Chapter 9

Agroclimatological Services

WEATHER AND AGRICULTURE

Weather plays the dominant role in farm production. Weather is always variable, and farmers have no control over this natural phenomenon. Climate variability persisting for more than a season and becoming a drought puts great pressure on land and vegetation. Normal land-use and management systems become imcompatible with prevailing climate, and farm production is drastically reduced. Abnormalities such as drought and associated farm losses are not very frequent, but losses due to short-term climate variability and sudden weather hazards such as flash floods, untimely rains, hailstorms, and severe frost do occur year after year. Losses in transport, storage, and due to parasites, insects, and diseases are the indirect results of abnormalities in weather conditions and are a recurring feature. It has been estimated (Mavi, 1994) that, directly and indirectly, weather contributes to approximately three-quarters of annual losses in farm production. Complete avoidance of all farm losses due to weather factors is not possible. However, losses can be minimized to a considerable extent by making adjustments through timely and accurate weather forecast information.

When specifically tailored weather support is available to the needs of farmersand graziers, it contributes greatly toward making short-term adjustments in daily farm operations, which minimize input losses and improve the quality and quantity of farm produce. The seasonal weather outlook also provides guidelines for long-range or seasonal planning and selection of crops and varieties most suited to the anticipated weather conditions (Mjelde et al., 1997).

WEATHER AND CLIMATE FORECASTING

Three types of weather forecasts are prepared by the weather forecasting agencies in most of the countries of the world. These are the short-range forecast valid for 48 hours, the medium-range or extended forecast valid for five days, and the long-range or seasonal forecast valid from a month to a season. Each of these forecasts has a role to play in agriculture. Whereas short-range forecasts are most valuable in daily farm operations, mediumrange and seasonal forecasts are important in longer-term farm operations and planning. Based on these forecasts, farmers can make the best use of favorable weather conditions and adjustments can be made for adverse weather.

Short-Range Weather Forecast

A short-range weather forecast is based on a detailed analysis of the physical processes occurring in the atmosphere. It incorporates information about current weather conditions and forecast information on high and low temperatures, wind velocity and direction, time and amount of precipitation, relative humidity, sunshine duration, and sudden weather hazards. This forecast information is available through television, radio, and newspapers and via the telephone from the forecasting agencies. The information is sufficiently accurate and can be effectively used for many field operations including spraying, hay making, sheep shearing, nitrogen top dressing, and preventing damage from frost.

Extended Weather Forecast (Up to Five Days)

The basis for preparing extended forecast information is similar to that of the short-range forecast, but the forecast is not very detailed. An extended forecast contains generalized information including change of weather type, sequence of rainy days, extended wet and dry spells, and general weather hazards such as cold and heat waves. The forecast information is sufficiently accurate and available from meteorological centers. In Australia, the National Climate Centre (NCC) and Special Services Units of the Bureau of Meteorology prepare extended forecasts. The extended weather forecast is most effective and useful in agriculture as it gives sufficient lead time for both planning and executing farm operations.

Seasonal Climate Outlook or Long-Range Weather Forecast

A seasonal climate outlook or long-range weather forecast is essentially a statistical product relating past climatic data with phenomena such as Southern Oscillation Index and sea-surface temperature. Of late, coupled ocean-atmosphere general circulation models (OAGCMs) are being increasingly used to make long-term forecasts by modeling the circulations and interactions of the ocean and the atmosphere. The seasonal forecast emphasis is on abnormalities in rainfall and temperature. Seasonal forecasts are prepared in every country by its national meteorological center. In Australia, the Bureau of Meteorology and Queensland’s Department of Primary Industries prepare seasonal forecasts. The products are available at the Internet sites of the respective organizations and can be obtained by fax as well.

While using the forecast information, it is important to bear in mind that weather forecast accuracy is inversely related to the lead time of the forecast. The shorter the lead time, the greater the accuracy of the forecast. Weather forecasts for longer time spans become more and more generalized, and their accuracy decreases as the lead time increases. This happens because regional-scale changes in atmospheric patterns occur suddenly, which cannot be accounted for in the methodologies used for making longrange forecasts. A 24-hour forecast is more accurate and comprehensive than a 48-hour forecast. A five-day forecast is less accurate and less specific than a 48-hour forecast. Similarly, a long-range or a seasonal forecast is much more generalized and less accurate than a five-day forecast.

TAILORING CLIMATE INFORMATION FOR AGRICULTURE

There are excellent sources of information on general weather, and this information is readily available. Generalized forecasts have, however, limited use in farming.Weather information for agriculture needs to be tailored to meet the needs of farmers and graziers (see Figure 9.1). It should not be a repackaging of the general weather forecast of the national forecasting centers. It should be a tailored product that can be effectively used in growing crops, managing animals, and controlling pests and diseases. A comprehensive agroclimatological forecast or a farm advisory is an interpretation of how expected weather in the future and weather conditions accumulated to the present will affect crops, livestock, and farm operations.

An agroclimatological forecast usually has five components: weather synopsis, interpretation of weather for crops, interpretation of weather for farm operations, interpretation of weather for livestock, and interpretation of weather for crop pests and diseases.

- *Weather synopsis:* This is the description of locations and movements of low pressure systems, high pressure systems, upper air troughs, fronts, and associated weather with these systems. This information is derived from synoptic observations, prognostic charts, and visible and infrared imageries from meteorological satellites. For seasonal forecasts the inferences are drawn from historical data, sea-surface temperature, SOI values and phases, and other relevant tele-connections.
- *Interpretation of weather on crops:* Interpretation of weather conditions on crops takes into account the impact of weather on germination, growth rate, freeze protection, and irrigation demand.

The cumulative effect of weather encountered and anticipated is used to determine dates of harvest, duration of harvest, and quality and storage capabilities of grains, fruits, and vegetables.

- *Interpretation of weather on farm operations:* Interpretation of weather on farm operations takes into account the drying rate of soil, evaporation losses, effect of heat, cold, and wind on applications of chemicals and fertilizers, and the drying rate of curing, wetting, and rewetting grains and hay.
- *Interpretation of weather on livestock:* Various combinations of heat and moisture in the atmosphere cause comfort or discomfort to animals. Indices are available that express the combined effects of temperature and humidity on animals. The indices provide indications of heat stress, cold stress, shelter requirements, and the effect of weather on meat, milk, and egg production. These indices are used to give imely warnings of anticipated weather dangerous to the health and safety of livestock.
- *Interpretation of weather for crop pests and diseases:* A close relationship exists between many animal and plant diseases, insect pests, and weather. The incidence of these diseases and pests is forecast in the light of accumulated and anticipated weather. Simulation, synoptic, and statistical techniques are used for forecasts which pertain to the probable development, intensity, spatial and temporal spread, or suppression of diseases.

IMPACTS OF WEATHER ON SPECIFIC INDUSTRIES AND THE ROLE OF FORECAST INFORMATION

An overview of the necessary decisions and the associated climate information required by agricultural industries is presented in Table 9.1 (p. 225).

This table is based on information from a large number of personal communications, publications, and written comments from those engaged in specific industries (Mavi, 1994; O'Sullivan, D. B., personal communication). infrared imageries from meteorological satellites. For seasonal forecasts the inferences are drawn from historical data, sea-surface temperature, SOI values and phases, and other relevant tele-connections.

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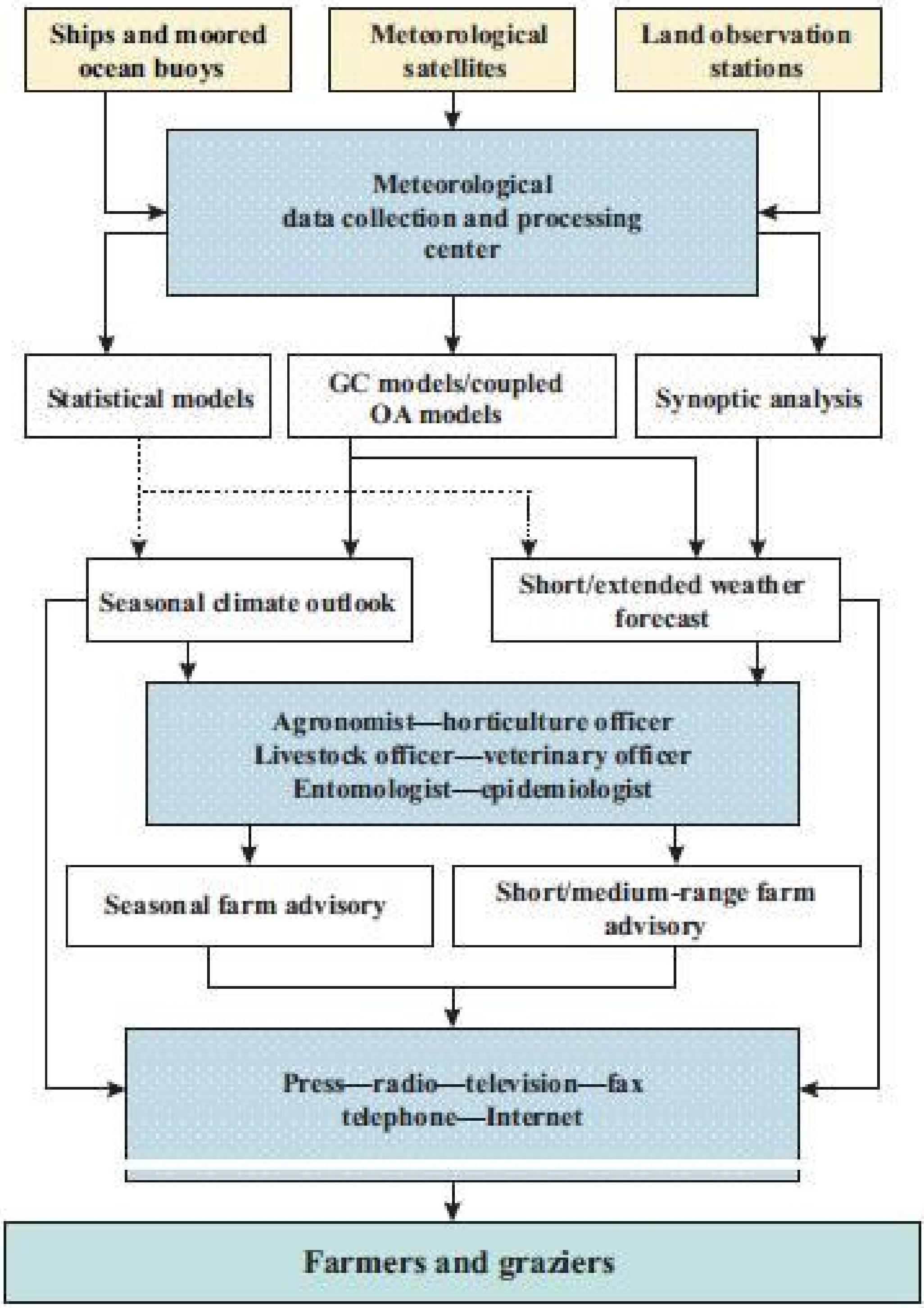

FIGURE 9.1.Weather information flow to farms

AGROCLIMATOLOGICAL INFORMATION SERVICES IN AUSTRALIA

Bureau of Meteorology

The principal information base for describing the climate of Australia, its variability, and its long-term trends is provided by the Bureau of Meteorology (1997a) which has national responsibility for meteorological (including climate) monitoring. It operates the official national climate observing infrastructure and the National Climate Centre, the latter being the custodian of Australia's historical climate records.

Short-term weather and seasonal climate forecasts are made available through the media, including newspapers, radio, television, and the World Wide Web (Bureau of Meteorology, 1997b). The former include the daily and three- to five-day rainfall and temperature forecasts released every few hours, along with specialized forecasts concerning inclement weather that threatens horticultural and agricultural crops and the survival of livestock (especially shorn sheep and newborn lambs and calves). Frost risk forecasts provide information on overnight minimum air temperatures of –2°C or lower when it is expected over significant areas. This information is available in all the states from June to mid-August.

The National Climate Centre currently provides a wide range of climaterelated services and products, including data, maps, predictions, and consultative services (Beard, 2000). The most important agriculture-related products are three-month seasonal outlooks of both total rainfall and seasonal average maximum and minimum temperatures, together with enhanced information on the Southern Oscillation Index and the likelihood of El Niño or La Niña events. In addition to the general weather forecast and the products from the National Climate Centre, the Bureau of Meteorology also issues specialized weather forecasts (FARMWEATHER) for agriculture through its Special Services Units located at each state capital. FARMWEATHER is a detailed rural forecast available on demand. It combines a weather graphics page, a recent satellite picture, together with an expert opinion composed by meteorologists in plain English. The information describes the weather outlook to four days ahead for particular regions, allowing effective short-term management decisions to be made by farmers. FARMWEATHER is available via fax for more than 20 regions throughout mainland Australia.

State-Sponsored Agroclimatological Services

The extension and advisory services of the various state departments of agriculture and primary industries provide advice, backed up by ongoing scientific research, to assist producers manage their properties and farm businesses while exposed to a variable climate and various forms of risk.

NSWAgriculture provides climate services for producers throughout the state. Seasonal rainfall and weather outlook for the next three months is an important component of the *Regional Review,* a monthly update of seasonal conditions and outlook for agriculture in New South Wales. Farmers and other users can look at climate information on the department's external Web site in the *Regional Review.* Climate workshops are one of the most important climate information delivery channels of the NSW Agriculture Department. NSW Agriculture also runs an irrigation and disease forecast service for the fruit growers in Northern Rivers region of the state. It provides quantitative data on evaporation, rainfall, and soil and air temperature for six stations in the region pertaining to the past week. Other information is on water used by the various fruit trees, with an advisory for irrigation. A section of the advisory is on fruit tree disease status, warnings, and advice on spray applications (NSW Agriculture, 1997). In southern NSW, the Riverwatch service is designed for updated information on the state of the urrumbidgee, Tumut, and Murray Rivers pertaining to height, trend, temperature, salinity, and turbidity for the next four days (Bureau of Meteorology, 1997c). The Queensland Centre for Climate Applications (QCCA) is a joint venture of the Department of Primary Industries (QDPI) and Department of Natural Resources and Minerals (QDNRM). It provides a range of climate services and tools to farmers (Balston, 2000; Bureau of Meteorology, 2001). The "Long Paddock" is the QDPI/QDNRM climate Web site and contains information on rainfall, rainfall probabilities, sea-surface temperatures, Southern Oscillation Index, the seasonal climate outlook, and drought status. The SOI phone hotline consists of a two-minute recorded SOI message-containing information on the SOI, recent rainfall, SSTs, seasonal rainfall outlook, and ENSO status, updated weekly.

The Aussie GRASS project outputs are produced regularly for Queensland, New SouthWales, South Australia,Western Australia, and the Northern Territory. These include recent and current pasture production conditions relative to previous seasons. Seasonal climate outlook indicators include the average SOI, variations in sea-surface temperatures, forecast rainfall, pasture conditions, fire risk, and curing index, updated monthly.

Most Aussie GRASS products are available on the Long PaddockWeb site. In addition to these services, conducting climate workshops for farmers is an important activity of the Queensland Department of Primary Industries. The South Australian Research

and Development Institute (SARDI) has developed practical climatological information resources, services, and tools to assist land managers to understand and manage the effects of climate variability on their farming enterprises (Truscott and Egan, 2000). The tools and services SARDI provides or supports include climate risk management workshops for delivery across southern Australia, and climate risk management decision support trials incorporating the Climate Risk and Yield Information Service. In Western Australia, climate services provided by Agriculture Western Australia (AGWA) have focused on the development of decision support tools that enable farmers to prepare and respond to climate variability. Modeling of agricultural production has progressed to the point at which farmers can use management tools to assist decision making, or utilize the delivery of timely information on crop development and yield potential (Tennant and Stephens, 2000). Decision support tools to respond to climate variability that have been developed in AGWA include TACT, MUDAS, PYCAL, NAVAIL, STIN, SPLAT, and FLOWERCAL. Most of the modeling developments have been used largely within western Australia, but some have been extended to other states. The information service is a weekly “fax back” delivery system that provides information on stored soil water, the progress of the season, expected yields, and other information to participating farmers in western Australia.
The STIN model is used to produce soil moisture (at seeding) and wheat yield forecasts for every wheat-growing shire in Western Australia. This is mapped on a monthly basis and supplied to ProFarmer which distribuyes their magazine to major grain trading, marketing, and transport agencies. Output can also be accessed from the AGWA web site.

Private Agroclimatological Services

Several private weather forecasting services provide advisories to farmers and some other sectors of economic activity (Anonymous, 1996; Lyon, 1997; Jones, 1997). These forecasting services use similar techniques as those of the Bureau of Meteorology to prepare the forecast information.
There are also private agricultural, environmental, and natural resource management consultants who are skilled in advising on how to cope with short-term and seasonal variability in climate, production, and product prices. Many are registered with the Australian Association of Agricultural Consultants (AAAC), a section of the Australian Institute of Agricultural Science and Technology.

USE AND BENEFITS OF CLIMATE FORECAST INFORMATION

The National Farmer's Federation of Australia, in its publication *New Horizons* (White, Tupper, and Mavi, 1999), endorses the view of many farmers that improved seasonal forecasting is a high research priority to assist them in managing their properties. This has also been highlighted in several surveys (Stone and Marcussen, 1994; Elliott and Foster, 1994;
Nicholls, 1985). Managers of water and other climate-sensitive sectors of the economy also claim that they would like to see significant advances in skill levels and lead times in seasonal forecasting (Albrecht and Gow, 1997). Another survey conducted by QCCA (Paul, Cliffe, and Hall, 2001) revealed that many graziers do use the forecasts to aid their stocking and stock-trading decisions, even though the reliability of forecasts remains an issue in many areas. Farmers in Queensland have certainly reacted to adverse SOI information by sending cattle to market, thereby reducing stocking rates on their properties. Surveys of grain growers in New South Wales and Queensland have shown that farmers have used four-day weather forecasts to plan their sowing and spraying operations. They have also used frost risk information to switch crops and crop cultivars, and they have used the seasonal rainfall outlook to increase their nitrogen application rates and the area sown to crop.

Meinke (2000) has cited specific examples in which farmers and several agencies in Queensland use the model-based information. The Queensland University of Technology surveyed (Hastings and O'Sullivan, 1998) primary producers, cattle producers with some dairy farmers, croppers, and others in agricultural production in southeast Queensland. The aim was to gauge producer opinions of the impact of seasonal climate patterns and seasonal forecasting. Two other surveys to get feedback on the needs and use of climate information were conducted in New South Wales (Albrecht and Gow, 1997; Crichton et al., 1999). Combined and generalized, the surveys revealed that producers are vitally interested in climate information and predictions of important weather parameters such as rainfall and frost. There is a large need for relevant and user-friendly information about climate in rural Australia. The surveys suggest that there is room to improve official forecasts to build more confidence and also to establish a better understanding of official forecasts.

Many investigations are available in which economic benefits from agroclimatological services are quantified (Adams et al., 2003). Additional but unquantified economic benefits of agroclimatological advisories are through checking land degradation from wind and water erosion and decreasing environmental pollution from fertilizer leaching and chemical spray drifts.

The value of the weather forecast depends on the ability of the user to effectively translate such information into economic values and profit margins at the individual-farm level. Katz and Murphy (1997) have cited studies showing savings from frost forecasts for orchards in the range from $US 667 to $1,885 per hectare. In maize production the savings range from $17 to $58 per hectare; in wheat production, a perfect forecast resulted in a savings of $196 per hectare; and in grape production, an accurate three-week forecast resulted in a net profit of $225 per hectare.

The value of a seasonal outlook depends on the skill or accuracy of the forecast and its marginal value relative to other readily available sources of information to the manager of a particular production system. Effective application of seasonal climate forecasts of reasonable accuracy leads to decisions that generate improved outcomes. To be effective, however, the decision changes must produce positive changes in value by improving the relevant aspects of targeted performances. If the information is ignored or it does not lead to changed decisions, it has no economic impact or value (Freebairn, 1996). If the forecast is inaccurate, then the information is likely to have a negative value in the current season. In a research study, the Kondinin Group has looked at the accuracy and reviewed the usefulness of seasonal climate forecasts for on-farm decision making in southern and western Australia (Buckley, 2002). The study revealed that long-term climate forecast models can predict rainfall for threemonth periods with accuracy levels that are better than a guess. Most of the models were more accurate with a lead time of zero and one month. Longer lead-time forecasts were not accurate enough to use for on-farm decision making. Furthermore, the forecast accuracy is very low during the critical time of autumn, which means climate forecasts are best used as only a small component of the farm decision-making process.

The benefits of seasonal forecasts vary between industries and across regions (Hammer, Carberry, and Stone, 2000). Soils and vegetation exponed to high climate variability in pastoral areas can benefit through destocking in advance of drought so as to avoid overgrazing, stock losses, and accelerated erosion. Crop producers can assess whether to sow or fertilize a crop if the chance of a harvest is significantly diminished. Demands for irrigation water can be better estimated.

The value of seasonal forecasts to crop producers can be significant, but it varies with management and initial conditions, as well as with cropping systems and location. The forecasts can influence decisions on what crop, when and what area to sow, and whether to irrigate and/or fertilize a crop.

Hammer and colleagues (2001) have cited case studies of how the applications of climate prediction at field/farm scale to dryland cropping systems in Australia, Zimbabwe, and Argentina have improved the profits of the farmers. In the northern part of the Australian grain belt, significant increases in profit (up to 20 percent) and/or reduction in risk (up to 35 percent) can be achieved with wheat crops based on a seasonal forecast available at planting time (Hammer, Holzworth, and Stone, 1996). This can be achieved through tactical adjustment of nitrogen fertilizer application or cultivar maturity, with significant financial benefits (Marshall, Parton, and Hammer, 1996).

Petersen and Fraser (2001) suggest that a seasonal forecasting technology which provides a 30 percent decrease in seasonal uncertainty increases annual profits of the farmers in Western Australia by about 5 percent. In northwestern Victoria, if the seasonal forecast suggests adequate soil moisture in October, then a sunflower crop can be sown with a high probability of a good harvest (Jessop, 1977). In a similar way, seasonal forecasts can be used to determine whether a particular cereal, oilseed, or legume crop should be sown, based in particular on the probability of a favorable harvest.

The El Niño-Southern Oscillation has a dominant effect on climate in a number of the world’s large-scale crop production areas. The SOI information contributes some skill to improving management decisions in Australia (Carberry et al., 2000). By changing between fallow-cotton, sorghumcotton, or cotton-cotton rotation based on SOI phase in the August to September period preceding the next two summers, the average gross margins for the two-year period increased by 14 percent over a standard fallow-cotton rotation. At the same time, soil loss from erosion was reduced by 23 percent and cash flow was improved in many years. Clewett and colleagues (1991) used a crop model to show that growing crops in seasons with a strongly negative SOI before planting were unprofitable, compared to seasons with a strongly positive SOI before planting. SOI data can therefore be used to adjust the management strategy according to the level of climatic risk.

Dudley and Hearn (1993) used a SOI model to examine irrigation options for cotton growers in the highly variable, summer rainfall environment of northern NSW. The study demonstrated that if irrigators knew the current SOI before the commencement of each cotton season, more profitable timing of investment in plant and equipment might result. These benefits might be extended to suppliers of farm inputs and to processors.

Rangelands in the eastern half of Australia are particularly sensitive to the climatic events of ENSO, with consequences for stocking rate and land degradation. A policy of reducing stocking rate on the basis of El Niño forecasts can significantly reduce environmental degradation in adverse seasons (McKeon and White, 1992; Stafford Smith et al., 1996; Clewett and Drosdowsky, 1996). Bowman, McKeon, and White (1995) examined the value of seasonal outlooks to wool producers in northern and western Victoria, assuming forecast accuracy for the next 12 months of 60, 80, and 100 percent. They concluded that the more accurate the seasonal forecast, the better was the long-term financial performance of the farms through reduction in livestock deaths and protection of the natural resource base.

TOWARD OPTIMUM UTILIZATION OF CLIMATE INFORMATION AND FORECAST PRODUCTS

Anthropogenic climate change, climate variability, and nvironmental degradation issues are among the big challenges of the twenty-first century.

Greater responsibility has been imposed on farmers for climate-related risk management, and they must increasingly rely on climate forecast information for operational and strategic decision making. Advancewarning of hazards and extreme climate anomalies at different time scales is therefore extremely important for them. Such early warning information can also form a crucial component of national/regional disaster preparedness systems, which will help to minimize loss of life and property, including damage to agricultural investments (Ogallo, Boulahya, and Keane, 2000). Apart from the traditional weather information, agricultural systems would Benedit from the following, among many others.

Agrometeorological Database

Crop-weather as well as animal-weather relationships are derived from historical records of both climate and agriculture. Such records are also used in deriving the basic statistics and risks that may be associated with any climate-based planning and operational decisions (Doraiswamy et al., 2000).

Availability of long-period, high-quality climate and agricultural records are therefore crucial for maximum application of climate information and prediction services in agricultural planning and operations. For some agroecological regions, such records are not available. The length and quality of the climate and agricultural records are key issues that should be addressed, as they provide the information base in any efforts to optimize applications of climate prediction products in agricultural planning and management. User-specific computerized databases in acceptable formats need to be generated.

Real-Time Climate Information

Many agricultural operations, services, and research studies require realtime weather information on a daily, weekly, or ten-day basis. This information can be generated through an efficient network of agrometeorological stations, which at this time is very poor in most countries (Gommes, Snijders, and Rijks, 1996). Wherever the weather stations are available, most of them do not followthe pattern of agroecological zones.Weather stations installed and maintained by the meteorological departments in various countries are usually located near towns and at airports, where recorded observations are not representative of the agricultural landscape (Ogallo, Boulahyab, and Keane, 2000).

Research

Optimum utilization of any climate prediction product in agriculture requires applied agrometeorological research with two basic components: interdisciplinary research and multiscale research (Hatfield, 1994). The topics include understanding of the local climate/agricultural systems and the associated linkages, especially with respect to extreme events, climate, and pest/disease linkages, and adaptation of agricultural systems to local climate variability. Improved and integrated data sources and interpolation methods, locally validated crop models, and regional numerical forecast models are realistic and attainable goals for the near future. Enhanced research efforts are required on the determination of the scale and time at which seasonal predictions are suitable for application to agriculture and the environment and on the connection between the past and present weather and the upcoming predicted season.

Downscaling Short- and Medium-Range Weather Forecasts

The science and technology of short- and medium-range weather forecasting with computer models are now quite advanced. Availability of operational short- to medium-range weather forecast products is increasing day by day. For such products to be more useful and effective in agricultural applications, they must be downscaled to the regional, local, and ultimately individual-farm levels. However, most regional/local downscaling techniques require a good knowledge of regional/local climate processes. This knowl edge is highly inadequate due to serious limitations of basic local meteorological data and research. Downscaling forecasts to a local level is one of the most difficult tasks ahead. Several downscaling techniques have been developed in recent years (Von Storch, Zorita, and Cubasch, 1993; Hughes and Guttorp, 1994; Zorita et al., 1995; Kidson and Thomson, 1998). However, much more effort is needed to achieve the desired goals.

Seasonal Climate Prediction

Improvement in seasonal climate prediction is one crucial factor that could reduce the vulnerability of agricultural systems to severe impacts of extreme interannual climate anomalies. The science and technology of climate prediction within monthly, seasonal, to interannual time scales is still young and is currently under intensive investigation worldwide. The last decade of the twentieth century, however, witnessed a major advance in understanding the predictability of the atmosphere at seasonal to interannual time scales (Palmer and Anderson, 1993; National Research Council, 1996; Carlson, 1998). El Niño and Southern Oscillation are some of the known key drivers to interannual variability and have been associated with worldwide extreme climate anomalies, including changes in the space-time patterns of floods, droughts, cyclone/severe storm activity, and cold and heat waves. For some of these, agricultural application models have been Developer which transfer projected ENSO signals directly into agricultural stress indices (Nicholls, 1985; Cane, Eshel, and Buckland, 1994; Glantz, 1994; Keplinger and Mjelde, 1995; Hammer, Holzworth, and Stone, 1996; Mjelde and Keplinger, 1998). Fast development in computer software, communication technology, and advances in climate science during the past few decades suggest that useful model-based seasonal forecasts are possible in the near future (Serafin, Macdonald, and Gall, 2002). Results from computer models have demonstrated that it is possible to predict sea-surface temperatures and El Niño over time scales extending from a few months to over one year. At present, numerous impediments are obstructing the optimal use of seasonal forecasts. Nicholls (2000) has reviewed these impediments and has suggested strategies to overcome these problems so as to improve the use of seasonal forecasts. The challenge to improve climate predictions for seasonal to interannual scales has been taken in the WMO program known as the Study of Climate Variability and Predicability (WMO, 1997a,b). It needs to be addressed at national levels as well.

Skilled Multidisciplinary Human Resources

The interdisciplinary nature of agrometeorological services is a weakness that has to be addressed (Hollinger, 1994). At present, skilled multidisciplinary human resources for integrated agrometeorological applications are relatively limited. If an agricultural meteorology scientist alone has to deliver the most effective products to users, then he or she must be fluent in both biological and physical sciences, so as to look at theworld from a different perspective than the physical or biological scientist. There is a great need to strengthen and equip national and regional climate and agrometeorological institutions/units with human resources with multidisciplinary training.

Tailored Products

The perspectives of many meteorologists are based on long-standing traditions about the type of information expected by their agricultural clients (Seeley, 1994). There is a need to address the climate information requirements of specific sectoral agricultural users so that climate prediction centres can produce custom-tailored products. Information has value when it is tailored and disseminated in such a way that end users get maximum benefit from applying its content (Weiss, Van Crowder, and Bernardi, 2000). Areas of agricultural expertise that have prospered throughout the years are those with a product that is wanted and used in agricultural production. The future will see increased availability of real-time, high-resolution weather data.

Opportunities for agricultural meteorology services will grow dramatically if agricultural meteorologists meet the challenge of making custom-tailored products, defined and presented in their clients' language, to meet their precise needs, and educate agricultural producers in using weather data in a variety of management decisions (Perry, 1994). Rijks and Baradas (2000) suggested that the identification of clients' needs could be made through a process of listening to people in the industry and through dialogue about the issues that could make their work safer, easier, and more reliable.

Forecast Services and Users' Interface

There is an overexpectation of forecast accuracy among users. The common perception is that both long- and short-range forecasts are not reliable enough to use in decision making (Crichton et al., 1999). The difficulty is to convince the users what forecast accuracy is attainable with the current state of the art. It is crucial that farmers have good knowledge of the skill and limitations of any climate prediction products. To achieve this, agroclimatologists have to take a more proactive role than they have at present (Blad, 1994). Extension education programs are needed to educate agricultural producers about agrometeorological products and the skill and limitations of any climate prediction product (Stigter, Sivakumar, and Rijks, 2000). To conclude, reducing the risk associated with increased climate variability has a high potential for increasing productivity and quality while protecting the environment. Agroclimatological services generate the possibility of tailoring crop and animal management to anticipated weather conditions either to take advantage of favorable conditions or to reduce the effects of adverse conditions.