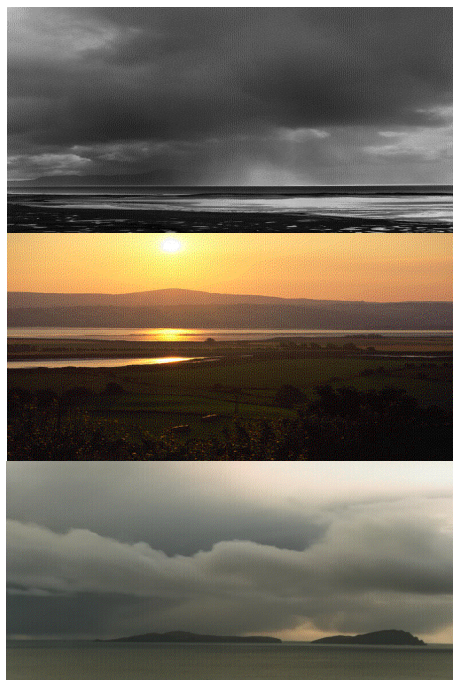
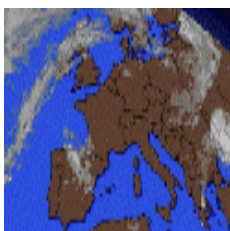


AGMET

Agrometeorological Needs Review and Analysis for Ireland



Editors:
G. Murphy
N.M. Holden



AGMET Group Report 2001

The AGMET Group

AGMET was founded in 1984 and has the full title of “Joint Working Group on Applied Agricultural Meteorology.” Membership is open to anyone with an interest in the subject. Currently members are drawn from Met Éireann, Teagasc (the Agricultural Development Authority), Geological Survey of Ireland, Environmental Protection Agency, Office of Public Works, Universities, other third-level Colleges, Department of Agriculture, Food and Rural Development (Dublin) and Department of Agriculture and Rural Development Northern Ireland. **AGMET** draws on the expertise of other organisations (RTÉ, IFA, ICMSA, The National Farm Centre, Bord Iascaigh Mhara) when topics of a specialist nature are under discussion and review.

In 1985 **AGMET** reported on the Irish national needs in the area of agrometeorology. A number of recommendations were made that have since been adopted by various organisations in the State. A notable initiative was the introduction of the very successful weekly weather forecast for farmers on RTÉ television every Sunday. **AGMET** has also produced a number of major publications since its inception, and has held a number of conferences and workshops that have attracted both national and international delegates. **AGMET** gratefully acknowledges the goodwill and support it has received from the organisations to which members belong.

AGMET publications and conferences:

(* out of print)

**Climate, Weather and Irish Agriculture*, edited by T. Keane, 1986

Weather and Agriculture, edited by T. Keane, 1988
(proceedings of a conference at University College Dublin)

**Weather, Soils and Pollution from Agriculture*, compiled by M. Sherwood, 1992

The Future of Irish Agriculture—Role of Climate, edited by J. F. Collins, 1992
(proceedings of a conference at University College Dublin)

**Irish Farming, Weather and Environment*, edited by T. Keane, 1992

The Balance of Water, edited by T. Keane and E. Daly, 1994
(proceedings of a conference at Trinity College Dublin)

Agroclimatic Atlas of Ireland, edited by J. F. Collins and T. Cummins, 1996

Weather and Agro-environmental Management, edited by D. McGilloway, 2000
(proceedings of a conference at the Geological Survey of Ireland)

Agro-Meteorological Modelling – Principles, Data and Applications, edited by N. M. Holden, 2001

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Introduction

As we begin a new millennium both Irish Agriculture and the organisations that provide it with information and advice face many new challenges. As well as being production-orientated, agriculture is focusing more attention on care of the environment. Means of gathering data to assist farmers and researchers are now much broader. With the advent of computerisation the range of products that can be developed for disseminating information to the agricultural community has increased. The ethos of organisations such as Met Éireann, Teagasc and the Universities has also changed significantly in recent years.

AGMET, in considering how best to meet the challenges posed by these changes, set-up five working groups to examine and make recommendations about how meteorology can be best used to help and improve Irish agriculture. This report is the result of the work carried out by the five groups.

The structure of this report is:

- A definition of the subject areas and the members of the *working groups* that carried out the review are given
- Taking the work of the five working groups into account, four *fundamental principles*, seen as overall goals of future work in this area, are presented
- Eight major *conclusions* are presented; these should form the basis of policies for the next decade. Specific recommendations within the individual working group reports are cross-referenced
- The specific *reports from the working groups* have been compiled to provide a detailed explanation of the *recommendations* that make up the main findings in the report

Working Groups

Five working groups were set-up to assess the present and future needs in specific sectors of Irish agriculture. Details of the subject areas and the persons responsible are provided below:

1. Crops and Animals

Assessment of climate and weather factors that have the most impact on fundamental farm-based agricultural productivity

David Mc Gilloway (Co-ordinator) – Dept. Agriculture, Food and Rural Development; William Murphy – Teagasc, Johnstown Castle (retired); Anthony Brereton – Dept of Agricultural and Food Engineering, UCD

2. Alternative Uses of Land

Assessment of current services and service requirements for alternative land uses such as aquaculture, energy, forestry, horticulture, leisure and organic farming

Tom Keane (Co-ordinator) – Met Éireann (retired); James Collins, Áine Ní Dubháin – Dept of Crop Science, Horticulture and Forestry, UCD; Gerry McNally and Sean Ganly – Bord na Móna; Denis Kennedy and Fionán Mac Néidhe – Teagasc, Clonroche; Rick Watson – Dept of Electronic and Electrical Engineering, UCD; Pat Neville – Coillte; Michael Maher and Michael Bulfin – Teagasc, Kinsealy; Michael Walsh – Teagasc, Athenry; Noel Culleton – Teagasc, Johnstown Castle; Tom Scanlon – Bord Iascaigh Mhara

3. The Physical Environment

Assessment of climate and weather factors that have the most impact on the needs of managers of the physical environment (atmosphere, hydrosphere, geosphere and biosphere) not specifically included in the consideration of primary production or secondary agricultural activities

Thomas Cummins (Co-ordinator), Yvonne de Kluizenaar – Dept of Environmental Resource Management, UCD; Peter Cunningham – Environmental Protection Agency; Thomas Murphy – Central Veterinary Research Laboratory; James Collins – Dept of Crop Science, Horticulture and Forestry, UCD; Nicholas Holden – Dept of Agricultural and Food Engineering, UCD; Tom Keane – Met Éireann (retired)

4. Services to Agriculture

Assessment of forecasts, information technology and other services required by farmers and other agriculturalists

Gerry Murphy (Co-ordinator) – Met Éireann; Stephen Alexander – Teagasc Kinsealy; Jim O' Mahony – Teagasc, Kildalton; John Hempenstall – ICMSA; Fintan Conway – IFA; Andy Doyle – The Irish Farmers' Journal

5. Data Requirements

Assessment of meteorological data requirements for agricultural research and for the provision of improved meteorological services to agriculture

Gerry Murphy (Co-ordinator) – Met Éireann; Tim Gleeson – Teagasc Kinsealy; Brian Coulter – Teagasc, Johnstown Castle; Leslie Dowling, John Hogan, Robert Leonard – Teagasc, Oak Park

Fundamental Principles

Four principles, extracted from this needs review, that should form the basis of policy decisions related to agrometeorology and rural environmental management are:

Principle 1: Improve the quality of weather forecasts by providing accurate information on finer scales and tailoring forecasts to a wide range of specific users
Principle 2: Increase the density and geographical representativeness of meteorological observations, thus making the data more valuable to a wide range of users
Principle 3: Develop interactive access to data for use in models tested for Irish conditions
Principle 4: Educate current and potential users about the value of agrometeorological information

There is a clearly defined need for forecasts with a range of time horizons (now-casts to long-range, weekly forecasts) that are accurate, specific to much smaller geographical areas than currently and having content tailored to specific needs of day-to-day farm operations such as nutrient management planning and pollution control.

In order to supply such forecasts, even with advances in numerical weather prediction, it will be necessary to increase the meteorological observation network and to ensure that each observation site is representative of its geographical region.

In order to tailor forecasts to specific uses, predictive models must be employed to supply expert information (in the form of Decision Support Systems – DSS) to forecasters who can then use this information as part of the forecast service. Similarly, individual users should have real-time, interactive access to data for use with their own management systems.

Farmers themselves identified the need for training and education in agrometeorology. There is a clear need for training and education programmes to support the introduction of improved services.

The Main Conclusions

Irish Agriculture has undergone many changes in recent years. Farmers are faced with the challenge of increasing productivity or maintaining productivity with improved quality, while at the same time being subject to both societal and legislative demands that they take demonstrable care of the physical environment in which they work. In order to achieve the right balance of quality, productivity, profitability and care of the environment, farming is becoming more scientific and will in the future come to rely on Electronic Information and Communication Technology (EICT). As farmers start to use currently-emerging technologies and methods, *gaps of knowledge* (e.g. simulation model theory), the steady *supply of reliable data* and *timely delivery of services* will arise. From the work carried out by the **AGMET** working groups, the following key areas have been identified in which there are fundamental requirements to improve agro-meteorological services in Ireland.

Weather Forecast Services

Conclusion 1:

Continually improve forecast services with an emphasis on regulated, *accurate*, *localised* weather forecasts that can be *tailored* to specific user demands

Farmers require a forecast service that will help them decide what to do and when. For example, spraying and slurry spreading are both weather dependent and weather sensitive, and need localised forecasts that are accurate over the short term (<1 day). In the case of slurry spreading, longer-term weather (<5 day) will dictate whether pollution results, therefore a localised, longer-term forecast is also required.

A survey of farmers carried out as part of the Review revealed that the most important requirement is *accurate* forecasts. Farmers use short range forecasts (<1 day) in order to take account of the weather in relation to immediate tasks (spray/spread or not?), and long range forecasts (1-5 days) for planning their work in the days ahead (will spreading be followed by rain in the next few days?). The most significant requirement of farmers in relation to forecasts is *localisation*. Farmers are aware of the improvements in forecasting techniques in recent years and want more exact information on the weather in their local areas, not just their regions. Land managers other than farmers also have a significant demand for localised forecasts that are *tailored* to their occupations, such as drying rates for the peat energy industry.

It is clear from the Review that the density and geographical location of current observation stations is inadequate for the detail, accuracy and localisation that potential users require. Farmers are now aware that it should be possible to provide a forecast for areas of 15 x 15 km for the whole country. To ensure the reliability of such forecasts it is necessary to have more observations for testing of forecast models. The improvement required in the forecast service is therefore closely related to recommendations relating to local automatic weather stations. A further requirement of the forecasts is that they include risk and alarm elements related to specific farming and land management activities, such as pest and disease outbreaks, land trafficability, pollution risk, wind activity, drying rates (tailored to specific products such as peat), fire risk, frost and cold units. It is suggested that the suitability of various forecast elements be assessed to ensure that farmers are provided with useful, accurate information. The inclusion of probabilities

associated with specific events is also considered a necessary development. Given that farmers are lifelong risk managers, such information is both meaningful and valuable in management planning on the farm (and for other rural enterprises). The short-term specific requirements of farmers for changes in TV, radio and telephone/fax forecasts were assessed, revealing a need for a more frequently updated service, more regional detail and more farming-specific information in the regular forecasts. Farmers are particularly interested in receiving information about severe events in advance in order to have time to prepare.

See specific recommendations for supporting arguments:

1.2, 1.6, 1.7, 1.8, 1.10, 1.11, 2.2, 2.4, 2.6, 2.9, 2.10, 2.14, 3.3, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 4.14, 5.2

IT Services to Agriculture

Conclusion 2:

Put in place a funded, co-ordinated, collaborative system for development and testing of Decision Support Systems and other agrometeorological models for Ireland to ensure that suitable models and data are available for operational applications

It is recognised that farmers will benefit greatly from access to decision support systems (DSS) and forecast models which will become an integral part of farm management over the next few years. The application of DSS will arise from an increased use of computers, supported by an increased predictive accuracy from agrometeorological models and, most importantly at present, due to demands by food vendors for quality assurance (such as spray justification for potatoes). Teagasc have carried out an examination of a number of DSS for the control of potato blight and are keen that development of an Irish DSS be undertaken. In order to exploit the advantages of DSS, co-ordinated development implementation and co-operation between relevant organisations are essential. Development of these services requires funding, research and EICT implementation. There is a need for Teagasc, Met Éireann and the Universities (all with state funding) to set up and test available DSS tools and ensure their calibration and functional utility. Other organisations such as the Environmental Protection Agency and local authorities are also likely to have applications for such systems and should be invited to participate.

There are many thousands of models developed for research and management activities in agriculture. It is essential for the successful introduction of expert systems, DSS and models into the day-to-day running of agriculture and rural management, that currently available models are tested for Irish conditions. The identification of application models (as opposed to research models) is essential to ensure that the correct tools are made available. The introduction of DSS has to be associated with a provision of data and training in the uses and limitations of models. To ensure that farmers, who may not wish to become experts in modelling, are able to access high quality, reliable models, a national testing programme should be put in place. Data and forecast models, such as crop disease models, form an integral part of DSS.

It is not clear whether there should be a ‘recommended list’ of DSS tools for Irish conditions, but there is likely to be a need for such a list if farmers start to use DSS tools for making management decisions associated with legal obligations such as pollution control and IPC licences.

See specific recommendations for supporting arguments:

1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 2.7, 2.9, 2.10, 2.11, 2.15, 2.17, 3.2, 3.6, 4.14, 5.1, 5.2, 5.9, 5.12

Conclusion 3:

Develop an Irish agrometeorological Internet Portal that will provide a first port-of-call for citizens seeking (localised, accurate, tailored, quality) data, information, help, services, models, expert systems, education and forecasts relating to weather, farming and the rural environment. Met Éireann, Teagasc, the Universities, Environmental Protection Agency and relevant government departments should co-operate (with funding, resources and personnel) to develop and support this service

Met Éireann focuses on the meteorological and Teagasc on the non-meteorological aspects of agrometeorology. If both organisations present their data, models and information in separate places, the development of services will be retarded. An integrated agrometeorological portal is required to facilitate access and learning for farmers and land managers. With increased computerisation and access to the Internet, an increasing number of farmers will be able to access IT products to help them in decision making processes. Since non-PC based Internet connection (such as mobile telephones – WAP, SMS) may become more attractive to farmers and land managers, some attention should be directed towards non-web based Internet products. Furthermore, increased computerisation has enabled more complex models to be developed to predict plant and crop processes and diseases. Using the Internet (in all its forms), agricultural researchers, advisors and farmers should be able to access agrometeorological services including data, weather forecasts and models.

Users require data and information more rapidly. There is a clear need to advance the development of service provision. Probably the best approach is to use the Internet by virtue of its accessibility from TV, PC and mobile telephone. The demand for directories of services, pricing structures and clear information about the mechanism for tailoring an industry-specific product can be met using an Internet portal dedicated to agrometeorology. Such an interface to Met Éireann would allow a transparent assessment of the value of services being provided. Farm and other rural users constitute a large user group requiring a portal separate from the general Met Éireann web site. As such an information source would integrate with agricultural modelling and DSS information, links and contributions from government, Teagasc and Universities departments would be required. A portal would be the first port-of-call for all users who need to develop tailor-made products and services (such as Bord na Móna and the horticulture industry), and would provide a vehicle for an ongoing review of services and needs. There is a clear need to undertake a cost-benefit study of such a portal and to consider carefully who would own it and its commercial and intellectual property rights.

See specific recommendations for supporting arguments:

1.1, 2.1, 2.7, 2.9, 2.10, 2.11, 3.1, 4.10, 4.12, 4.13, 5.2

Data Requirements

Conclusion 4:

Improve the meteorological observation network with respect to density, geographical distribution, standardisation of observations and the variables measured

The creation of accurate, localised and tailored weather forecasts with a range of time horizons will require a better observation network for the initialisation and calibration of ever-improving numerical weather prediction models and to supply information to forecast experts. Radar will also contribute to observation of variation in time and space, and the provision of better, localised forecasts. Good quality meteorological data are also essential for use in agricultural research since many processes in crop and animal production are weather dependent.

One of the main areas in which meteorological data are used is in agrometeorological modelling. These data are used as inputs to models and for testing models. A comprehensive review of exact user data requirements should parallel the development of the observation network. With increased computer power and theoretical understanding, models are becoming more complex and require more data for initialisation and running.

There is an increased demand for meteorological data of a much higher spatial and temporal resolution than are currently available in Ireland. There are only 15 synoptic stations in the Republic of Ireland measuring data on an hourly basis, seven of which are located in coastal areas. Data from climatological and rainfall stations are sent to Met Éireann on a monthly basis only. In order to supply sufficient data to users wishing to take advantage of DSS and other agrometeorological models, there is a need to greatly increase the meteorological observation network with an emphasis on the requirements of all potential users. All major geographical regions should have an observation station similar to the current synoptic stations. For example, the Teagasc Moorepark Research Centre, Fermoy is an ideal location for such an automated station. Data should be processed through a single quality control system and then be made available to users by whatever means they wish. A tailored provision of data should be possible with real-time, interactive access via a continually updated directory of available data and services. A more representative coverage of observation sites will eventually lead to more client-oriented climatological products.

The observation of wind has been highlighted as being particularly important for prediction of energy generation, drying rates and crop damage. Wind data will only be useful at a suitable spatial scale. A parallel can be made with atmospheric gas observations and the importance of drivers of climate change and other atmospheric pollutants (such as the demand for further monitoring of atmospheric ammonia concentrations). Improved observations will also allow for better development of warnings, alerts and alarms for specific user needs.

See specific recommendations for supporting arguments:

1.2, 1.3, 1.4, 1.5, 1.9, 2.3, 2.7, 2.8, 2.12, 3.5, 3.6, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 5.10, 5.11, 5.13

Conclusion 5:

Investigate the role of site-specific automatic weather stations (as used for local DSS data acquisition) as contributors to the national observation network, with an emphasis on quality, standardisation and integration

The development of on-farm DSS, wind energy generating stations and computer-controlled glasshouses will lead to a much greater number of local weather stations around the country. These weather stations will collect a valuable amount of data that may, unless co-ordinated, never be archived, analysed, quality controlled or used beyond their immediate design requirement. While it is recognised that such systems will not contribute directly to the mainstream observation network, it is possible that they could be used to test spatial interpolations and down-scaling procedures, and therefore a review of how such data could be used, perhaps on a *quid pro quo* basis by Met Éireann and other relevant bodies should be undertaken.

See recommendations for supporting arguments:

1.2, 1.9, 2.11, 5.11, 5.12, 5.13

The Physical Environment

Conclusion 6:

Increase coherent exploitation of meteorological models and services in the management and protection of the rural environment

Conclusion 7:

Develop a national climatic atlas with appropriate regional scales, containing climatologies for the elements used by all common and emerging agricultural enterprises, by co-operation of appropriate institutions using state funding

Farming and other land management activities have a significant effect on the physical environment. Farmers and land managers have a responsibility to take care of the environment and to minimise any deteriorating influences. The two areas in which agriculture has the most impact are its management of soil and water. Tailored meteorological models, forecast and warning services can greatly assist farmers in taking account of environmental effects of weather on farm activities.

It is important to ensure that agricultural managers are aware of: the effects that their activities are having on the environment; the legislative framework for environmental protection that is in place in Ireland and the EU; and information and support systems that facilitate the management of individual enterprises for profit while maintaining environmental quality.

An updated, comprehensive atlas is needed for various agrometeorological purposes with regard to the interaction of the physical environment and the weather. Specific areas of consideration are wind energy, forestry, horticulture and organic farming.

See recommendations for supporting arguments:

1.6, 1.7, 1.8, 2.5, 2.8, 2.9, 2.12, 2.13, 2.14, 2.16, 2.17, 3.2, 3.3, 3.4, 5.14

Education and Training

Conclusion 8:

Include meteorology and agrometeorology in farming courses at agricultural colleges and as part of all third-level agricultural qualifications. In addition training, information services and support systems should be established to help farmers remain profitable while maintaining a high quality rural environment. The method of education delivery should be tailored to the target market

From the survey of farmers and consultation with experts linked to other rural industries, most farmers and land managers are interested in learning more about agrometeorology and its relationships with their activities. Preferences for the means of communication included TV programmes, videos, information leaflets, books and courses in agricultural colleges. There is clearly still a lack of interest in learning via Internet services.

AGMET has a role to play in the development of training and education programmes by expanding its activities and membership, and using the combined knowledge of its members to contribute publications, workshops and educational material to the Irish agricultural community.

See recommendations for supporting arguments:

1.5, 1.10, 1.11, 2.1, 2.15, 2.16, 3.3, 3.4, 3.6, 3.7, 4.7, 4.12, 4.15, 5.12

Report of Working Group 1: Crops and Animals

Introduction

Climate and weather are major factors impacting on Irish agricultural productivity. Directly and indirectly they influence both the quantity and quality of the final product, and ultimately are significant factors in determining the profit returned by farming enterprises. The objective of this report is to determine the agrometeorological requirements of researchers, advisors and farmers for planning and management of pasture, livestock and crop production systems

As a working scenario for this review, it is assumed that all agro-production systems in the early decades of the new millennium *will 'seek to enhance the profitability of the enterprise through cost efficiencies and optimal animal husbandry practices, and that this will be achieved via sustainable, environmental and welfare friendly practices which meet consumer perceptions of quality'*. This 'goal' is seen as applying equally to the large-scale producer and the part-time farmer (of which there will probably be many in future years) deriving all or part of the family income from farming.

An individual farmer's requirement for agrometeorological information depends on the physical, economic, social and cultural environment of the farm, and varies widely. However agrometeorological data in their 'raw' form (basic numbers) are of little use to the average farmer since he/she is not in a position to interpret data, but rather acts on the results of a prior interpretation. Interpreted data, once communicated, becomes information if, and only if, understood by the recipient. This means that farmers need a sufficient level of training to be able to understand emerging types of agrometeorological information such as model output. Given the volume of the data now being collected and the complexity of the systems being simulated, the requirement inevitably becomes one for models, both new and existing, with increased reliability and where practicable, a readily accessible user interface. However, the development of useful models requires a co-ordinated approach between several agencies and institutions: Met Éireann for collating and storing data; Teagasc for research, education and advisory services; the universities for research and education; and government departments to play an integrating role at the national and EU level.

Implementation of any model is only as good (or bad) as the data used in its construction – this applies equally to the meteorological data collected by Met Éireann and agronomic data collected by Teagasc and the universities. It is therefore pertinent to ask if the most useful variables are being measured, and are the measurements reliable?

Meteorological observations

The meteorological variables currently being recorded evolved from the early 20th Century shipping forecasts, and have changed little over the years. Hence their relevance and applicability to agriculture, especially emerging systems such as organic farming and fish farming, is questionable.

Wind chill and exposure have serious implications for animal health and welfare such as spring lamb mortality. Wind chill calculations depend on measurements of temperature and wind speed. How relevant is wind speed measured 10 m (or 2 m in the case of smaller observation sites) above the ground to animals on the ground? Likewise, wind speed is crucially important to operations such as spraying. How accurate and sensitive

are our current measurements in relation to the environment at the surface of a standing crop? These questions raise the general issue of the applicability of a meteorological observation to an agricultural application. Some countries (Norway for example) have dedicated agrometeorological observations networks to address just this type of problem. The feasibility of an Irish state agency developing such a network is doubtful on economic grounds.

Wind is also an important vector of infection for both livestock and crops. It is greatly affected by local topography and shelter, and can vary hugely within very short time frames. However, for modelling purposes, often the only source of wind data is the closest synoptic station, which can be several tens of kilometres away. This is not a satisfactory situation for reliable expert system support services. Also knowledge of the maximum wind speed recorded, whilst of historic interest, is of little use to farmers. What is required by farmers is the pattern of wind change. Patterns of daily variation (for any variable) are crucial to the development of reliable models. Maximum, minimum and daily averages do not present a sufficiently accurate picture of the daily weather. Even without the development of modern data loggers and automatic weather stations, a strong case could be made for the provision of information on deviations from the norm or long term average of pertinent variables.

Rec 1.1 Make meteorological data available in real time with an indication of the variation that occurs over 24 hour periods

Rec 1.2 Supplement the network of synoptic stations with data collected using modern data loggers from on-farm weather stations

Within all agricultural systems, nothing stands still – crops and animals continue to grow and develop. Thus even under stable weather conditions, the immediate environment of the crop, such as a grass sward, can change significantly over a few days. During peak growing conditions grass can grow at rates in excess of 100 kg DM/ha/d, so that in 10 days a tonne of grass can be produced. This standing biomass can change the micro-environment markedly. Temperature in the upper horizons can be considerably higher than ambient air temperature, and that of the leaf surface may be significantly higher as well. The value of grass temperature observations in these circumstances must be questionable, as indeed is the protocol that maintains only a minimal grass cover at the observation enclosures.

Rec 1.3 For improved grass management, incorporate micro-environmental effects and influences of temperature into grass growth trials to allow the development of more effective long-term agrometeorological observations

The validity of recording sunshine hours must also be questioned. The radiation intensity associated with a short period of bright sunshine can vary enormously, as can the quality of the direct and diffuse radiation. For many crop growth models, the energy available for photosynthesis is pivotal to the final model estimate, yet agrometeorological data on the energy entering the system is often only available from empirical calculations. Similarly, most models to date have been tested using sunshine hours as a proxy for Photosynthetically Active Radiation (PAR). With developments in the measurement of radiation, and because PAR is a primary agrometeorological variable, greater emphasis needs be given to determining PAR.

Rec 1.4 Make greater use of photosynthetically active radiation in the validation of current and future agrometeorological growth models

Evaporation is an essential parameter for various agricultural, hydrological and engineering applications, *e.g.* growth models, drying conditions, soil moisture estimation, water balances. Current evaporation models generally lack sufficient accuracy. The automation of evaporation measurement is seen as important to developing an accurate picture of variation in evaporation rates throughout the day. A restricted network of evaporation measuring stations could provide ground truth data for developing (and widespread application of) evaporation models that use other observations from any meteorological site.

The accuracy of interpolation or extrapolation of data from point sources to other areas is of critical importance to researchers for constructing models and decision support systems (DSS). There is scope to increase the number of stations or locations at which meteorological data are collected. The development of relatively low-cost data-loggers and automatic weather stations for deployment at strategic locations needs to be investigated as a matter of priority.

Rec 1.5 Specify in detail for users, the accuracy and validity (or otherwise) of current measurements of wind speed, sunshine hours, evaporation, grass temperature, photosynthetically active radiation, other observed variables and data extrapolation from point sources

Livestock production

In Ireland, livestock production systems are dependent on grazed grass to supply a significant proportion of the animal intake requirement. The production systems are designed to maintain a level of animal production in circumstances where feed supply is subject to large variation. This variation is not in itself unmanageable. Systems have been developed where seasonal variations in pasture supply are managed by making reciprocal seasonal adjustments in the demand for feed. These adjustments are accompanied by systems of harvesting and pasture saving during periods of surplus, which can then be utilised during periods of feed deficit.

In general our current systems accommodate variation in pasture supply so long as variation follows a predictable seasonal pattern. Different systems are in place in intensively farmed lowland and in extensively farmed uplands. These represent strategic management adjustments to climate and economic forces. In any of these systems, when pasture supply differs significantly from the normal seasonal pattern, it becomes necessary to make tactical management decisions to minimise effects on livestock. Unfortunately, an element of uncertainty is often associated with forecast departures from the seasonal normal. Therefore precise decisions cannot be readily made. At farm level the tactical response adopted is not exclusively influenced by agrometeorological considerations. This is especially true of farmers operating intensive systems of milk production, where pasture supply is continuously monitored so that the state of the production system is largely known. However, for extensive producers, and at regional or national levels of administration, agrometeorological information may be of critical value.

Management of animal health and reproduction can be very dependent on weather. There are a number of important diseases (mostly parasitic) whose epidemiology are dependent

on weather. Nematodirus requires a cold period for maturation of the parasite's eggs. Liver fluke requires a sustained period of mild moist weather for development of the infective stage in the intermediate host (snail). Currently there is a national scheme which issues warnings relating to these two diseases, but there is a requirement for the prediction of other diseases such as Myiasis (Flystrike), tick activity (host for Babesia – Redwater) and Avian Influenza.

Land trafficability for machinery and livestock can be better managed to achieve higher levels of utilisation. Animal stock rates must be adjusted to avoid poaching paddocks, which can happen when ground conditions are soft. There is a requirement to know the likelihood of local incidents of heavy rainfall, which would facilitate the decision to move cattle to firmer ground. Such decisions specifically require localised forecasts.

Management of forage for mechanical harvesting in the current systems of production requires that herbage is conserved over the summer months as hay or silage, and is fed back into the system during the winter months. The conditions encountered during the harvesting process can have major repercussions on the quantity and quality of the resultant product. Trafficability for machinery to harvest the crop is an issue. Wilting is recommended to increase the DM concentration and to reduce effluent production and accurate forecasts are essential during this stage.

Pasture disease management is affected by the atmospheric, groundwater and wildlife environment of the farm, particularly during disposal of animal wastes, application of fertiliser, grazing and forage harvesting. Agrometeorological information has an obvious role to play in arriving at management decisions. In many cases short-term agrometeorological forecasts are required. Warnings based on forecasts with a lead-time of hours (localised now-casts) are relevant to silage wilting decisions and animal waste disposal activities. In other cases historical weather records can be used to assess disease risk (liver fluke). Combined historical rainfall data and short-term rain forecasts can be used to assess the risk of land damage due to wheeled or animal traffic. Organic farmers would benefit greatly from some form of agrometeorological forecasting service, as they are prohibited from using conventional drugs and antihelmintics. Disease forecasting would allow them to institute appropriate preventative husbandry/grazing regimes.

In the above examples relatively straightforward ideas have been presented. In reality, interpretation of meteorological elements in the agrometeorological context is often complex. For example, in the assessment of heat stress or cold stress in livestock, the critical temperature varies according to humidity, wind and precipitation (note that suitable equations exist for integrating these factors in a predictive manner). Similarly, the forecast of soil trafficability requires an evaluation of previous rainfall and evaporation (in the context of a specific soil type and landscape position) as well as data on forecast rainfall. These combined requirements make the localisation of a weather forecast essential if the maximum value is to be drawn from investments in the forecasting infrastructure. Due to the complexity of interpretation, agrometeorological information will increasingly be defined in terms of models. There is a perception that the national meteorological service does not devote substantial resources to the translation of meteorological data into agrometeorologically useful information. Similarly, resources available for the education of farmers wishing to take a more modern approach to agriculture using models and forecasts in a quantitative framework are limited. It is concluded that the agrometeorological requirements of pasture-based livestock producers,

as well as agricultural producers generally, should be provided through co-operation between various State agencies.

In addition to the practical production aspects of farming, weather forecast information has an increasingly important role in the environmental management aspects of farms. Thus the future challenge also includes developing strategies (i.e. models) which effectively assess environmental risk due to weather conditions.

Rec 1.6 Review and enhance forecast services to best provide information suitable for both environmental management and production aspects of farming

Rec 1.7 Review and enhance forecast tools for animal diseases, land trafficability and whole farm system impacts

Crop production

Many of the same arguments apply to crop production systems as for livestock production, but the requirement is often much more focused. At present many of the DSS rely on assessment of fungicide dose-response curves. Some models give reasonably accurate forecasts such as those for apple scab and potato blight. Models for diseases like *Septoria* on winter wheat or mildew on spring barley do not work reliably at the present time. There is also a requirement for information on weather conditions that affect soil conditions at sowing, fertiliser spreading, spraying and harvest times (similar factors prevail for land trafficability). The effect of weather on soil conditions has become more important as machinery size and ground pressures increase.

Rec 1.8 Review soil-weather interaction and instigate research to achieve reliable forecast tools for land management

Rec 1.9 Assess the potential for incorporating on-farm observations (necessary for some commercial decision support system tools such as NegFry) into the national meteorological observation network using a suitable quality control procedure

Unlike other production factors such as fertilisers, irrigation and breeding, agrometeorological relationships in crop production are always associated with risks not controlled by the farmer. The farmer can only manage the effect, not the cause. The culture of modern grassland farming tends to accept the meteorological factor as a risk with the same status as the demands in everyday life that are the currency of the insurance actuary. For this reason, the value of agrometeorological information and its application has to be assessed on a different basis. Its value is related to the degree of certainty associated with the information. Agrometeorological information has greatest practical value when it tells the 'now' situation. Local short-term precipitation forecasts based on radar have high value. In a sense, long-term averages for a region are 'now' forecasts that have high value for strategic management planning decisions. In a general way the benefit of agrometeorological information for tactical planning decreases as the period (days) of forecast increases. It can still be useful because the accuracy of forecasts decreases when the period of the forecast is greater than about 72 hours, but none-the-less, can be useful for a period of up to 10 days. This uncertainty means that many users accept the meteorological forecasts passively and for this reason decision responses are not made.

Rec 1.10 Educate crop producers in the value and benefit of using weather forecasts of differing lead times and different forecast periods (now-casting to long-range)

To increase the value and effectiveness of agrometeorological data it is necessary to develop forecasting procedures that include an estimate of the probability of an outcome. Furthermore, it is not sufficient to provide farmers with data on the basic meteorological elements. Farmers are not meteorologists and it is necessary that the data be presented to the user in a form that is readily interpreted in agricultural terms (i.e. as information).

The circumstances of individual farms and farmers, even within small geographical regions, are heterogeneous. Tactical management is a complex activity dictated by the separate demands of land, crop, livestock and environmental management. Meteorological data and forecast services need to integrate the meteorological elements with the elements of the complex systems that are farming. Only then can agrometeorological information relate meaningfully to the demands of tactical management. This approach is not available at present. The future of livestock producers, particularly in temperate regions, is likely to be one of reduced profit margins. There is a growing awareness of the implications of rural depopulation. For economic and social reasons therefore, it is important to reduce the risk element in Irish farming and to increase the security of the producers.

Rec 1.11 Include in forecasts an estimate of the probability of an event occurring

Weather has a major impact on agricultural efficiency, and whilst it is effectively beyond our control, considerable scope exists to develop models and prediction systems to warn against deviations from normal patterns, and to chart the current position, thus assisting with management of the whole-farm enterprise.

Report of Working Group 2: Alternative Uses of Land

Introduction

Over recent decades, agriculture has become a complex industry comprising various enterprises requiring sophisticated meteorological services. For the purposes of this review, the needs of alternative land uses (as distinct from general production agriculture) for meteorological services were considered. The areas identified for consideration as alternative ‘agricultural’ land uses requiring meteorological support services were:

- Aquaculture
- Energy generation
- Forestry
- Horticulture
- The leisure industry
- Organic Farming

Meteorological services are in a better position to meet the diverse needs of each of these sectors compared with the situation in the mid 1980s when **AGMET** compiled its first national needs review. The working group considered a range of requirements from on-line timely observational data, very short range detailed forecasts up to 6 hours (so called now-casting), short range forecasts up to 1-day and 2-days ahead, warning services, and medium range forecasts extending to a week. Also discussed were monthly and seasonal forecasts expressed in terms of probability of above/below normal (e.g. rainfall, temperature, windiness), but because of the uncertainty of the quality of these products, no further consideration was given them for this report. It was considered important as an initial, and later as an on-going task, that ‘customers’ of meteorological information should have at their disposal a listing of all the meteorological services that can be made available to them.

Rec 2.1 Provide a regularly updated directory of meteorological products/services including a statement on the means of delivery of the products (Internet, fax, mail, TV, radio, other media...) to relevant users

Each alternative land use will be considered separately.

Aquaculture

Aquaculture is a relatively new industry, having grown from an embryonic stage in the late 1970s to an output value of over €76 million today. A recent report, *Irish Aquaculture, The Future*, by the Department of Marine and Natural Resources (DoMNR) has indicated that the industry has the potential to grow by 305% in value over the next 15 years, partly due to world fish stocks being under great pressure. A number of environmental issues also affect the industry such as the EU 5th and 6th Environmental Action programmes on sustainability and visual impact, and the supermarket requirement for quality and reliability of source. The fact that aquaculture operations are mostly located in remote rural areas where there is little alternative employment makes the industry important in terms of providing a future for rural coastal communities. Aquaculture is concentrated on the indented Northern, Southern and Western coasts where there are many sites suitable to fish farming. The main species of fish and shellfish cultivated in Ireland, and their value are:

Species	Total Volume (t)	PPU (€)	Total Value (€)
Salmon*	18,872	3,315	49,263,694
Sea reared Trout	1,368	3,274	3,525,857
Freshwater Trout	2,286	2,877	5,177,790
Eels	25	9,074	181,483
Turbot	5	8,890	35,560
Bottom Mussels	14,105	439	4,882,261
Rope Mussels	9,519	655	4,911,851
Gigas Oysters	5,518	1400	6,080,567
Native Oysters [†]	432	2,921	993,140
Clams	226	3,495	622,127
Scallops [‡] (mature)	25	3,810	76,200
Total	52,381		75,750,529

[†] Native Oyster figures include farmed and fishery co-op production (the majority of this is from fisheries).

[‡] Scallop production excludes seed and juvenile production.

* Salmon figures are estimated from processor monthly returns

Meteorological services required by the aquaculture industry may vary from species to species. Generally the industry can be divided into three sections: freshwater finfish, sea-reared finfish and shellfish. For freshwater finfish, the most useful meteorological information is catchment rainfall history and, if possible, predictions. This information can be used to calculate sustainable water abstraction rates for trout farms. Eel and turbot are now reared on re-circulation (closed) systems, and so are not as dependent as other species on climatic conditions. Sea reared finfish represent the greatest proportion of the aquaculture industry. This section would benefit from forecasts of wave height analysis, current strengths and speeds and oceanic temperature and salinity. Information of this nature can be of great help in the site selection process. This sort of information will become increasingly important as the salmon and sea trout farms move further offshore (1 to 5 km). Some species of shellfish, such as mussels and scallops, are likely to move offshore in the medium to long term. Since shellfish are filter feeders, they are vulnerable to two specific environmental impacts in two ways. Firstly they are susceptible to contamination resulting from agricultural run-off after heavy rain. Secondly, they may be contaminated by naturally occurring Toxic Algal Blooms (TAB, known as 'Red Tides'). It is known that TAB can be predicted to a certain extent from local wind, temperature and salinity conditions. Rainfall is a key factor in Coliform counts in the water column of remote coastal areas. Using this information, warnings could be given for TAB and/or high Coliform counts. This could be done in much the same way as warnings for potato blight are given at present. For shellfish farmers, records and short to medium term predictions of critical parameters in their area would be very useful to assess the safest times for harvesting. Shellfish farmers would also benefit from information on oxidation/reduction conditions at their growing sites. This information is useful in assessing stress that may affect the growth and performance of the shellfish. While all of the technology and knowledge may not be available for the accurate prediction of TAB, the exercise of building up a data bank on these and other parameters will prove valuable in the future for all marine based activities.

In terms of availability of meteorological data it is a case of the more available the better. A website displaying long, medium and short term forecasts would be ideal. Short term, 1

to 24 hour, forecasts are very useful to the industry. In terms of priority, accurate short to medium term forecasts are most important. This is especially true of the salmon farming industry as the trend here is to move offshore leaving the farms more exposed to the elements and lost working days due to unfavourable weather. Shellfish farms are usually shore-based and located in sheltered sites. The main issue here with regard to meteorological data is rainfall and catchment run-off increasing the risk of high Coliform counts in the water. Projected rainfall values could be useful in deciding on harvesting and sampling times.

Now-casting would be most useful for the salmon farming industry where wind speed and wave height data are important factors. With existing sites, potential wind and storm damage requiring advance warning through weekly forecasts becomes as relevant as time-specific now-casts. Predicting algae blooms would also be relevant (wind and waves). Northern Ireland also has an aquaculture industry (particularly shellfish) so a cross-border integration of data would be useful.

Rec 2.2 Met Éireann, The Marine Institute and Department of Marine and Natural Resources should jointly review the meteorological services needed by, and made available to, the fish farming industry, and put appropriate services in place where gaps in warnings are leading to commercial losses

Energy generation

The activities considered in this section are energy generation from wind and peat. Short rotation forestry may also be classed as an energy crop but is only grown to a very limited extent in Ireland. Apart from the need for adequate climatological studies, the requirements for weather forecasts of wind, frost and rain for short rotation forestry are little different from that of more general forestry. Wave and tidal energy were not considered.

Wind energy generation. Wind energy is a clear alternative land use for farmers and has the potential to make a major contribution to electricity generation. In the main, wind energy generation involves public/corporate/private groups. Wind energy generation stations have been concentrated in many counties including Donegal, Mayo, Leitrim and Cork. A number of contracts await approval, but there is a difficulty at policy level (the pricing of wind energy makes it hard to compete with conventional means at present). At current prices for the generated electricity, farms must be sited at the high altitudes, thereby creating a negative visual impact. This situation is likely to change when the price offer improves. With a prospect of energy tax, the future looks better for wind energy generation.

For adequate mapping of climate, weather observations over a minimum of 15 years are desired at any location considered suitable for wind energy generation. There is a wide range of wind resource available in Ireland. The wind determines the energy harvest, electricity production and hence the economic viability of a wind project. The wind resource is the long-term wind regime at a location and is climatological in nature. It is currently necessary to estimate the wind resource at most particular locations based on height above ground level, geographic location and modelling. Measurement is expensive and the period of measurement needs to be sufficient to determine the statistics of the longer-term wind regime at a location, so the validation of models is essential. An increase in the climatic/synoptic observation sites would provide more data for the

development and testing of wind models, both for resource evaluation and short term prediction.

Requirements are both climatological and related to modelling. The *Irish Wind Atlas* is a tool to extrapolate winds from known places to others, and to produce detailed mapping of wind resource. The wind analysis (at 50m) on a 100 km grid was based on 28 stations including meteorological and wind energy generation stations. The *Irish Wind Atlas* will be a useful tool for the prospective wind energy generator but even more useful would be detailed wind resource maps of a region which can be produced using the wind atlas method (see under *Modelling* later in this section). A number of sites have been monitored for wind over the last few years and it would be most useful if this data could be assembled and archived by a body such as Met Éireann for the general good. Unfortunately data are often seen, by individuals who have carried out the measurements, as commercially sensitive.

Wind forecasting. As wind is variable, there is a need for wind forecasting in the operation of wind energy generation stations. A general wind forecast might give information on calm periods, which would be suitable for maintenance planning to avoid loss of production. Of more interest would be detailed wind power forecasting for the upcoming 48 hours. Three users of this type of service can be identified. The transmission system operator needs to schedule conventional generation methods to meet the variations in load demand, based on the in-feed from wind energy generation stations. As the contribution of wind energy generation stations increases it will become increasingly important that an accurate forecast of the wind power production is available in order to operate the system economically and reliably. In the newly deregulated electricity sector, the energy trader is also a potential user of a wind power forecasting service. The green energy trader buys electricity from wind energy generators and sells it on over the transmission system to customers. To optimise income the supply/load profiles must be matched. In the longer term the individual wind-farmer might also be interested in the context of a completely deregulated market. An accurate, localised and tailored forecast of production can ensure the best price for the energy produced.

At Risoe, Denmark, a model has been developed based on HIRLAM and the wind atlas method to provide a wind power forecasting service. How this might be implemented in the Irish context is currently being investigated and funding possibilities are being pursued. A study in offshore wind resource is also being undertaken. An ESB study is in its final stages. In the context of liberalisation of energy markets, the scenario is for energy traders to buy their electricity from wind energy generators for a price based on short-term estimates on demand. Thus better prediction is needed on the load side and on the supply side. Offshore production is coming soon to the eastern coast of Ireland in the next few years and will compete with existing producers in UK, Denmark and the Nordic Sea, which has significant implications from the meteorological point of view, i.e. different wind profile and a lack of measurements.

Rec 2.3 Archive wind measurements (for example by Met Éireann) made at wind energy generating stations as public information. Due to commercial sensitivity, appropriate protocols for supply, quality control and access to the data should be negotiated and put in place

Rec 2.4 Since there is a niche in the market for wind energy forecasts, put in place a weekly outlook forecast aimed at the wind energy sector as a public service (e.g. in the weekly farming forecast) and as more detailed/tailored 48 hour forecasts by private contract

Modelling. Modelling techniques can be divided into physical and statistical types. An example of a physical modelling technique is the wind atlas methodology, which seeks to model the physical, local effects on the wind due to orography, roughness and obstacles. So-called wind atlases are based on long term wind data (such as those recorded at Met Éireann synoptic stations) by 'cleaning' the measurements. The process accounts for local orography, roughness and obstacles to form regionally representative wind climates. The technique can then be applied to a location where the wind resource needs to be "found" by combining wind atlas information with effects of orography, roughness and obstacles. The method is the basis of the *European Wind Atlas*, published in 1989, and also the basis of the *Irish Wind Atlas* which has been prepared by Rick Watson (Department of Electronic and Electrical Engineering, UCD) and Lars Landberg (Risoe National Laboratory, Denmark) over a period of years and should be available in 2002. The *Irish Wind Atlas* is an expanded and hopefully improved version of the Irish section of the *European Wind Atlas*.

Another modelling technique commonly used is called MCP (Measure-Correlate-Predict). MCP is a statistical technique which requires short-term measurements at the location of interest which are correlated to contemporaneous measurements at a long-term station and the results are used to adjust the measurements at the long-term station to provide a prediction of the long-term wind resource at the location of interest.

Rec 2.5 Develop finer scale wind atlases for the areas of Ireland with most potential for wind energy production

Peat Harvesting. Peat for energy is now produced under licence from the Environmental Protection Agency. Production is totally dependent on solar drying to reduce the water content of milled peat from about 85% (wet weight basis) to 45-50% prior to stockpile storage. At this point the quality of the peat depends on avoidance of re-wetting and therefore precipitation. The enormous variability of peat leads to very different rates of drying and potential re-wetting. It is theoretically possible to harvest target output (a desired mass of peat) in 40 days: 2.5 per cent per day; 12 crops per year; and a 3-4 day drying period per crop. It usually takes 90-95 days per year to achieve the target harvest.

At present Bord na Móna avails of a 4-day rolling forecast of weather but there is a degree of dissatisfaction with the accuracy beyond the first 24-hour period. There seems to be no great confidence amongst the production managers in current forecasts. A 4-day forecast for the midlands during periods of broken weather covers too large an area and is of very limited value at specific production sites. The question arises as to the possibility of having predictions for individual bog areas that are more site specific. Rainfall climate is the most important (although other parameters are also relevant such as wind speed, humidity and temperature, which all effect evaporation rate). Environmental concerns are becoming more important to the industry now that it produces under licence. These demands may force Bord na Móna to assess the weather in winter months for planning maintenance and development operations. The industry also requires a confidence level for each forecast. It may be necessary for Bord na Móna to collect more site specific

meteorological information using automatic stations in the future. Peat drying/re-wetting models should be available to forecasters for the tailoring of forecasts to the industry.

Rec 2.6 Met Éireann and Bord na Móna to liaise and discuss methods of creating localised and tailored meteorological services for peat production

Rec 2.7 Undertake research to assess the value of new technologies (observations and models) suitable for the peat industry

Forestry

In recent decades forestry has become an important rural enterprise occupying about 8% of Ireland's land area, but being confined to mostly upland or peat covered sites. Recent developments have led to an expansion into lowland (fertile) land holdings. Issues now generating interest in forestry circles are the physical environment, exposure (wind speed/direction; gale-gust days), atmospheric deposition, long-term sustainability, biodiversity, climate change impacts, concentrations of gaseous ozone and greenhouse gases, and a sustainable nutrient balance. The most important meteorological information required relates to rainfall, temperature and wind. Wind is particularly important in determining exposure, wind-throw and the spread of fires. Forecasting of strong winds is also useful in harvesting operations which may become dangerous.

As most forestry is in upland areas, the data acquired at meteorological stations are generally not suitable and thus most available Irish data are not entirely relevant to the industry. In the absence of suitably located meteorological stations, interpretative models need to be developed and tested to provide more accurate information for areas located between stations in the meteorological observation network. Such models would be similar to the wind atlas concept with its "adjusted" data for altitude, location, topography and obstruction at a site. There is a clear overlap in requirement between the demands of the wind energy sector and the forestry sector for better wind climate information.

Wind-throw. Wind-throw losses are the greatest threat to mature forestry in Ireland. More wind speed data collected using both anemometers and tatter flags located throughout the country at a range of elevations and at a range of topographical types are required. Also needed is more information on return periods for winds of various strengths. Transfer of knowledge on modelling wind patterns with respect to interaction between elevation and topography affecting wind speeds is a clear priority. Data such as these are essential to forestry.

Wind hazard classification is used in forestry to determine areas suitable or otherwise for the establishment of trees. Agroclimatological data have been used successfully in the past to determine return periods for the frequency of storms. Estimates of exposure are also useful for forest health studies. Indeed exposure has been identified as the most important factor affecting forest health in Ireland. From research, climatological estimates of exposure in terms of wind speed, wind direction and number of gale-gust days are extremely useful in forest health assessments.

Frost and Temperature. Dates of first/last air/ground frost based on regional climatologies, and return periods, would be valuable. An early warning system (e.g. 24 hour forecast) is also needed in this regard, especially for forest nurseries. More detailed data are needed so that relevant agrometeorological parameters can be calculated. Accumulated chilling hours are the number of hours < 5°C; these provide an indication of

cold stress in the crop. Degree hour sums are number of hours $> 5^{\circ}\text{C}$ and provide a measure of the growth of the crop. Information is needed on the effect of topography on ground/air temperature such as depth of accumulated cold air and its interaction with vegetation and soil type to influence site temperature. Temperature data are needed for various soil and vegetation types at locations covering the whole country. A more forestry specific issue is the establishment of temperature patterns with a variety of established forest types (i.e. temperature within conifer stands *versus* broad-leafed and mixed stands).

Atmospheric Deposition. Information about large scale air mass movements are important for atmospheric deposition monitoring and prediction. The impact of airborne pollutants on plant health needs further investigation. Coillte have precipitation collectors located throughout the country from which rain water quality is analysed on a monthly basis. An index of ozone concentrations at ground level would be extremely interesting in terms of assessing plant damage possibly caused by high concentrations of ground level (tropospheric) ozone.

Rec 2.8 Perform a comprehensive climatological study through the co-operation of Met Éireann, Coford, Coillte and the universities resulting in development of an atlas tailored for forestry needs

Fire Warnings. In terms of fire warnings, March and April are the crucial periods. However, any prolonged period of drought leads to high fire risk indices. Accurate weather forecasting is critical in late spring/early summer to provide a 3-5 day alert period which would be valuable. Predictions of heavy rain may lead to cost savings in terms of helicopter and manpower management. Data on wind speed and direction, amount of rainfall and pattern of rainfall as well as temperatures needs to be made available to foresters on a 24 hour forecast basis so that preparation in the event of a fire can be undertaken.

Rec 2.9 Update as a priority the Fire Risk Model widely used in Ireland. As part of this update, an IT initiative should be included to integrate the supply of data with the model and the final delivery of the resulting information

Nursery Stock. Frost appears to be one of the greatest influences on nursery stock performance. Frost warnings are vital for nurseries in terms of protective measures for young trees. Late spring and early autumn frosts are most significant. Frost, in particular late spring frost, coincides with bud bursting in spruce and may have a serious effect on tree vitality. Indices of frost are also important at the establishment phase of forestry in respect of soil hardness and exposure of the young crop. Weekly and 24 hour outlooks are very important in the nursery industry in terms of planning operations. Crop irrigation may not be needed if rain is forecast; likewise the effectiveness of some insecticides is inhibited by rainfall. On the other hand, some sprays are sensitive to sunlight and may not be applied on very sunny days.

Rec 2.10 Develop timely, localised and accurate meteorological support services for the forest nurseries by co-ordination between the industry and Met Éireann

Horticulture

One of the problems when considering the requirements of horticulture is that horticulture is composed of a number of quite different sectors. We can distinguish between those crops grown under protection in greenhouses or mushroom tunnels and those grown in

the open. Outdoor crops include vegetables, fruit (a tendency for more protection), ornamental, and most nursery stock. Vegetables and fruit have the same needs as cereals and other arable crops. Supermarkets are demanding limits to the amount of chemical treatments used on horticultural products. The advent of decision support systems (DSS) raises the question whether Met Éireann stations are site-specific enough to provide acceptable data to individual growers. Now-casting would be very useful for immediate operational planning and for alarms and warnings. Also to be considered are aspects of amenity horticulture such as parks, amenity gardening maintenance, landscape gardening, playing fields and golf courses. It seems that there has been a substantial increase in activity in this area but the precise meteorological needs, if any, are unknown.

Open field crops. Probably the most notable development in field horticultural crop production has been the increase in the scale of production. Increasing labour costs are leading to greater use of automation, which demands larger scale production to justify costs. Thus our fruit and vegetables are being produced by a much smaller number of growers than in the past.

In relation to weather conditions, the most interesting development has been the introduction of DSS which can be used both to maximise the effectiveness of pesticide sprays and to reduce their number. A DSS can be simply a model of degree-days from a particular date to predict emergence of a pest, or of temperature and humidity to predict the spore release of a disease. This information is then used to aid the decision of when to spray and with which pesticide. What is lacking for the industry is the necessary site-specific meteorological and climatological data to drive the prediction model for a particular pest or disease. These developments are being encouraged by supermarket chains which will insist in the future on a DSS being an integral part of the crop production protocol as part of an environmentally responsible approach to food production.

Can Met Éireann provide weather data that are site-specific enough to provide accurate information to the predictive model? If so, then it is conceivable that the models could be run on Met Éireann computers and that a warning service could be operated, perhaps through the Internet on a subscription basis. However, the approach taken so far has been to install a small weather station on the site, connected to a PC, which acts as a data logger and also runs the predictive software. The decreasing price of such equipment, along with the increasing scale of production make this the most likely way that DSS will develop. This situation also leads to the question of whether such sites could provide suitable quality data to Met Éireann.

Any outdoor production system stands to benefit from accurate weather forecasts. For instance, if a decision to spray has been taken using a DSS it is necessary to know the likelihood of rainfall within a particular period of time (hours or days) so that the spray is not simply washed off the leaves. A forecast of wind speed and direction is also vital in order to minimise the effect of spray drift. An accurate short term now-cast may indicate that it would be better to postpone the spraying operations for some time in order to achieve more effective results. These considerations apply to any horticultural crops grown outdoors (vegetables, fruit or nursery stock). Some crops, in particular fruit, are susceptible to frost, especially at flowering time. In cases where some preventive measures can be taken such as straw with strawberries and the use of sprinkler systems for top fruit, a frost alert system during the late spring could be very useful.

Rec 2.11 Develop networked meteorological services appropriate for Decision Support Systems for horticulture by close co-operation between Met Éireann and other relevant institutions

Rec 2.12 Produce a detailed wind map of Ireland for the siting of new enterprises. Maps of the incidence of late spring frosts are also necessary

Protected crops. Greenhouses used for heated crop production, usually tomatoes in Ireland, are nowadays usually equipped with a climate computer and a weather station which monitors outside temperature, solar radiation, wind speed and direction and occurrence of precipitation. The computer typically controls the heating system, ventilators, carbon dioxide supplementation system and thermal screen, if present. This level of sophisticated control leaves the heated greenhouse nursery less dependent on weather forecasting or climatological data. Where computers are not used and simpler control such as thermostats are employed, the most important forecast information would be news of impending storm conditions so that ventilators can be shut independently of temperature to avoid structural damage.

Mushrooms are grown in double-clad polythene tunnels with a layer of insulation between the sheets of polythene. For the most part simple control systems are used although an increasing number of producers are installing computer systems. Like the heated greenhouse producer, mushroom growers do not have a great dependence on weather forecasts or climate data.

Nursery stock in containers. Most ornamental shrubs are now produced in containers filled with a peat-based growing medium. This means that the volume of growing medium per plant is much reduced compared with field production and therefore irrigation is needed. In the future this will be accomplished either by direct measurement of the water status of the growing medium in the pots (by tensiometers), or indirectly by using an evaporation model. The model would calculate potential evapotranspiration and use a factor to allow for the crop and the stage of development. As with the DSS, the necessary weather data could be collected by a local automatic weather station and a computer would then control the irrigation systems. The possibility of Met Éireann supplying tailored, site-specific weather data as a service to growers (to avoid the necessity of installing weather stations) should be examined. This arrangement could also apply to golf green irrigation.

Amenity crops and general horticulture. Many horticultural activities combine some outdoor and indoor work. Weather forecasts have potential value when planning the work strategy over the coming days or weeks. For instance timing of harvesting vegetables, mowing of grass and many other operations are very weather dependent. Although these operations were carried out intuitively in the past, as management standards become more demanding, there is likely to be a demand for 5-day and longer forecasts to enable better planning of the tasks ahead.

Soft Fruit. The use of plastic tunnels and cloches is increasing, mainly in the south-east of the country. The market for processed fruit is decreasing. While soft fruit is now a very protected crop under polythene, wind and frost continue to be important issues for the sector. DSS may be useful in this industry.

Elsanta is the main strawberry variety grown for the fresh market in Ireland. Elsanta and other June bearing strawberry varieties require a period of low temperature in order to produce satisfactory fruit yields. In field crops this period of chilling occurs from the beginning of October to the end of March. There are indications that the number of cold units increases as one moves northwards and that the chilling factor may be a lesser problem in Dublin and Meath than in Wexford and Cork. It is planned with the aid of Met Éireann to investigate this possibility further. Soil type and sunshine hours are also important elements in successful strawberry production and these need to be seriously considered when assessing the most suitable location for soft fruit production. A cold unit service would be beneficial, as would an evaluation of the impact of climate change on the horticulture industry as a whole.

Rec 2.13 Provide as a planning service, constantly updated climate data suitable for a wide range of horticultural crops

Rec 2.14 Met Éireann, Teagasc and the universities to evaluate late spring frost warning services and cumulative cold units for the soft fruit industry

Rec 2.15 Educate amenity horticulture managers (such as local authority employees and golf green keepers) in the use of meteorological information and forecasts for planning work

Leisure industry

The leisure industry is fast becoming the largest single industry in Ireland. It is believed that meteorological forecasts are widely used by the industry but to what extent is hard to reckon. Agri-tourism is multifaceted. All activities under this heading require good meteorological data. In fact, this sector of tourism could be the major beneficiary of a range of services, particularly now-casting. The following leisure groups have been identified as being users of weather forecasts: water sports (sailing canoeing, angling, windsurfing); golfing (including golf course management); equestrian sports; hill walking; rock climbing; track and field athletics.

A number of sports organisations and leisure management agencies were contacted with a view to gathering information (including, but not exclusively, Bord Fáilte, Marine Institute (water sports), Department of Tourism (sports activities), Mountaineering Council of Ireland, Glenans, Equine establishments, Golf Union of Ireland, Irish Farmhouse Holidays, Irish Country Holidays) but there was a lack of response from the great majority surveyed. Of the replies received, the equine industry listed a number of requirements of the sector.

Despite the low response to enquiries, the working group still feels that this sector of rural environment users is a major beneficiary of meteorological information and ongoing efforts at the corporate level should be made to collect more focused information on requirements.

Rec 2.16 Pursue corporate contact with the various enterprises associated with the leisure industry with a view to ascertaining their exact meteorological needs, leading to enhanced and tailor-made products

Organic Farming

The market for organic food in Europe has more than doubled in the last five years and is currently worth approximately €5.7 billion, or about 2% of the overall food market. The

average amount of land farmed organically in the EU is 2.1% with Austria and Denmark farming at 8.4% and 6.0% respectively, compared to 1.8% in the UK. Growth of organic production has been slower in Ireland, with less than 1% of land being farmed organically. Some 70% of the organic food that is consumed in Ireland is being imported. Organic farming requires sophisticated management and farming is best conducted in harmony with soil and climatic conditions. The use of fertiliser nitrogen, herbicides, pesticides and fungicides is eliminated and only very limited use of antibiotics is allowed. The emphasis is on animal welfare, environmental protection and disease prevention.

In the absence of the chemical intervention solutions available to intensive agriculture, organic farming is very dependent on climatic conditions and the immediate synoptic situation *e.g.* without nitrogen, the commencement of growth in spring, silage yields and grass growth in mid-summer are very dependent on adequate temperature and rainfall. Similarly, weather has a major influence on methods of weed control in cereals. Accurate weather forecasting is therefore absolutely vital to successful organic farming. Extension of the current service that predicts disease outbreaks could become an integral part of organic farming. For instance, accurate predictions of when weather conditions are conducive to disease outbreaks like liver fluke and/or stomach worms would be very helpful to organic livestock production. Curative forecasts are of little value.

The relationships between life-cycles of various pathogens and climatic conditions need to be studied more carefully with a view to determining how management and climatic conditions can be used to break the life-cycle and lower the incidence of disease. Similarly, the influence of humidity and housing conditions on the outbreak of diseases like pneumonia in animals needs to be more fully understood, if outbreaks are to be prevented rather than cured. There are some predictions that organic farming will continue to grow to 5-10% of total production in the next 10 years. This growth will present challenges to the agrometeorological services provided by Met Éireann. The influence of the various components of weather on plant growth, disease outbreak and life cycles of pathogens will need to be more fully understood. It is conceivable that models could also be developed that use climatic and biological data to suggest management strategies to reduce the incidence and severity of a whole range of diseases.

Rec 2.17 Produce an organic farming specific agroclimatology of Ireland and develop improved, localised agrometeorological models such as grass growth models without nitrogen fertiliser strategies

Report of Working Group 3: The Physical Environment

Introduction

What is meant by ‘physical environment’ in this context? The ‘physical environment’ can be defined as the total assemblage of matter and forces within which we exist materially. Albert Einstein said “the environment is everything that isn't me”. From the viewpoint of agrometeorology, the physical environment may include the input of radiation to the planet, the atmosphere, the hydrosphere (extending from the atmosphere to the oceans, precipitation, surface and ground waters and ice), the geosphere from solid rock (lithosphere) to soils (pedosphere), and permeating all of these, the biota, including ourselves (biosphere).

The physical environment is managed by a range of people whom society holds responsible for its actions. The atmosphere is managed by those who emit substances directly to it through combustion processes, separation of gases, consumption of gases, or management of vegetation and land cover which affects gas exchange. The hydrosphere is managed by water abstraction and emissions of and from wastes. The geosphere is managed at the surface (pedosphere) by agriculture and construction activities, by spreading and burial of wastes, and in the lithosphere (and hydrosphere) by mineral extraction. In all these activities, the decision-makers may be distant from the action, both upstream to policymaking and downstream to consumers in the production chains which influence these processes.

The extent of impacts caused by environmental management (anthropogenesis) depends on the mobility of the medium, the scarcity of any resources consumed, and the way in which products are distributed. If the effect of management is large compared to natural changes, the "impact" may be considered significant. Increasingly, the pressure of population and the reach of development, combined with improved understanding of processes up to planetary scale, have led to more awareness that important impacts exist. Mankind's responsibility for its actions increases both with increased understanding, and with an ever-growing ability to manipulate our environment. The aggregation of decision-making in administrative institutions, and in commercial corporations, increases the gearing between decisions and their environmental responses.

Agrometeorological needs in management of the physical environment

Table 3.1 attempts to identify those managing (or impacting), and those responsible for, the physical environment. First listed are those whose decisions impacting on the environment, but who may not be primarily influenced by environmental management considerations. Individual consumers, or small players within a larger sector (*e.g.* many small or part-time farmers) are very important because of their collective impact. An individual may make environmentally-sensitive decisions, but unless many others act in the same manner, the net effect is inconsequential. The second sector consists of those who manage substantial portions of the physical environment, and who can also take responsibility for decision-making on the basis of their impacts (such as many larger farm enterprises, landfill owners, industrial estate developers, quarry owners,...). This sector can influence consumer or small-business manager behaviour and therefore has wide reaching influence. Thirdly, agencies which are not directly involved in environmental management, but influence policy making, monitoring, regulation and control are listed. Decision-makers in all three groups responsible for the management of the physical environment have a range of specific agrometeorological needs.

Table 3.1: Decision-makers involved in the management of the physical environment in Ireland, and their agro-meteorological needs

Responsible decision makers:	Agrometeorology information needed:	Approach:
Distributed individuals:		
Consumers	Now-casts	
Commuters	Forecasts	Public media forecasts
Hauliers	Severe weather alerts	Subscription media forecasts
Small farm owners/managers	Farm forecasts	
Service industries		
Corporations:		
Large combustion plants	Now-casts	
Nuclear reprocessing	Forecasts	
Electricity production	Severe weather alerts	Public media forecasts
Bauxite smelting	Tailored weather alerts	Subscription media forecasts
Chemicals producers	Farm forecasts	Access to meteorological data in real time
Pharmaceuticals producers	Tailored forecasts	Access to climate data archives
Fertilisers producers	On-site meteorology	Automatic weather stations
Forestry	Site-specific climatology	
Airlines	Dispersion model inputs in real time	
Mining & quarrying		
Peat extraction		
Cement manufacture		
Food processing		
Public transport		
Medium to large farm owners/managers		
Developers		
Integrated Pollution Control licensees		
Policymakers & Regulators:		
Kyoto Protocol signatories		
Intergovernmental Panel on Climate Change		
Montreal Protocol signatories		
OsPar Convention signatories	Now-casts	
European Union agencies	Forecasts	Access to meteorological data in real time
Dept. Environment and Local Government	Severe weather alerts	Access to climate data archives
Dept. Marine and Natural Resources	Tailored weather alerts	Meteorological monitoring
Dept Agriculture, Food & Rural Development	Regional climatology	Emissions monitoring
Environmental Protection Agency	Probabilistic climatology	Atmospheric concentration monitoring
Radiological Protection Institute	Dispersion model inputs in real time	Meteorological and climatic modelling
Marine Institute	Emission statistics	Involvement with WMO and international agencies
Local Authorities	Water recharge rates	
An Bord Pleanála	International data exchange	
Teagasc		
Forest Service		
Dúchas The Heritage Service		

Agrometeorological needs of the Environmental Protection Agency and other environmental regulators

In addition to its statutory functions in the control of emissions to land, air and water from municipalities and major industries, the Environmental Protection Agency undertakes and co-ordinates monitoring of quality and, where relevant, flow of rivers and lakes, groundwaters, estuaries and coastal waters. The Agency, and the local authorities that also perform a variety of regulatory and emergency response functions in relation to the environment, have clear potential needs for access to real-time meteorological data. These functions include flood and drought monitoring, and determining the behaviour of emissions to air, waters or land resulting from accidental releases. In addition, the environmental regulatory bodies are facing a steadily increasing need for high quality and readily accessible data in synoptic form, such as rainfall, temperatures, insolation and wind dynamics. Improved access to these data will be required as inputs for River Basin Management Systems, the main functional tools to be developed under the EU Framework Directive on Water. These systems will incorporate emission modelling of

nutrients and dangerous substances, quantitative modelling of groundwater and surface water hydrology and dynamics of the aquatic biological communities. All of these are, and will be, greatly dependent on meteorological data. To date, it has been found difficult to obtain relevant synoptic data in sufficient quantity and quality and in a reasonable time for use in pollution modelling and other work; comprehensive datasets may also be prohibitively expensive.

Agriculture is the largest single industrial sector in Ireland, and is the one with the greatest potential impact on the environment. This impact is realised in several areas, notably the loss of nitrogen (N) and phosphorus (P) to waters and the emission of radiative forcing gases. While P is the critical nutrient for freshwater eutrophication, excessive N is endangering the quality of the estuaries of a number of major rivers, as well as damaging a number of groundwater resources used for drinking water supply (See *Weather, Soils and Pollution from Agriculture*, compiled by M. Sherwood, 1992).

According to the EPA, agriculture is responsible for over 75% of the total quantities of nitrogen and phosphorus entering freshwaters (*Ireland's Environment: A Millennium Report*, EPA, 2000). This figure is disputed by farming organisations and independent commentators, and it is therefore essential that this review creates momentum for the funding of research to clarify and resolve (equitably and transparently), these conflicting claims. Prominence should be given to agrometeorological data to assist with advising farmers on timing the spreading of fertilisers, manures and slurries in order to minimise loss of nutrients to waters. Specialist work (under EU initiatives and international conventions such as the OsPar) for developing methods of accurately estimating emissions of nutrients and other substances to water is ongoing. In particular, the EuroHARP programme is intended to provide for detailed modelling of nutrient sources and pathways to the marine environment. There is a considerable demand for basic meteorological data in relation to this programme. Ireland's commitment to management of emissions is summarised in *National Climate Change Strategy, Ireland*, (The Stationery Office, Dublin, 2000).

Policing of environmental protection also has to consider the many other demands on environmental resources (road construction, water supply infrastructure, rural factories, energy generation plants, forestry,...). Many of these demands derive indirectly from the urban population. In the coming years, "distributed individuals" (Table 3.1) living in urban areas will have to accept a greater responsibility for their actions and their impact on the rural environment. While individual impacts will be mediated through the decisions of corporate managers, the producers of waste, those demanding roads, those wanting low-cost houses and other similar facilities will all affect how our environment is managed.

Agrometeorological needs of managers of the physical environment

A number of issues relating to the management of the physical environment were identified with specific reference to agrometeorology. In each case the issue was assessed with respect to: (1) definition of the issue; (2) identifying the relevant decision-maker; (3) establishing the decision makers' needs from agrometeorology; and (4) establishing what could usefully be recommended.

Protection of Freshwaters (Rivers, Lakes and Groundwaters), Estuaries and Coastal Waters, especially from eutrophication. The sources and mechanisms of transfer of

phosphorus found in freshwaters are a matter of lively debate, and are by no means resolved. Agrometeorology has a decisive role to play in the elucidation of the transfer pathways and mechanisms through soil, surface-runoff, and hydrological properties of catchments. Surface water protection will also involve monitoring the water outflow from fish hatcheries for certain chemicals and pharmaceutical compounds. Information on rainfall and drought periods in addition to hydrological information on the water catchment will help hatchery and fishery managers in instituting husbandry procedures to conserve freshwater and to delay medication for times when the water is plentiful.

The EU Framework Directive on Water calls for the setting up of River Basin Districts, each of which will be managed at a local level. The directive calls for detailed monitoring of water quantities and ecological effects of water quality and uses. All of these areas will be heavily reliant on accessible, timely and locally-relevant measurements of all aspects of weather. Protection of groundwater supplies from undesirably high nitrate concentrations, bacterial contamination and industrial effluent contamination are issues at local and regional level. Hydrogeological data are necessary for informing decision-makers at land-surface level what impacts on aquifers and groundwater supplies may occur as a result of their decisions.

The decision makers are: Environmental Protection Agency; Local Authorities; Water Boards; Fisheries Boards; Hatchery and Fisheries Managers; Department of Environment and Local Government; Department of Agriculture, Food and Rural Development; Department of the Marine; Geological Survey of Ireland; European Union; and OsPar Convention.

Data and modelling needs are identified as:

1. data required for accurate monitoring and modelling of nutrient sources, loss mechanisms and effects in the aquatic environment. These include: basic meteorological information in synoptic form (daily, weekly, monthly and annual, with user-selectable time periods); data for as many individual monitoring sites as possible; and data at regional and national scales
2. development of water availability models for each water catchment system utilising agrometeorological data.

Rec 3.1 Provide Internet access to continually updated synoptic, daily, weekly, monthly and annual information

Rec 3.2 Evaluate and publicise the best available models and decision support systems in the area of water quality

Rec 3.3 Integrate information from Met Éireann and Teagasc to provide advisors with support for the promotion of spreading of fertilisers, manures and slurries at times and by methods suitable for both optimal agricultural benefit and minimal polluting potential

Greenhouse Gas Emissions. Greenhouse gas emissions are becoming a major issue at national level. Carbon dioxide emissions are most in focus, but the two gases for which much potential for emission reductions exists are methane and nitrous oxide. Major land use decisions may be made on the basis of the projected impact on greenhouse gas emissions (for example, densities of cattle, certain uses of cutaway bogs, or national afforestation policy). Agrometeorology has a major role to play in the development and

assessment of models used for decision making and the scrutiny of implemented decisions.

The decision makers are: Kyoto Protocol signatories; Intergovernmental Panel on Climate Change; Electricity generation companies; Peat extraction companies; The Forest Service; Farmers; Teagasc; Department of Agriculture, Food and Rural Development; Environmental Protection Agency.

The data and modelling needs are identified as:

1. budgets and estimates for fluxes & balances of radiative forcing gases as a basis for carbon credit trading
2. models to help in the siting and design of suitable houses for over-wintering animals and also in determining the maximum density of animals kept in any one site
3. models for quantifying non-agricultural contributions to radiative forcing gases

Rec 3.4 Interaction between expert groups dealing with greenhouse gas emissions from forestry, agriculture and other industries in order to reduce any duplicated effort

Ammonia Emissions. Ammonia emissions are the subject of internationally binding targets to which Ireland is a subscriber. It is plausible that emission reductions will be needed, with farmers, especially those handling large volumes of cattle slurry, coming under pressure to operate emission-controlling practices. Agrometeorology can support the operation of ambient ammonia monitoring, leading to the development of ammonia dispersion modelling in real time. This in turn can be interpreted in terms of current atmospheric suitability for land spreading of slurries, that can be implemented at farm level. The findings of a one year, EPA-funded, ammonia monitoring network resulted in the conclusion that only ongoing monitoring, and modelling can reliably provide an emission estimate upon which (costly) abatement strategies can be founded.

The decision makers are: Environmental Protection Agency; Teagasc; Farmers; Independent farm consultants; REPS advisors; nitrogen fertiliser industry; and industrial ammonia emitters

The data and modelling needs are identified as:

1. Ammonia emissions inventory
2. Ammonia concentration monitoring
3. Ammonia dispersion & deposition modelling
4. Management options for ammonia retention

Rec 3.5 Establish a permanent state-wide ambient ammonia monitoring network

Note: Recommendation 3.3 also applies to ammonia emission.

Ozone. While stratospheric ozone (O₃) protects organisms at the earth's surface from radiation, high levels of O₃ at a tropospheric (ground) level can have harmful effects. Tropospheric ozone is known to have adverse effects on both human and animal health, and can seriously affect vegetation as a result of its phytotoxic properties. Critical levels of ozone have been defined for the protection of vegetation. The critical level is based on the hypothesis that long-term damage results from cumulative exposure above a certain threshold concentration over the growing season. Over large parts of Europe tropospheric

O₃ levels exceed critical levels, indicating possible major crop losses. The critical level is based on the hypothesis that long-term damage results from cumulative exposure above a certain threshold concentration over the growing season. Only daylight hours are included in the exposure evaluation, since vegetation is physiologically active and most susceptible to damage during daylight. Unlike many other major air pollutants O₃ is not emitted directly into the air, but mainly formed photochemically from emission of precursors, such as nitrogen oxides (NO_x) and volatile organic compounds (VOC). The formation of O₃ is largely dependent on meteorological factors such as sunshine, temperature and atmospheric stability. In Europe the highest O₃ concentrations occur during summer in combination with stable high-pressure events and clear skies.

Rec 3.6 Develop ozone monitoring, public health alerts and vegetation damage prediction models

Other examples of rural environmental management that should consider agrometeorology for planning and operational strategy. This report has focused on some specific considerations regarding management of the physical environment with a particular view towards policing of environmental protection legislation. There are a number of other issues that need to be considered with regard to users of the Irish physical environment. It is difficult to expand on exact requirements and needs because many of the issues facing rural environment managers are not clearly understood. Some specific examples will highlight the issues at stake:

1. *landspreading of urban waste* – there are now a number of landspreading contracts operating in Ireland for disposal of treated urban sewage sludge. There is a need to balance the environmental regulations applying to farmers with regard to nutrient applications with the demands for disposal of waste. Agrometeorological data and models are likely to be crucial for the balanced and informed management of this very sensitive issue. Urban dwellers will not be able to ignore issues of water pollution as being a problem for rural dwellers alone. All residents in the State are contributing to potential pollution problems
2. *high intensity rainfall events and runoff from hard surfaces* – there is some evidence that runoff from farm yards is a more significant point pollution source than diffuse pollution from fields. Other hard surfaces (factory sites, garages, industrial estates,...) may also be sources of pollution (BOD, oil, particulates, detergent) in high intensity rain
3. *septic tank efficiency* – the location and function of septic tanks for rural houses needs careful review, and planning regulations should take account of soil type, rainfall and water table activity. In areas where soil hydraulic conductivity is low, increasing housing density may lead to saturation of poorly sites filter fields and there may be a need to restrict developments
4. *effluent from landfill* – the urban dwellers in the State are responsible for much of the waste that needs to be disposed of in rural environments. Proper siting and operation of landfill is dependent on agrometeorological data (such as infiltration rates and effluent volumes)
5. *smoke-stack plumes* –there is much public debate about incineration of animal and urban waste. The location and safe operation of smoke-producing plant requires careful consideration of weather influences, particularly prevailing wind (speed and direction) and atmospheric stability
6. *housing estate planning* – with the increased spread of housing for urban workers who commute, there is a great demand for creation of housing estates in rural areas.

These introduce waste, hard-surface runoff, service provision and garden chemicals to new locations. The siting, planning and management of such developments should consider environmental and agrometeorological factors

7. *introduction of coniferous forestry* – there is evidence to suggest that a deterioration of soil and surface water quality follows a change in land use from pastoral agriculture to coniferous forestry

In the examples sited above, the theory and science associated with these non-agricultural problems are directly comparable with conditions arising in agricultural situations. The same physical, mechanical and chemical processes occur, and the knowledge base of the agrometeorological community is a valuable asset that should be drawn upon to assist in the optimum management of the rural environment.

Rec 3.7 Raise awareness of local government and planning officials to the role of meteorology with respect to non-agricultural activities in the rural environment

The cost to the user of meteorological and climatological data

The pricing structure for access to data is critical to the provision of useful services. Services provided must give Met Éireann the required return for its ongoing investment, while recognising the public value and historical, publicly funded investment in the service. Commercial users will be willing to pay for products which satisfy their needs (accurate, localised and tailored). However, there are many potential users, frequently providing much utility to the community, who are not in a position to pay full commercial rates. These include students, individual researchers, educators and local community groups. There are other groups whose ability to pay may not be clearly defined (NGOs), but who will not make use of services at commercial rates.

The pricing and access to meteorological and climatological data should be fully transparent, and set using appropriate fee scales for commercial use. These should be published and regularly reviewed. The pricing structure should be flexible to allow for tailored products. Cognisant of public investment in the meteorological service, and sensitive to, and fostering of, the public sense of ownership, reduced rates or waivers for data use by public agencies, when in the public interest, should be favourably considered.

Rec 3.8 Develop a transparent pricing policy which provides for appropriate access to data

Report of Working Group 4: Services to Agriculture

Introduction

Services to agriculture fall into two distinct areas: data services and forecast services. Data services are important to researchers, forecasters, modellers and advisors in order to enable provision of the best quality products, services and advice to farmers. For farmers, good forecast services are important. Farmers need information presented to them in an easily understandable manner that they can use in their work. This section examines the services aimed directly at farmers, in particular weather forecast services. Data services for agricultural advisors and researchers were addressed in the report of Working Group 5 – Data Requirements.

In order to assess the opinion of farmers on current meteorological services, and to obtain suggestions for improvements to services, a survey was devised. The survey questionnaire was distributed to 375 farmers throughout the country. In all, 195 farmers completed and returned the survey. The text of the survey is presented at the end of this Working Group 4 report, followed by a summary of the main findings. The survey was distributed by the ICMSA, IFA and members of the working group. The following is a summary of the main points from the survey and recommendations for improvements in meteorological services resulting from it after consideration by the working group members. The Survey form, and a list of comments made by farmers, are given at the end of the report.

Farmer assessment of the available forecast services in Ireland

Sunday Farming Forecast. Many farmers watch the ‘Sunday Farming Forecast’ on RTÉ regularly, and Sunday remains the ideal day for the farming forecast. The vast majority of farmers feel that the forecast should be given at a fixed time each Sunday. If it is not possible to fix the time around lunch time, then after the 6pm news is the most popular alternative. Some farmers are in favour of having a second farming forecast during the week. Wednesday night after the 9pm news was the most frequently suggested time for this forecast. In terms of content, the forecast for the next 48 hours and outlook for the coming week are the most important points. The Sunday Farming Forecast is primarily used by farmers to plan their week’s work. A significant number of farmers commented on the need for greater localisation of the Sunday Farming Forecast. Grassland and tillage farmers mentioned the areas of their work for which the service is most useful and which, combined with expert knowledge, could be tailored to their needs. It is suggested that the Sunday Farming Forecast could contain information in the following areas:

Grassland

fertiliser application:	rainfall; grass growth; soil temperatures; wind speed (particularly gusts)
Slurry application:	rainfall
Silage harvesting:	rainfall; drying conditions for coming week

Tillage

Sowing:	rainfall (dry weather is essential for soil workability and trafficability); frost
Spraying:	wind speed (particularly gusts)
Crop monitoring:	crop disease warnings; rain event forecasts (diseases spread by splashing)
Harvesting:	rainfall; drying; rates of change of crop moisture content

Rec 4.1 Present the RTÉ Sunday Farming Forecast at a fixed time (Met Éireann and farming organisations should liaise with RTÉ)

Rec 4.2 Update the week-long Sunday forecast in a second forecast on Wednesday evening

Rec 4.3 Include more localised detail for specific regions in the Sunday Farming Forecast as well as relevant information on specific aspects of farming operations for the current time of year

Daily TV forecasts. The daily TV forecast watched by most farmers is at 9.30pm, on RTÉ 1. From comments made in the survey, the following recommendation is made:

Rec 4.4 Include in the presentation specific regional forecasts, better graphics and ensure that the balance of detail for the next 24 hours and the general outlook is correct

Radio Forecasts. The most popular radio forecast for farmers is the RTÉ Radio 1 forecast at 7.55 am, with the lunch time forecast second and hourly forecasts on local radio, third. It was noted that the forecasts tended not to provide sufficient relevant information. Some farmers in the western half of the country pointed out that the weather being forecast on local radio stations had often passed through before it was presented. Localisation of forecasts is very important to farmers. They feel that local radio forecasts are potentially very useful but are not properly developed or supported. They should be updated more frequently.

Rec 4.5 Give priority to issues of relevance to current farm management such as drying potential, wind gusts and blight warnings on the RTÉ Radio 1 forecast at 7.55 am

Rec 4.6 Update forecasts on local radio every three hours as a minimum, in the same way as the RTÉ short forecast is updated every three hours

Newspapers. Survey results show that most farmers do not use daily newspapers as a source of weather forecast information. Most however, do read the weather page in the *Irish Farmers' Journal*. On the *Irish Farmers' Journal* weather page, the rainfall prediction forecasts are considered to be very useful. The text weather forecast is not considered to be very accurate due to the fact that it is very often out of date by the time the farmer gets to read it. Suggestions which have been made to improve the weather page include: increasing the number of rainfall prediction graphs, graphical forecasts of wind, temperature and frost, information on drying and a regionalisation of parameters already presented. Presentation of new, possibly season-specific information would also be valuable, such as Ontario Heat Units for Maize growers.

Rec 4.7 Met Éireann to work closely with farming newspapers to improve weather presentation in farming newspapers

Rec 4.8 Undertake an ongoing review of information presented to farmers in newspapers, to address rapid changes such as the emerging demand for Ontario Heat Units now that maize production has taken off

Telephone weather services. Many grassland farmers and tillage farmers use Weatherdial, Met Éireann's forecast service. In terms of content there were no strong

recommendations. However many farmers want information on a more localised basis. For example, the Leinster Region is considered to be too big, with significant differences between North Leinster and South Leinster. In addition, the development of mobile telephone specific applications should be investigated. Technology now permits farmers to receive weather information in the field either by voice, data or SMS services.

Rec 4.9 Increase the number of regions for telephone weather services. The regional layout should be based on meteorological and climatological considerations

Rec 4.10 Make telephone weather services accessible from mobile phones including farming specific SMS (short messaging service) alerts

Rec 4.11 Make Met Éireann's Weatherdial Service accessible from Northern Ireland

Fax Services. Only 2% of grassland farmers use Met Éireann's Weatherdial fax service but about 28% of tillage farmers use the service. Required improvements in the service include: greater localisation; improved layout of maps; some information in tabular form instead of maps; station names on maps. The working group also considered that there was a possibility for providing user-specific tailored fax services that include interpretative information and advice.

Internet. The Internet is seen as the future for agrometeorological services. It will become the medium through which the farmer will access up-to-date weather forecasts. It is not yet clear what the technology for access to the Internet will be. It is likely to be a farm PC, but it would be very wrong to plan for the future based on this assumption. Mobile services may prove more attractive to farmers in the future. From the survey, 51% of the total number of farmers surveyed have a PC for farm use, and 8 % of these use the Internet for accessing weather information.

The Internet has the potential for use by farmers in a number of areas. These include access to: text forecast information for a particular area or region; graphical forecasts of all meteorological variables; up-to-date weather radar images; up-to-date satellite images; crop and animal disease forecasts; an interface to crop disease decision support systems (DSS); regularly updated warning, alarm and alert services.

Rec 4.12 Met Éireann, in conjunction with Teagasc and the universities, to examine exact requirements for service provision on the Internet, including an assessment of emerging technologies and access methods

From the farmer survey, discussions within the group and wider consultation, the ideal Agrometeorological Internet service should contain the following information:

- A general forecast for the whole country for the next 48 hours with a detailed outlook for the following three or four days
- Graphics to include current and forecast synoptic situation including fronts, and facility to run a chart sequence in a similar way to that seen on TV
- An interactive map of Ireland both of the 32 counties (people currently clearly understand this geography) and by appropriate agroclimatic regions. For either division of the country, the user should be able to access a detailed forecast more appropriate to local conditions
- A facility whereby a user can key in his/her geographic co-ordinates and obtain predictions of meteorological parameters for the next 7 days as output from a

numerical weather prediction model integrated with a suitable agrometeorological model. The resolution of this information would depend on the spatial resolution of the model forecast output but 10-15 km seem reasonable with current technology

- An introductory section to contain: (1) up-to-date warnings when necessary, with more detail of the warning on an attached page; (2) clear links to other services; and (3) links to assist in the interpretation of the information provided and to develop a readily available educational resource
- Crop disease forecast page
- Animal disease forecast page
- Direct and derived agrometeorological data including soil temperatures, degree days, potential evapotranspiration and soil moisture deficits

Rec 4.13 Met Éireann to evaluate the cost and practicality of providing farming-specific information on the Internet

Warnings

Farmers made a number of comments and recommendations in relation to warnings: (i) potato blight warning are not accurate enough or given regularly enough to control potato blight; (ii) warnings are too general and not location-specific; (iii) location-specific wind/gale warnings over land would be useful; (iv) localised details of thunder and lightning would be useful; (v) flood warnings are increasingly valuable; and (vi) warnings of high humidity and sprouting in unharvested ripe cereals could assist planning

Rec 4.14 Carry out research on all types of warning systems to improve forecast accuracy of magnitude, timing and location of severe weather events which have important consequences for agriculture

Education and Training

65% of farmers surveyed said that they understand all of the symbols on the TV forecasts and 35% understand some of them. 75% said that they would like to learn more about the weather. Asked to list their preferred means of receiving education in meteorology, TV programmes were the most popular choices, followed by leaflets and videos. A number of farmers suggested that appreciation of weather be given a higher priority on school curricula and that weather courses be given for both primary and secondary levels. There is also a clear need to ensure that agrometeorology education remains a core part of third level courses in the agriculture colleges and universities. Farmers would also like to know more about the environment, how their work affects it and how it affects their work. Climate change is of interest to some farmers.

Rec 4.15 Review and improve agricultural education with respect to both traditional weather services and new emerging technologies like decision support systems and models

Conclusion

From the farmer survey it can be concluded that accurate short and long range forecasts are the most important meteorological services which farmers require. A point that came out very strongly from the survey is that farmers want forecasts to be more localised. Producing and improving localised forecasts should be made a priority. Furthermore, there is a clear need to provide tailored forecasts so that farmers do not become overloaded with information and thus lose sight of the relevant parts.

Text of Farmer Survey for **AGMET** Working Group on Services to Agriculture Farmer's Agri-Weather Survey

General

1. Which of the following meteorological services to agriculture are you aware of, and which services do you use.

Aware of	Number of times used in the past month
TV Sunday Farming Forecast	<input type="checkbox"/>
TV forecasts	<input type="checkbox"/>
Radio forecasts	<input type="checkbox"/>
Newspaper Forecasts	<input type="checkbox"/>
Telephone Services	<input type="checkbox"/>
Fax Service	<input type="checkbox"/>
Internet Service	<input type="checkbox"/>
Other (specify)	<input type="checkbox"/>

Forecast Services

Sunday Farming Forecast

- 1) Do you watch an RTE TV Farming Forecast on Sunday Yes No Sometimes
- 2) Is it important to you that the forecast was held at a fixed time each Sunday Yes No No Opinion
- 3) If it is not possible to define a single time around lunchtime for the Sunday Farming Forecast, which of the following times would be most suitable to you After 6.00 pm news After 9.00 news Other (specify)
- 4) What day of the week is most suitable to you for the Farming Forecast.
- 5) Would you be in favour of a second farming forecast during the week Yes No No Opinion
- 6) If YES What would be the best day and time for the second forecast Day

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7) In each box below, please gives marks out of 10 for each of the following elements of the Sunday Presentation in terms of usefulness to you. If an element is not relevant to you, please leave the box blank

- (a) The summary of the past weeks weather (rainfall, temperature, sunshine)
- (b) The detailed forecast over the next 48 hours.
- (c) The information on grass growth over the past three weeks
- (d) The overview forecast for the coming week.
- (e) The information on current soil temperatures.
- (f) Information given on Soil Moisture Deficits.

- 8) In what way(s) is the Sunday Farming Forecast helpful to you in your work
- 9) Please give any additional comments and suggestions you have in relation to the Sunday Farming Forecast Presentation.

Daily TV Forecasts

- 1) Do you watch an RTE Forecast presentation on TV each day, Yes No Sometimes
- 2) If YES, which of the RTE forecasts do you watch (Please tick as appropriate) Lunchtime After 6.00 pm news RTEI 8.00 pm Network 2 After 9.00 news RTEI After News2 at 11.00 pm Other
- 3) What would be the ideal time for you to watch the RTE TV weather forecast?
- 4) The detailed forecasts after the 6.00pm news and after the 9.00 pm news give a good picture of the weather forecast for the next 24 hours Yes No No Opinion
- 5) Please give any additional comments and suggestions you have in relation to the daily Forecast Presentation.

Radio Forecasts

- 1) Do you listen to a Weather Forecast presentation on radio each day Yes No Sometimes
- If YES, which, if any, of the following radio forecast presentations do you listen to: RTE Radio1 7.55am RTE Radio1 12.55pm (Lunch) RTE Radio1 6.55 pm RTE Radio1 11.55 pm
- Hourly Forecasts on 2FM Hourly Forecasts on Local Radio Station Other (specify)
- 2) Of the RTE Radio1 forecasts, the time which is most suitable and useful for me is 7.55am 12.55pm (Lunch) 6.55 pm 11.55 pm Other time (specify)

- 3) Would you be in favour of a daily radio forecast primarily geared towards farming Yes No No Opinion
- 4) If YES What time would you recommend this forecast should be presented at
- 5) Please give any additional comments and suggestions you have in relation to the radio Forecast Presentation.

Newspaper Forecasts

- 1) Do you read the weather forecasts in the daily papers Yes No Sometimes
 - 2) Do you read the weather page in the Farmers Journal Yes No Sometimes
 - 3) In the box please gives marks out of 10 for each of the following elements of the Farmers Journal weather page in terms of usefulness to you. If an element is not relevant to you, please leave the box blank
- | | |
|---|--------------------------|
| (a) Weather forecast for the coming week..... | <input type="checkbox"/> |
| (b) Day to Day Rainfall Predictions..... | <input type="checkbox"/> |
| (c) Information on recent grass growth | <input type="checkbox"/> |
| (d) Recent Rainfall (4 weeks) | <input type="checkbox"/> |
| (e) Recent Rainfall (4 weeks) | <input type="checkbox"/> |
| (f) Recent Sunshine (3 weeks) | <input type="checkbox"/> |
| (g) Recent Soil Temperatures (1 week) | <input type="checkbox"/> |
| (h) Recent Soil Moisture Deficits (10 days) | <input type="checkbox"/> |
| (i) Tsuns (Degree Days) | <input type="checkbox"/> |

- 4) Are there items you feel should be added to the presentation – Please specify

- 5) Please give any additional comments you have in relation to the Farmers Journal weather page

Telephone Weather Services

- 1) Do you use telephone forecasting weather services Yes No
- 2) Do you use WEATHERDIAL, Met Eireann's telephone forecast service Yes No
- (WEATHERDIAL is 1550 723 PLUS 850-Munster, 857-Leinster, 852-Connaght, 853-Ulster, 854-Dublin)
- 3) If you use WEATHERDIAL
 - (a) Is the forecast information given, detailed enough Yes No No Opinion
 - (b) Is the outlook satisfactory in terms of content Yes No No Opinion
 - (c) Do you listen to the farm commentary at the end of the recording Yes No Sometimes
- 4) The WEATHERDIAL phone numbers are split into Ulster, Connaght, Leinster, Munster, and the Dublin Region. Is this layout satisfactory for you Yes No No Opinion

Please give any additional comments you have in relation to Met Eireann's WEATHERDIAL service

Fax Service

- 1) Do you use Met Eireann's WEATHERDIAL FAX service Yes No
- 2) If YES what products do you use

- 3) Are there other products would you like to see on the Weather Fax service

Internet Services

- 1) Do you use a computer for Farm use Yes No
- 2) Do you have access to the Internet Yes No
- 3) If YES Do you use a Weather service on the World Wide Web Yes No
- 4) If so what service do you use

- 5) Met Eireann is currently designing a Web Site. What services would you like to see placed on this site

Warning Services

The following Warning services are included in Met Eireann Forecasts when appropriate

- (a) Bright Warnings

Overview of the Farmer Survey Results

The following is a list of the most common answers provided by farmers to open questions in the Farmer Survey.

Sunday Farming Forecast

- Used for planning activities of coming week (most frequent comment)
- Grassland –spreading fertiliser, risk of pollution from slurry spreading, harvesting, silage, grass growth
- Tillage – Sowing, spraying, harvesting
- Make specific suggestions for activities – e.g. drying, wind at sprayer height, % risk of run-off for slurry,...

Improvements:

- Improve accuracy of rainfall forecasts, timing etc.
- Concentrate on forecasts, not history
- Fix the time of the Sunday forecast and/or repeat on Sunday night.
- Split the forecast into provinces/regions
- Have a similar forecast on Wednesday night

Daily TV Forecasts

- Time favoured by vast majority is After 9 pm news
- Comments
- Improve accuracy of rainfall forecasts and timing of rainfall - % chance of rain
- Improve info on timing of movement of weather systems from west to east. (Main comment) Split into regions / provinces, more detailed information for specific regions
- No advertising between end of news and forecast
- Use qualified meteorologists
- Drying forecasts for both grassland and tillage
- Leave out Europe
- Show synoptic chart over next 48 hrs changing more slowly and for longer
- More info for spraying conditions

Radio Forecasts

- Most popular forecasts – 1. 7.55 am, 2. Lunchtime, 3. Local radio
- Local radio stns are often forecasting weather that has already gone through
- Mention particular regions more specifically
- More detail on timing of weather

- (b) Gale Warnings
- (c) Frost Warnings
- (d) Severe Weather Alert

1. Are the warning services provided with Met Éireann Forecasts satisfactory Yes No No Opinion
2. Suggest ways in which current warning services might be improved

3. Suggest other items for which warnings should be included in the forecasts in addition to (a), (b) and (c) above.

Knowledge of Weather and Education

1. Do you understand the lines and symbols on the weather charts in TV forecasts. Yes No Some
2. Would be interested in learning more about the weather Yes No No Opinion
3. If YES please state the three best ways for you to learn more about the weather. Mark your preferences 1, 2, 3 in the appropriate boxes:
 Videos Leaflets Course in VEC college course in Agricultural College
 Internet TV programmes Other (specify)
4. Please give any comments or suggestions you may have in relation to education in the weather

Other

Having completed the above questionnaire please give any additional comments on the weather services available to you and list and other products and services that you feel would be useful and should be made available to you.

Profile information

Information you provide here is **strictly confidential** and is for statistical purposes only. It is required for to ensure correct analysis of the survey since different Farm Enterprises and locations have different weather service requirements and priorities.

1. Location (County):
2. Age Profile (tick appropriate box): Under 25 25 – 35 36 – 49 50 – 60 60+
3. Number of Acres Farmed (tick appropriate box): Less than 50 50 – 150 150 – 350 350+
4. Type of Farming (tick appropriate boxes): Dairy Beef Sheep Tillage Horticulture Amenity
 Other (specify)
5. Please circle which type of farming is most important you and give details (only approximate numbers required)

Dairy: _____
 Number of Dairy Cows _____ Beef: Total Number of Cattle _____ Sheep: Number of breeding Ewes _____
 Tillage / Horticulture: _____
 Number of acres of cereal _____ Number of acres of Sugarbeet _____ Number of acres of Potatoes _____
 Number of acres of Horticultural crops _____
 Other: _____

6. Additional Information: _____

- Drying information
- Ensure consistency of forecasts in time and between different media
- 2FM appears to be geared to Dublin only
- More detail on meteorological situation

Recommend that forecast at 7.55 am be specifically geared towards farming, and include forecast information on conditions depending on the activity e.g. Sowing – mention soil temperatures, ground conditions, Spraying – mention expected wind speeds, rainfall.

Newspapers

- Daily newspaper forecasts not that popular
- Farmers Journal weather page is read by most farmers
- For grassland farmers, the order of importance of information is:

1. Weather forecast
2. Rainfall predictions
3. Grass growth and soil temperatures
4. Tsums
5. Soil Moisture deficits
6. Recent rainfall
7. Recent sunshine

For tillage the breakdown is:

1. Weather forecast
2. Rainfall predictions
3. Soil temperatures
4. Tsums
5. Grass growth and sunshine
6. Rainfall, soil moisture deficits

Comments:

- Impressions good overall.
- Give wind speed in m/s for past week and coming week
- Too difficult to give accurate forecast in print media – outdated quickly, v. vague for a week
- Forecasts of wind, temperature, frost.
- Forecast for each day
- Forecasts and parameters on provincial scale
- Include pollen count
- Outlook guessing by midweek

- Put weather on page 2 or 3 of Journal 1
- More charts for rainfall prediction
- Drying forecasts
- Crop disease forecasts
- Interesting historically but not very accurate for forecasts

Telephone weather service

- Around 66% of both grassland and tillage farmers use Met Éireann's Weatherdial service
- Good satisfaction with level of detail
- Satisfaction not as good in relation to outlook
- Taking 'yes' and 'sometimes' together, about 60% of grassland farmers listen to Farming commentary, and about 44 % of tillage farmers

Comments:

- Intro too long – takes too long to get to the point
- Main comment (should be more localised) – county by county if possible
- Leinster should at a minimum be split into two
- A lot of comments on cost – some recommend going to 1850 instead of 1550
- Should be accessible from a mobile phone
- Not accessible from the North
- Get a sponsor and supply service free of charge
- Should be able to speak to forecaster (Note: this service does exist)
- Update hourly

Fax

Not many seem to use fax service

Internet

- Update weekly farming forecast each day
- Regional forecasts, weekly forecasts
- Radar
- Historical daily, weekly, monthly climatological data
- Weather forecast on a county basis
- Weather outside my door for next 48 hours
- Contain same information as on Farmers Journal page and Sunday farming forecast
- LOCALISED
- Include isobars on weather charts
- Detail – 9 pm forecast typed out and graphics provided

Report of Working Group 5: Data Requirements

Introduction

High quality data, particularly meteorological data, are essential for research and the development of future services to agriculture. This report summarises the current availability of core meteorological data for use in agrometeorological applications, and assesses future demands on the meteorological observation network including a brief consideration of requirements for numerical weather prediction (NWP) related users. Issues such as the importance of high quality data, current data availability, requirements for specific types of data (global radiation, wind speed and direction, evaporation, evapotranspiration, relative humidity and water balance), and communication of data, are addressed. Recommendations are made in relation to meteorological measurements, data quality control and data availability. Some areas for further research in agrometeorology are indicated.

The issue of the linking of data suppliers with data users is not specifically addressed, but it should be kept in mind that there will be an ongoing demand for trained personnel with good knowledge of the availability, strengths and limitations of data. It will become necessary for suppliers and users of data to employ such personnel to act as independent advisors. To derive maximum benefit from data, personnel must be well educated and trained.

Importance of high quality data availability

There are a number of reasons why the availability of high quality data is important in agrometeorology. Farming is becoming more and more scientific and demands high quality, timely data in large quantities. High quality weather forecasts are essential to farmers in planning activities and making decisions. With significant increases in computing capabilities in recent years, access to the Internet and other information facilities, forecast models (weather and other secondary applications such as disease spread) are becoming increasingly useful. There is a broad range of such models encompassing weather prediction, impact prediction, crop growth, crop quality, weeds/pests and diseases, animal productivity, animal welfare and farm economics. High spatial and temporal resolution observations and NWP predictions are required to optimise agrometeorological models and to allow scientists and advisors to analyse particular weather influenced situations. NWP models of the atmosphere are achieving greater accuracy and finer spatial resolution. as a result NWP output can potentially provide a large amount of high quality data which will be useful as inputs to agrometeorological models.

Rec 5.1 Prioritise research into the exploitation of high resolution numerical weather prediction models for testing and operational use of agrometeorological models

Current observations and future requirements

The main meteorological elements currently measured at synoptic and climatological observation stations are discussed with suggestions for future modifications and extensions.

Temperature (15 synoptic stations, every 60 minutes; ~80 climate stations, daily)

Temperature can be a limiting climatic factor in agricultural production in temperate regions. While weather factors in combination ultimately determine production, temperature is at times particularly important, e.g. at either end of the growing season, and the localised incidences of frost. It should be noted that quite a number of the stations are located near the coast and thus are not fully representative of inland areas. Other observations are affected by their location (such as the stations at airports for instance), while the lack of wet soil temperature observation is a significant omission in a country with such high, year-round rainfall.

Precipitation (15 synoptic stations, every 60 minutes; ~80 climate stations, daily; ~800 rainfall stations, daily)

Precipitation can be limiting at critical periods for crop growth. Even in Ireland where precipitation is plentiful, the annual rainfall is unlikely to be as important as its distribution during various crop production stages from soil tilling to reaping. As rainfall is highly erratic in intensity and amount (both in time and space), a unit of a month is not usually adequate to properly describe its impact on plant/crop growth, which is affected by short-term variations in soil moisture conditions. If monthly totals only are available, consideration needs to be given as to whether the precipitation occurred over a short spell, or if the spell was preceded or followed by a period of (effective) drought. Drought may well result in irrecoverable damage to a vulnerable crop, particularly at critical stages of development. Thus the water available to crops needs to be estimated on a continuous basis over short intervals of time.

A decrease in numbers of stations observing only rainfall may occur, but this could be offset by the introduction of automatic stations on farms. It is hoped that some climatological stations may be upgraded to automatic synoptic type observation stations in the near future. There is also the question of the potential of joint NWP and radar outputs yielding processed rainfall data to augment the rainfall network. Such radar based services for agriculture are operational in Denmark (and other countries) with positive results.

Rec. 5.2 Evaluate the application of NWP and radar rainfall data to provide real-time, site-specific rainfall data

Solar Radiation (7 synoptic stations, 2 Teagasc stations, various time intervals)

Solar radiation is a very important determining factor in the growth rates of crops. For crops with adequate supply of nutrients and water, solar radiation is the only source of energy for physical and biological processes and can often be a determining factor for successful crop production in Northwestern European climates such as Ireland. In Ireland, the standard deviation (s.d.) in global radiation is about 5 per cent on an annual basis but nearly 10 per cent on a monthly basis.

Rec 5.3 Measure radiation at all Teagasc Research Centres and Met Éireann synoptic observation stations. Standard calibration of all instruments is required

Global and diffuse solar radiation are measured at seven Met Éireann stations. Net radiation is measured at two stations: Valentia Observatory and Kilkenny. Processing, quality control and quality assurance of Met Éireann solar radiation measurements are carried out at Valentia Observatory. Solar radiation is an important input parameter into a

number of agrometeorological applications. The most important uses of radiation data are:

- Input to crop growth models for estimation of photosynthetically active radiation (PAR)
- Input into crop disease models in which radiation amount has an effect on the incidence of disease or an effect on other factors which influence the disease
- Net radiation is a parameter used in estimation of evapotranspiration using the Penman-Monteith formula. Usually it is estimated from global radiation amount.
- For use in growth models global radiation is of much greater benefit than sunshine hours because the actual radiation associated with sun hours depends on sun angle and atmospheric conditions, thus sunshine hours are less accurate

Net radiation is a difficult parameter to measure accurately and calibration of net radiation instruments is expensive. It can be estimated from global radiation measurements with sufficient accuracy for evapotranspiration calculations.

Rec 5.4 Locate radiation instruments at Teagasc centres to form a national network. Quality controlled data should be available in near real-time

Relative Humidity (15 synoptic stations, every 60 minutes)

Vapour pressure is one of the more conservative climatic variables despite marked regional discontinuities over short periods of time due to changes of airmass. Relative humidity is calculated from differences in the readings between wet and dry bulb thermometers. High relative humidity is associated with moist airmasses and upland areas, and night-time values are usually higher than day-time values. For the purposes of agriculture, high values of relative humidity are usually associated with poor drying conditions and the spread of fungal and other pathogenic diseases of crops. On the other hand, low values of relative humidity which can be detrimental to agriculture are not normally a factor in temperate climates (low values are however beneficial for conserving hay and harvesting cereals and peat). As relative humidity is spatially fairly conservative (apart from the elevation effects and discontinuities in frontal zones), its measurement does not need such fine spatial resolution, and interpolation is quite reliable.

Wind (15 synoptic stations, 60 minutes interval)

Met Éireann archives hourly wind speed and direction, measured at a height of 10 m, for all its (15) synoptic stations. However, most agricultural activity takes place below the 2 m level, where wind speed is much less. At a number of climatological stations the run of wind (i.e. daily 24-hour sum) is read at 2 m but this is not archived. Wind measurement is now more significant due to the wind energy industry, and the specific issue of wind energy generating station location. Furthermore, the current network of stations does not adequately meet the needs of an increasingly environment-conscious agricultural sector.

Rec 5.5 Measure wind speed and direction at a more appropriate height above the ground for agriculture

Rec 5.6 Improve the geographical distribution of wind observations

Evaporation, Evapotranspiration and Water Balance (15 synoptic stations, class A pan evaporation every 60 minutes)

Evaporation measurements are generally used for the following purposes:

- to obtain information during drought conditions;
- estimating runoff occurrence;
- monitoring of wetland ‘health’;
- predicting grain harvest quality and grain/peat drying requirements during harvest

Current manual Class A (and similar) pan evaporation observations are prone to error and maintenance problems, and are poorly representative of the country. A conversion to a quality controlled automatic observations would provide better information, particularly for land trafficability warnings, pollution warnings and during harvest.

Rec 5.7 Update and automate the class A pan evaporation measurement network

A simple water balance may be adequate to provide a good estimate of soil moisture deficit for surfaces covered by short grass. In common with many countries, the balance is derived by maintaining running totals of rainfall and evapotranspiration, which are accumulated over intervals of a week to ten days through the growing season or from the start of the year. If the evapotranspiration formula (such as Penman-Monteith) is sufficiently accurate, then it is preferable to update the water balance on a daily basis. Evaporation (E) from a water surface and potential evapotranspiration (PET) from a grass crop are generally regarded as standard reference observations similar to temperature or radiation and thus are normally observed or calculated. PET is sometimes measured by a special grass (or other crop) canopy-covered lysimeter. However, because of the lack of observing stations, PET is now normally derived by a formula, such as the so-called Penman combination equation or Penman-Monteith. Such formulas require as input the various weather variables observed at the synoptic and many climatological stations.

Evapotranspiration (ET) is measured at 4 stations using Lysimeters, the results of which can be used for soil moisture deficit calculations. Many countries have ceased making evapotranspiration measurements and use the Penman-Monteith formula estimates of potential evapotranspiration. The current measurement systems can be used to test calculated evapotranspiration values, and the current observation network is essential for this task.

In the past, evaporation-based observations/estimations have been made but put to little visible use. The lack of a historical record of ET values will have an adverse impact on the introduction of models and decision support systems (DSS) in Ireland. There will be significant work required to test models with respect to ET prior to “going live”.

Rec 5.8 Maintain and continue current evapotranspiration measurements

Rec 5.9 Initiate a project to test and calibrate evapotranspiration models such as Penman-Monteith for Ireland with an appropriate grid spacing

Other observed/derived parameters

Other meteorological parameters available in Ireland include rainfall chemistry and derived parameters such as degree-days. A detailed discussion of these is not possible here, but the quality of derived parameters will depend directly on the quality of the

observation network. If real-time chemical analysis becomes feasible for synoptic stations, the reporting of rainfall and atmospheric chemistry values may be valuable in the future.

The meteorological observation network

There are a significant number of sites throughout the country measuring meteorological parameters and contributing data to the National Meteorological Climate Database at Met Éireann. There are a number of shortcomings in the present system which are pointed out here:

- The only meteorological data that can be made available to end users shortly after measurement are data from Met Éireann's 15 synoptic stations
- Rainfall and maximum/minimum air temperatures are measured only on a daily basis at most climate stations
- Wet and dry bulb temperatures are measured only on a 9 hour basis at climate stations
- Rainfall and temperature data from climate and rainfall stations are submitted to Met Éireann only once per month
- There is no system in place whereby data from Teagasc sites can be accessed easily from other Teagasc stations
- There is no system in place whereby meteorological data of any type can be accessed *easily* by end users, including educational establishments
- The geographical distribution of observations is not appropriate for the many agricultural land uses now operating in Ireland
- The spatial and temporal resolution of available data are insufficient for many agrometeorological models

Rec 5.10 Install a standard set of automatic weather stations at all climate stations and all Teagasc Research Centres as part of Met Éireann's climate network. Fill in gaps in the network distribution.

Rec 5.11 Carry out research to establish the best locations for additional observation stations

The following is a list of parameters which should be included in an automatic weather station measuring system:

Rainfall (mm/h)

Atmospheric pressure

Wind speed

Wind direction

Air temperature (°C) (dry bulb)

Wet bulb temperature

Relative humidity (calculated from wet and dry temperatures – most accurate)

Grass temperature

100 mm soil temperature

300 mm soil temperature

Leaf wetness

Decision Support Systems

It is envisaged that one of the main uses of meteorological information in agriculture in the coming years will be in DSS. Using potatoes as an example, large supermarket chains are expected to require farmers to justify the number of sprays they apply to a crop. This

will ensure that the supermarket can give assurances of quality and monitoring to its customers and may allow the farmer to be paid more for his produce. Potato Blight DSS involve in-crop measurement of rainfall, temperature and relative humidity, wind speed and wind direction. These data are transmitted to a logging PC. By logging into the DSS, the farmer sends the data to a central processing system. The data are used as input into a Potato Blight forecast model. The model output gives the farmer information on the likelihood of incidence of the disease and may also give information on conditions for spraying. A number of Blight models are available for use.

There are a number of potential shortcomings with this approach for farmers in general. In Ireland the number of growers is small therefore the commercial viability of this system is marginal, and it is likely that it would always be run from another country with little site-specific support. Unless the system is very closely monitored, data quality and regularity may become unacceptable. Use of the data by the farmer for other purposes may be limited if the system is collecting in-crop without regard to standardisation. Finally, the data would be under utilised as they would be available to one user only and would not be available for other potential users, such as neighbours, Met Éireann, EPA, Teagasc and university researchers. Due to these shortcomings, the following recommendation is made:

Rec 5.12 Set up an Irish Decision Support System as a collaborative project between Met Éireann, Teagasc and the universities, with government funding. Examine the type, placement and quality control of on-farm meteorological observations as well as the integration and use of output data

The system might be based on a formal network with regular automatic station spacing, data transfer to Met Éireann, processing through models and then communication to farmers. Alternatively, farmers could choose the system they want on their farm, select from an approved list of DSS and then start to supply data to the national network in exchange for a level of assistance at the outset and ongoing maintenance advice.

Distribution of meteorological measurements

There is a shortage of meteorological measurements in upland areas and also in the west of Ireland in general.

Higher altitudes are associated with:

- higher rainfall and cloud cover
- lower solar radiation
- lower temperatures
- lower evaporation / evapotranspiration.
- lower crop growth rates
- Wetter soils, lower bearing capacities and water surpluses at the soil surface

Upland measurements are needed for:

- better water management
- better forecasts for recreational users in upland areas
- improved animal nutrition models in upland areas
- soil erosion control (such as REPS-related decisions)

Met Éireann synoptic stations, like Teagasc research stations, are biased towards the better soils and towards lower altitudes. There is good coverage of upland and remote areas in Met Éireann's rainfall network. However this can not be said for other variables.

Rec 5.13 Met Éireann and Teagasc to co-operate in deciding strategic rainfall stations in upland and remote areas which can be converted to climate stations. Give these stations a high priority on an improved automated Met Éireann Climate network.

Data Mapping products

There is a need for a number of mapping products derived from meteorological data, most especially temperature data. Temperature maps should be equal in detail to rainfall maps. With the elevation contours shown on the O.S. 1:50,000 scale maps temperature data shown on this scale would be very useful for land-use planning and crop management. The application of crop models and production blueprints could be done more accurately with the availability of such maps. Data presented should include:

- mean temperature
- growing degree-days (above 0°C, 5°C, 10°C) for certain periods of the pre-growing season, the growing season and the winter growing season (useful for grass)
- chilling or freezing hours
- killing frost hours
- heating degree hours for agricultural and domestic use

Rec 5.14 Production of high resolution, critical property temperature maps

Solar radiation and wind severity maps could also be produced from extended climate station sites.

Conclusion

Meteorological data have a major role to play in agricultural research and decision making. The lack of a third-level (University or College) department dedicated to agrometeorology, and hence the shortage of trained personnel to lead research and extension services in this area is noted with regret. This report has sought to outline the ways in which these data are important and recommend ways in which current levels of data availability to agriculture can be improved. It is important at this stage that Met Éireann, Teagasc, universities and other relevant bodies work closely together to act on the recommendations presented above.