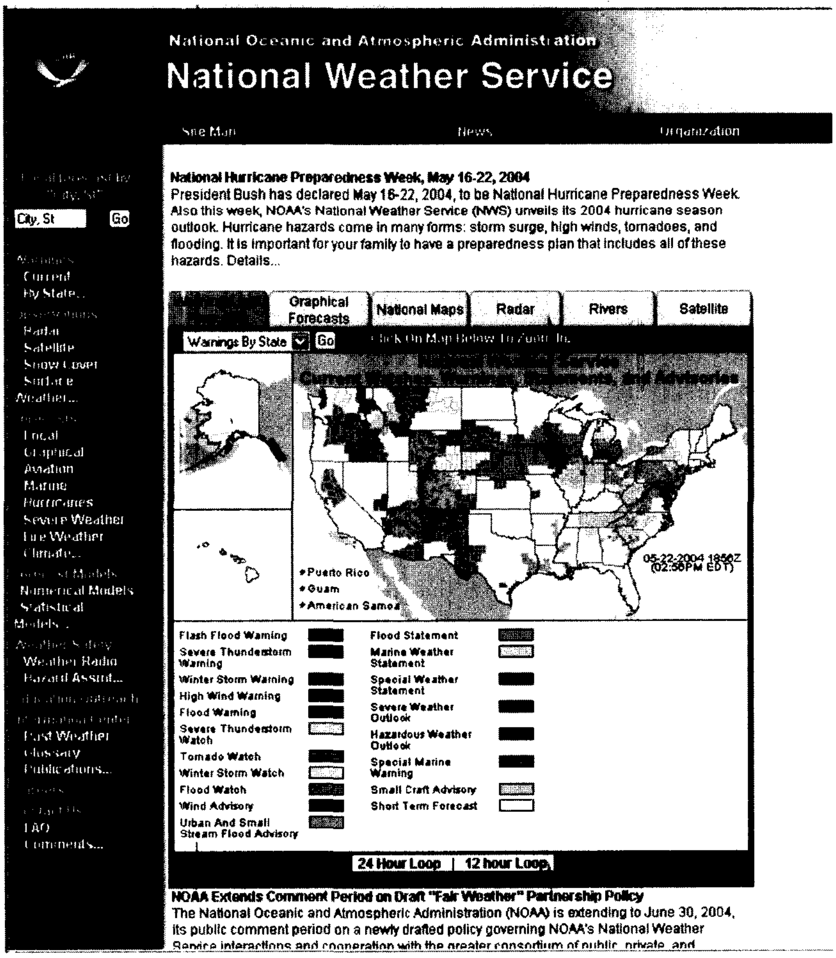

Fig. 1. The US National Weather Service home page showing range of products and services offered at no cost.

http://www.fao.org/giews/english/giewse.htm

2.3. National networks United States of America

United States National Weather Service (NWS) provides weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters and ocean areas, for the protection of life and property and the enhancement of the national economy from its home page (http://www.nws.noaa.gov/) illustrated in **Fig. 1**. NWS data and products form a national information database and infrastructure which can be used by other governmental agencies, the private sector, the public, and the global community. It is accomplished by providing warnings and forecast of hazardous weather, including thunderstorms, flooding, hurricanes, tornadoes, winter weather, tsunamis, and climate events. The NWS is the sole United States official voice for issuing warnings during life-threatening weather situations. Traditionally, the National Weather Service (NWS) was a major information provider to agriculture in the USA. The NWS forecast offices routinely had provided (a) forecasts of agricultural weather parameters to farmers (b) agricultural advisories for major crop areas (advice for the management of crops due to current or expected changes in the weather), (c) fruit frost forecasts, among other services. In addition, the NWS financially supported several university efforts to provide operational agricultural weather support to their state's growers and farmers, as well as support to specialized agricultural weather observing networks, which provided much of the basic data to which forecasts were applied. However, after more than a century of support, the NWS discontinued specialized weather services to U.S. agriculture in 1996 due to financial reasons.

There is some revolution in few developing countries, such as the USA, where rapid transformation is taking place in terms of who is to deliver weather information. Since that time agriculture has adjusted to a variety of solutions to offset this loss. Among these have been (in no particular order): establishment and/or expansion of a number of private weather companies; more reliance on the public weather forecasts provided by the NWS; use of basic meteorological data provided on the Internet, including sophisticated state or university run observation networks; more reliance on weather forecasts provided by the media; and of course, in many areas, less reliance on weather forecasting in general. In the area of observational networks, many of the specialized agricultural observation sites remain discontinued. However, some have been taken over by private companies, farmer cooperatives, and state or university management. Some old non-NWS networks have been expanded and a few new networks have been established. The before-and-after lists above are not meant to be comprehensive, but merely show the magnitude of the change that has occurred over the last several years, with respect to weather support to agriculture in the USA. How well have non-NWS entities responded in providing needed weather service to agriculture? The answer is that on a national scale, we don't know. For one, management of agricultural weather services is more fragmented today than it was prior to 1996. It is more difficult to determine who-does-what in the agricultural weather support arena.

Following discontinuation of NWS services, many regional weather networks were created at the request of various grower organizations. For example, in the absence of such a system in the state of Florida, a devastating freeze in January 1997 caused over $300 million damage to the citrus crop (Jagtap *et al.*, 2002). These networks provide an ideal framework for incorporating climate information and management aids targeted for specific commodities or clientele. The Georgia Automated Environmental Monitoring Network (www.GeorgiaWeather.Net) has grown from four stations in 1991 to 57 state-of-the-art weather stations today. One of the main goals of this network is to collect weather and other environmental data in locations where agriculture is an important economic activity. This not only includes traditional agriculture, such as row crops, but also fruits and vegetables, ornamentals, turf for golf courses and recreational activities, and other non-traditional agricultural operations. Each records data every second on air temperature, soil temperature at three different depths, soil moisture, solar radiation, wind speed and direction, and precipitation (**Fig.** 2). Some stations also record pan evaporation and leaf wetness. The entire system is powered by battery, which is recharged via a solar panel during the daytime. Every 15 minutes, the individual station calculates and stores a data summary, which is transferred to its headquarter, and back out to the Internet. Web site visitors can access information close to the time the station collected it. At midnight, the station summarizes the days data and calculates the maximum and minimum temperature and total rainfall.

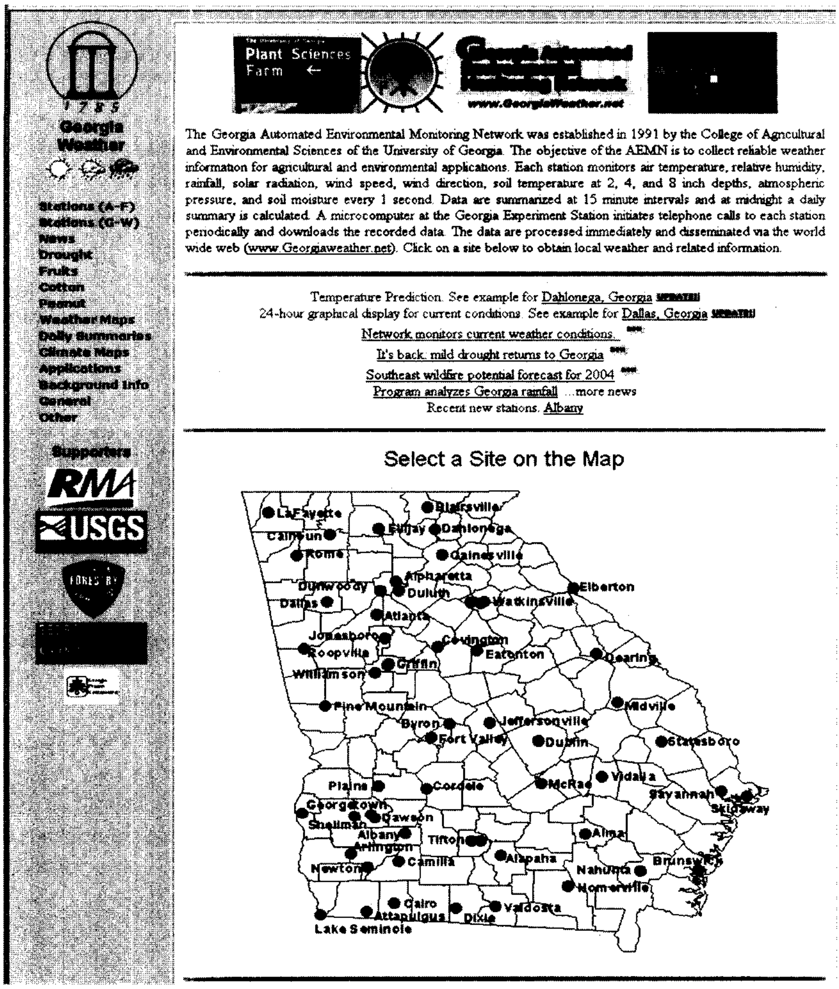

Fig. 2. Example of a local agrometeorological service provider in Georgia, USA.

Besides current and historical weather data, the web site also includes several weather maps. These maps are based on an interpolation of the individual station data, using various software programs. Maps are provided for all weather variables, including temperature and rainfall, and are updated daily as current data become available. The website also provides tools to make better decisions for irrigation scheduling, pesticide applications and planning for harvest (using degree days). The reliability of the data collected by the network has already helped researchers to prepare groundnut (peanut) leaf spot advisory, which combines recent rain events with a five-day forecast to better time fungicide applications. With the recent droughts, water is now a precious commodity and as a result, weather data and associated applications for drought management are becoming prominent on many websites. The most dynamic applications are the model-based products, which link computer models to the weather data. Some examples include a water balance calculator, in which the user can define the period for which to conduct the calculation; a degree day and a chilling hour calculation, for use by utility and heating and air conditioning companies. Other states have similar commercial services, but Georgia is one of the few that provides the data and analysis free on the internet. In reality, it isn't totally free because they have direct and indirect financial support form many business, and agencies, while the University of Georgia foots most of the bill for the network by providing salaries for people who help monitor and maintain the weather stations across the state. But the most important thing is that the information at no charge to anyone who needs it. It is all there on the website and can be retrieved remotely. All it costs the farmer or user is a little time.

Brazil - In Brazil, two systems have been developed by the National Institute of Meteorology (INMET) for dissemination of meteorological and agrometeorological information. They are "VISUAL TEMPO" and "VISUAL CLIMA". The first system allows the user to have access, through different modalities (BBS or Internet), to real-time meteorological information as weather forecast or satellite imagery. Through the second system, the user can have access to the agrometeorological information as published in the decadal and monthly bulletin. The software to get access can be downloaded free, (http://www.inmet.gov.br/frameset.htm). Also in Brazil, the National Confederation of Agriculture (CNA), in collaboration with the Council of the Small and Mid-Size Enterprise Supporting Service (SEBRAE), has implemented an Internet system called "SIAGRO" providing useful information about prices, weather, databases on rural legislation and crop and animal protection laws and measures. (http://www.siagro.com.br/siagro/ClimaTempo.html).

Europe - The United Kingdom of Britain's Met Office has a range of forecast services designed to help farmers and growers plan their day-to-day activities, in a cost-effective manner. Cost-effective services that help the agriculture industry to minimize loss and maximize profits, designed for farmers, growers, market gardeners, horticulture, floriculture and agrochemicals, now deliver forecasts direct to mobile phone or other digital handset using WAP (wireless application protocol) capabilities and the short message service (SMS). The users can receive forecast by phone, fax, web sites or from a Met Office forecaster directly. Tailored consultancy and weather/climate data services are provided to agrochemical companies and other organizations, too. SMHI (Swedish Meteorological and Hydrological Institute) offers extensive services. AgriMet provides weather-related information, ideal as decision-making basis and as model database for Individual farmers, Service organizations, Institutions such as agricultural advice centers, Forestry management officials. AgriMet offers the following products in Sweden and Finland: 3-6 hours precipitation forecast (from radar), 12-18 hours forecasts, 5-day forecasts, 10-day forecasts, Risk frost next night, Graphs weather statistics for cities, Animation radar image every half hour, Satellite image Scandinavia and Europe, Met Direct - quick-access meteorological service. The "AgroExpert" Disease Forecasting System developed by Adcon Telemetry GmbH (http://www.adcon.at/Products/AgroExpert.html) is a complex system intended to reduce the amount of chemicals used in the treatment of plant diseases. Basically, the system uses climatic data which is processed according to rules developed by plant protection researchers, to establish the optimum time for chemical treatments. The system has been used in northern Europe for the past five years. It employs a network of solar-powered weather stations to monitor rainfall, humidity, temperature, leaf wetness and other factors. Farmers can be contacted by phone or pager, or can access the system directly via a PC and modem to determine the optimum time for chemical treatment.

Sudan - Sudan Agrometeorological Information System (SAMIS) was developed in 2003 collaboratively by the Dept Meteorology of the University of Reading in collaboration with the Sudan Meteorological Authority with funding from the World Food Program (Sudan) Vulnerability Assessment and Mapping Unit. SAMIS is an operational system to produce agro-meteorological information from meteorological ground station and satellite data (METEOSAT and NOAA). SAMIS is operated at the Sudan Meteorological Authority (SMA) and at the Sudan Early Warning Unit of the Humanitarian Aid Commission (SEWS) and outputs a set of information products relevant to a range of user institutions involved in the management of agricultural, hydrological and environmental resources. SAMIS has a network of 28 meteorological synoptic stations that provide daily gauge rainfall, maximum and minimum temperature, wet bulb temperature, sunshine hours and wind speed. This data is used in the preparation of 10 day rainfall estimates (gauge rainfall) and 10 day potential evapotranspiration (PET) values. A variety of products are produced and published on the internet including: daily, decadal rainfall, length of dry spells, etc. (http://www.mundo.u-net.com/samis/smaintro.htm)

China - In China, there are many internet web sites at three levels for the dissemination of meteorological and agrometeorological information. The three levels are national, provincial and districts respectively. For meteorology service to agricultural, many provinces have built the agricultural economical networks by meteorological bureau. And its content includes meteorological and much agricultural information for farmers. The national agrometeorological information service is under NMC (National Meteorological Center) websites (http://www.nmc.gov.cn). 10-day and monthly Agromet Bulletins are released at fixed interval. The contents are the past 10-day's weather condition (rainfall, temperature and sunshine), crop development status and weather's effect on crop, agrometeorological hazards, future weather outlook and suggestions for farmers, and some figures and tables about agrometeorological factors were attached (http://www.nmc.gov.cn/agro/). The products derived from remote sensing data, agricultural drought, crop growth condition and yield estimation and winter wheat area evaluation, are also in the site (http://www.nmc.gov.cn/remote/). In provincial level, agro meteorological information, in general, is part of the Provincial Meteorological Networks. For example, as a column, agrometeorological information of Hebei Province was in the Hebei Meteorology Internet. It includes agrometeorological information, forecasting information, remote sensing monitoring products etc. The special agrometeorological website is also existed, e.g. Tianjin Agricultural Meteorological Information Network (http://www.tj-aminfo.com). It provides real-time agrometeorological bulletin (decadal and monthly AgroMet bulletin) and agricultural remote sensing information as crop growth condition, drought (soil moisture). In addition, other items like crop meteorology, agricultural climate and meteorological knowledge are all included for viewers. The user can access freely. But for the special service, the registered user can access the web site by his/her name and password. He/she could

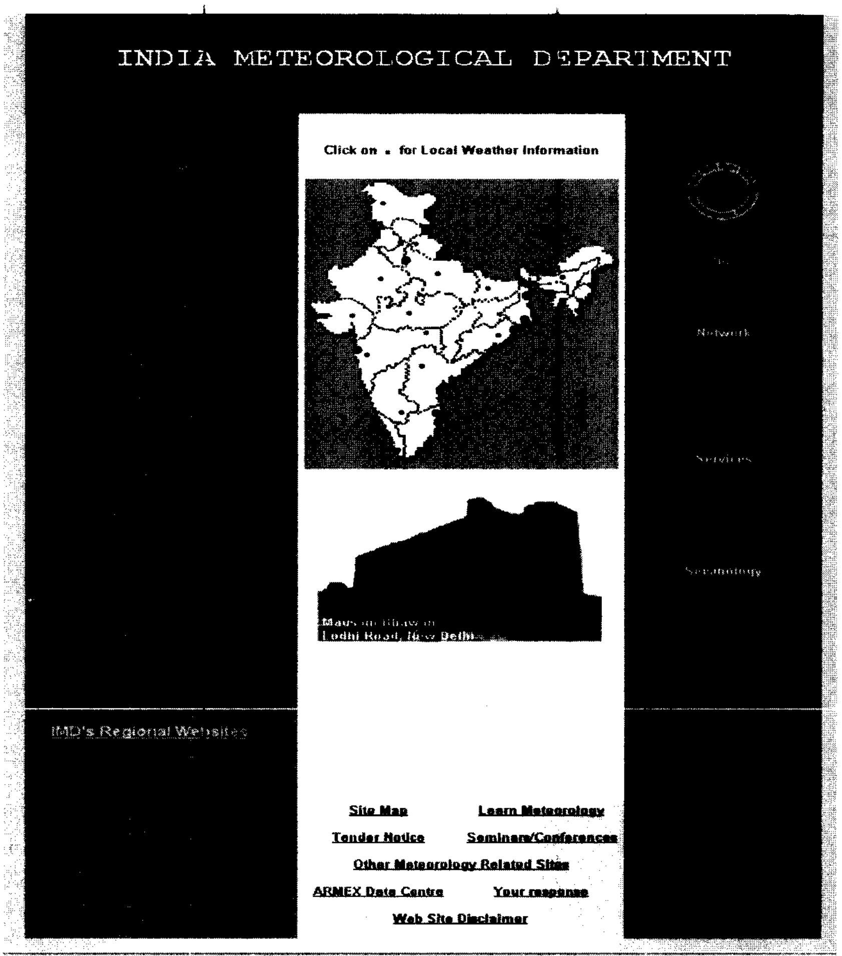

Fig. 3. Example of agrometeorological service provider from Asia.

obtain much more service according to the contract with the meteorological departments.

India - The India Meteorological Department (IMD), established in 1875, is the National Meteorological Service of the country and the principal government agency in all matters relating to meteorology, seismology and allied subjects. Many of IMD's activities are reflected on their home page shown in **Fig. 3**. It is responsible to take meteorological observations and to provide current and forecast meteorological information for optimum operation of weather-sensitive activities like agriculture, irrigation, shipping, aviation, offshore oil explorations, etc. It is also responsible to warn against severe weather phenomena like tropical cyclones, dust storms, heavy rains and snow, cold and heat waves, etc., which cause destruction of life and property. IMD provides meteorological statistics required for agriculture, water resource management, industries, oil exploration and other nation-building activities. There are two type of agrometeorological information for farmers in India. One is Farmer's Weather Bulletin. Crop weather calendars for different crops are prepared to use as a guiding tool for the preparation of Farmers' Weather Bulletin issued daily by the different meteorological centers of the country. These calendars depict the state and stage of crop, normal weather conditions and warning to be issued based on forecast weather parameters. The calendars also give a ready form of weather elements detrimental to crop in various developmental and growth stages. The Bulletins are issued daily by IMD's (India Meteorological Department) forecasting offices for broadcast in different regional languages through the stations of All India Radio in their evening programmes for farmers. A second bulletin is issued for broadcast in the morning during the rainy season. The bulletins are also published in newspapers. Weather Bulletins provide a district-wise forecast of weather during the next 48 hours, with an outlook for the following 2 days, taking into account the effects of weather on crops grown in their respective regions. Agrometeorological Advisory Service is prepared by IMD twice a week in consultation with agricultural experts of the State Agricultural Departments. They are broadcast by AIR stations and also telecast by Doordarshan. The advisories contain, besides information on past and expected weather, specific advice to farmers on what agricultural operations they may undertake in the context of these weather conditions. The agrometeorological advisories are very useful to farmers for scheduling of irrigation to save water, and choosing the optimum timing for spraying of pesticides, application of fertilizers, etc. http://www.imd.ernet.in/

Australia - In Australia, The Bureau of Meteorology provides several thousand products in a variety of formats using several delivery media. Most products are freely available; however some of the more specialized ones attract a cost recovery charge. For rural interests, meteorological and agricultural information were provided (SILO). Its products are weather reports, rainfall, drought, temperature, solar radiation, seasonal climate outlook and so on. Some delivery methods are used as world wide web, FTP (above for Free and Registered User access), fax, phone and radio (See : Http://www.bom.gov.au/catalogue; Http://www.bom.gov.au/silo/).

III. EARLY WARNING SYSTEM (EWS)

The need for every society to have an early warning system has been acknowledged for some time in the literature. For example, every region in the world potentially has an overwhelming need for modern and effective drought early warning systems. To develop such systems, challenges have to be met, as related to the reliability of long-range forecasts, selection of appropriate drought indicators, specialization tools, Agroecological characterization, and institutional arrangements. Therefore, attempt should be made to create a centralized source site that would provide users with access to all of the information necessary to develop a timely and reliable climate and weather information and "need based" assessment (i.e. food security, water supply, flooding possibilities, etc) for their state or region.

In the last 10 to 15 years there has been substantial investment in early warning systems. This has been very important in terms of improving the art of early warning, and developing and refining new methodologies and approaches. The U.S. Agency for International Development's (USAID) Famine Early Warning System (FEWS) is the most developed and best known in many countries (http://www.fews.net/). Currently, the World Wide Web is the preferred means of distributing any information. The obvious advantages to using the web are that there are no distribution costs, and the information is instantly available, always current, and free. The obvious disadvantage is that not everyone has access to the web. Users like the simplicity and ease of use. The system must be flexible, allowing it to continually evolve by responding to and incorporating the latest technologies and data available.

3.1. The quest for certainty and quantitative information

Early warning is an art, not a science. A EWS makes predictions based on analysis of available information, inevitably tinged with an element of judgment. The data are never as comprehensive and accurate as the EW practitioners would like, and the earlier the warning, the less certain it will be. This feature of EW sits uneasily with the culture of decision making almost everywhere. This culture is usually risk-averse, seeking quantifiable proof that an emergency is imminent or already exists. Thus, there is a tendency for decision making to be driven by downstream rather than upstream events, to be motivated by hard evidence rather than by predictions.

3.2. Ownership of an early warning information & delivery system

Research shows that who "owns" an information system is critical to how it is used. In other words, the source/provider must be known and trusted. For example, when in comes to drought related issues, donor agencies have frequently been skeptical of early warning information provided by national government, particularly where relations are strained and motives suspected. In effect, donors set up their own parallel early warning systems, only trusting the assessments carried out by them. Examples include Food and Agriculture Organization (FAO), and the World Food Programme (WFP). I have seen, for example, joint assessments involving government, the United Nations, and bilateral donors appear to be increasingly common in countries in sub-Saharan Africa. Although it might be argued that this proliferation of early warning systems enables cross-checking in the interests of greater accuracy, there is also a danger that different early warning systems generate contradictory information, confusing decision makers and delaying a response. The purpose of this partnership should be to develop new products collaboratively and bring together existing products under one umbrella to provide users better information. Such a product would be particularly well suited for use by mainstream media because it represents state-of-the-art scientific expertise, packaged as a timely product. The early warning and the assessment effort should incorporate local and regional experts in a formal review of the product/s before release. This review group could be made up of climatologists, regional representatives of the National Meteorological Service and other federal agencies, regional climatologists from regional climate centers, hydrologists, and agricultural specialists. The advance review of any product by such a group should help ensure the validity of the product by providing some ground truth for data analysis and interpretation, as well as for assessments of current impacts.

3.3. Who should be responsible for EWS?

When responsibility for EW is split between a number of different departments at the national level, the absence of a single EW bulletin providing a clear and consistent message is a hindrance to timely decision making. Institutional arrangements may determine success or failure of EW systems. The key characteristic of well-functioning early warning systems, whether for drought or food security, is that they are small but multidisciplinary and tightly integrated units. Of critical importance for the success of all early warning units is the free flow of information.

3.4. Improving the use of early warning information in decision making

Although there is still scope to improve early warning methodology, the greatest challenge facing many EWS is how to ensure that their information is taken seriously by decision makers and acted on to ensure a timely relief response. There are a number of ways of strengthening this link.

1. First and foremost, the EWS must make its information accessible and easy to interpret, and they must deliver a clear, consistent message to decision makers so that they can act on this information. Although this seems obvious, it can be hard to achieve in practice, if information is patchy and methodologies of different EWS conflict.
2. Early warning information is most likely to be used if it is trusted. And it is most likely to be

trusted if the decision makers have a stake in the system and really understand it. For this reason, it often makes sense for EWS to be jointly funded by key players.

3. To counteract the decision makers' tendency to delay a response until there is hard evidence of a crisis, ignoring genuine *early* warning, a phased response could be promoted by the EWS. An excellent example of this is the US drought monitor which categorizes drought into several categories based on its intensity. This allows agencies to mobilize their resources in the even those threats materializes.
4. For example, where drought is a frequent occurrence, the more that can be done in advance the better, in terms of contingency planning and identifying clear institutional and decision-making responsibility for an emergency response. As far as possible, contingency measures should be integrated into development plans and the development process, so that an appropriate response is expected, indeed is automatic, when drought hits, rather than having to be argued for every time. In other words, bureaucratic inertia works in favor of a response rather than against it.

IV. COMMUNICATION OF AGROMETEOROLOGICAL INFORMATION

As illustrated in earlier sections, many countries have a lot of agricultural meteorological information for farmers and government. The delivery system of information includes the modern INTERNET technology, and general media tools such as TV, radio, phone, fax and newspaper. In the developed countries, automatic weather stations networks have been existed for many years, and the data from these networks have been used in a diversified of applications, e.g., crop irrigation scheduling, phonological and yield forecast, agricultural diseases and pest management decision making. With the development of space information technique, the "3S" technology is used widely and deployed in agrometeorology, especially remote sensing and geographical information systems (G. Maracchi *et al.* 2000). Now, much information is integrated from surface observations and space monitoring. More recently, WAMIS (World Agrometeorological Information Service) is a new web site opened in 2004 by WMO and National Meteorological Services. It is a dedicated web server to make agrometeorological bulletins and advisories issued by WMO Members available to the global agricultural community and to provide training modules to aid Members in improving their agrometeorological products. Six regions are divided according to the geographical location, i.e., Asia, Africa, Europe, South America, North & Central America, and Southwest Pacific. Now, the following countries' agrometeorological bulletin were available on the site, they are USA, Peru, Malaysia, Malawi, Lesotho and Ethiopia. Some of the contents are under construction now (http://www.wamis.org/).

V. DISSEMINATION OF AGROMETEOROLOGICAL INFORMATION

AMI follows several delivery pathways from its creation to their use by end-users. Most countries are establishing a hub-and-spoke model for information generation and delivery at the national, regional and local levels. In this model, the national centers communicate with each other and transfer relevant information to regional centers. Regional center staff creates region specific useful content which is then passed on to sub-regional or local centers. The local centers receive queries from the local residents and transmit information, collected from the regional centers, back to them. An important feature of this model is the strong sense of ownership that the sub-regional communities have developed towards the sub-regional centers. The other key feature is the active participation of end-users in the management of the sub-regional center as well as in using it.

From the most of the agrometeorological services, we found that Internet is the most popular way to deliver information to users. In one hand, the application of computer network technology is extended; on the other hand, the cost of hardware is decreasing greatly. The obvious advantages to using the web are that there are no distribution costs, and the information is instantly available, always current, and free. Users like the simplicity and ease of use. The system must be flexible, allowing it to continually evolve by responding to and incorporating the latest technologies and data available. The obvious disadvantage is that not everyone has access to the web. Other styles of communicating are through TV, newspaper and radio. In addition, fax and phone are used in some countries. With a quick development of IT, new methods as SMS (Short Message Service), WAP (Wireless Application Protocol) are used also.

VI. SUMMARY

Droughts, floods, heat waves, frost and extreme weather all periodically wreak havoc on crops, pastures, and livestock and contribute to environmental damages off-farm. Improved management of climatic and weather risks is central to the profitability of our rural population and the ecological sustainability of its resource base. Applications of climate information in agriculture require easy and often timely access to a vast array of data. Experience shows that easy access to information more tailored to user needs would substantially increase use of climate information. Examples illustrated show the different approaches that can be used to generate and communicate agro meteorological information. It is not an exhaustive list and we understand that this is an area of rapid change. While it is conventional wisdom that, Internet is and will be play a major role in the delivery and dissemination of agrometeorological information, there are large gap between the "information rich" and the "information poor" countries. Rural communities represent the "last mile of connectivity". For some time to come, TV broadcast, radio, phone, newspaper and fax will be used in many countries for some time to come. The information needed for diverse groups of end-users is basically the same. The differences arise from the human and financial resources available to implement this information and the methods of information dissemination. These differences must be considered in designing any information dissemination system. What will limit the generation and dissemination of agrometeorological information in the future is the same that limits it today: the interaction of people, from scientist to extension worker, in the continuum from basic understanding to practical applications. Thus, to prepare for the future now, there must be better integration of the human capital available today. Specifically, we recommend that information and communication technologies be a component of the training of agrometeorologists in order to provide the best possible advice to farmers.

적 요

농업기상정보에 대한 수요는 흥미로운 내용보다는 농업현장에서 사용자가 직접 활용할 수 있는 내용이 점증하고 있다. 이러한 수요에 부응하기 위해서는 지역 또는 집단 별로 소속 농민을 위한 지역특성이 반영된 기후/기상 정보를 개발, 제공하여야 한다. 그리고 최종 사용자가 공식 기상기구에 의해 발표된 기상/기후 예보를 이해하는 데 도움을 줄 수 있는 도구가 제공되어야 한다. 특히 기본이 되는 근간자료를 포함하여 실시간 기상정보도 농민에게 함께 제공되어야 한다. 따라서 이상적인 농업기상정보시스템은 다음과 같은 요소를 포함하여야 한다. 1) 효율적인 자료 관측과 수집 체계, 2) 최신 통신시스템, 3) 표준 자료관리, 가공 및 분석 시스템, 및 4) 첨단 기술정보 배분시스템 등. 향후 인터넷이 농업기상정보 전달과 배분에 있어서 지속적으로 중요한 역할을 수행하겠지만 정보 풍요국과 빈곤국 간의 격차는 날로 심화되어 갈 것이다.

그리고 농촌지역은 정보통로의 가장 끝자락을 의미하는데, 앞으로 많은 나라에서 정보통신 수단으로 TV, 라디오, 전화, 신문 및 팩스 등에 의존할 것으로 보이며, 정보와 배분 수단 확충에 필요한 가용 인적 및 경제적 자원에 따라 국가간에 그 달성 여하에 차이가 있을 것이다. 이러한 차이점들은 농업기상 정보배분시스템 구축설계시에 반드시 고려되어야 한다. 과거 경험에 따르면, 사용자 요구에 적극 부응하는 정보들에 대한 손쉬운 접근을 통해서 기후정보의 활용이 근원적으로 증대한다는 것을 알 수 있다. 지리정보시스템과 원격탐사정보의 농업기상분야 적용도 향후 그 전망이 매우 밝은 분야라고 생각된다.

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