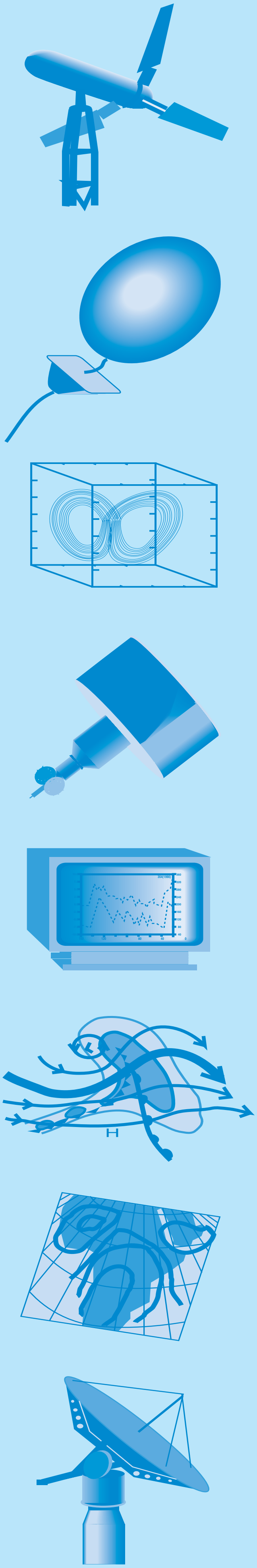

WORLD METEOROLOGICAL ORGANIZATION

GUIDELINES FOR THE EDUCATION AND TRAINING OF PERSONNEL IN METEOROLOGY AND OPERATIONAL HYDROLOGY

VOLUME I

SUPPLEMENT No. 2:

GUIDELINES FOR CURRICULA IN AGRICULTURAL METEOROLOGY

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CHAPTER 1

INTRODUCTION

Agricultural meteorology as an accepted term is only about 80 years old. During the first half of this period, it was developed in the Western world, Japan, India and China, and this was made possible through the evolving possibilities for quantification of the physical aspects of the production environment. However, agricultural meteorology has been completely modified since the 1980s. The increasing frequency of natural disasters, including pests and diseases, and growing climate variability and climate change are having an impact on the natural resource base, crop yields and incomes. There are increasing demands for improved preparedness and prediction to deal with these issues. It was necessary to balance the growing concerns for achieving greater efficiency in natural resource use while conserving the environment with the need for increased agricultural productivity to feed the growing populations of the world.

On the technology front, significant changes have occurred in the past two decades. The collection, management and analysis of atmospheric and surface data, often automated these days, is increasingly incorporating new techniques such as remote-sensing (hand-held and space-based) and geographical information systems. Furthermore, there are rapid advances in information and communication technologies, especially the Internet.

Agrometeorological applications and services in agriculture, forestry, rangelands and fisheries have grown enormously in recent times and these include, for example, specific weather forecasts and seasonal to interannual climate predictions in agriculture for better risk management; microclimate management or manipulation; the establishment of measures to reduce the impacts and mitigate the consequences of weather- and climate-related natural disasters for agricultural production; monitoring and early warning; and the development and validation of adaptation strategies to deal with increasing climate variability and climate change. Substantial research and development had occurred in the application of crop models ranging from the field level to the country level and even larger-scale modelling and models are also used in global climate change impact studies.

The level of education and skills of farmers, especially in developing countries, is insufficient to cope with new or aggravating problems, and there is a clear need for trained intermediaries who are equipped with services to assist the farming community in effectively dealing with these problems. Effective education and training in agricultural meteorology at the postgraduate level can ensure a continuous stream of well-informed intermediaries to serve the farming community.

There is now an urgent need to review carefully the curricula in agricultural meteorology at the undergraduate and postgraduate levels and to ensure that the curricula are fully revised to include new and emerging issues, and that adequate education and training material is prepared to serve the revised curricula. Hence, the World Meteorological Organization (WMO), in collaboration with the American Society of Agronomy, the Accademia dei Georgofili and the National Academy of Agricultural Sciences of India, organized the Expert Meeting on Review of Curriculum in Agricultural Meteorology in March 2007 to develop a revised curriculum as well as recommendations for its effective implementation.

This supplement starts with two general presentations: Agricultural meteorology at the global level; and Agricultural meteorology over the years and new priorities and consequences for curricula. These presentations provide background reading on the evolution of agricultural meteorology over the years and explain why there is now a real need to revise curricula at the university level.

After these two presentations, there is a short description of the WMO Expert Meeting on Review of Curriculum in Agricultural Meteorology, followed by the proposals for courses and their syllabuses.

CHAPTER 2

AGRICULTURAL METEOROLOGY AT THE GLOBAL LEVEL

2.1 INTRODUCTION

Agriculture is probably the most weather-dependent of all human activities. Variations in climate have been, and continue to be, the principal source of fluctuations in global food production, particularly in the semi-arid tropical countries of the developing world. Throughout history, temperature extremes, droughts and floods and various forms of violent weather have wreaked havoc on the agricultural systems on which people depend for food. There has always been a general recognition among farmers and livestock herders that weather and climate have a major influence on farm and livestock produce, and a number of risk-mitigating or risk-avoidance strategies have been developed by them to live with uncertain weather. Hence, agricultural meteorology has its roots in centuries of experience gathered and organized by farmers (Monteith, 2000).

Agricultural planning and the use of agricultural technologies require agricultural meteorology applications. Agricultural weather and climate data systems are necessary to expedite the generation of products, analyses and forecasts that affect agricultural cropping and management decisions, irrigation scheduling, commodity trading and markets, fire weather management and other preparedness for calamities, and ecosystem conservation and management.

2.2 WMO AND INTERNATIONAL COOPERATION IN AGRICULTURAL METEOROLOGY

The importance of meteorology to agriculture on an international scale was probably recognized as early as 1735 when the directors of European Meteorological Services first met to discuss meteorology at the international level. The first reference to cooperation between those involved in meteorology and agriculture was in correspondence between the International Meteorological Organization (IMO) and certain national institutes of agriculture and forestry, seeking an exchange of meteorological information and data. Although a formal commission, the Commission for Agricultural Meteorology (CAgM) of IMO, was appointed in 1913, it did not meet because of the outbreak of the First World War. The Commission was reconstituted in 1919 and held its first meeting in Utrecht, the Netherlands, in 1923. Subsequently, it held six additional meetings, the seventh and last being in Toronto, Canada, in 1947.

IMO underwent reorganization after 1947, and, in 1951, the newly established World Meteorological Organization (WMO), became one of the specialized agencies of the United Nations. WMO is the United Nations system's authoritative voice on the state and behaviour of the Earth's atmosphere, its interaction with the oceans, the climate it produces and the resulting distribution of water resources. WMO has a membership of 188 Member States and Territories. As weather, climate and the water cycle know no national boundaries, international cooperation on a global scale is essential for the development of meteorology and operational hydrology, as well as to reap the benefits of their applications. WMO provides the framework for such international cooperation. WMO promotes cooperation in the establishment of networks for making meteorological, climatological, hydrological and geophysical observations, as well as the exchange, processing and standardization of related data, and assists technology transfer, training and research. It also fosters collaboration between the National Meteorological and Hydrological Services (NMHSs) of its Members and furthers the application of meteorology to public weather services, agriculture, aviation, shipping, the environment, water-related issues and the mitigation of the impacts of natural disasters.

The policies and programmes of the last meeting of the IMO/CAgM became the foundation of the new CAgM under WMO. CAgM is responsible for matters relating to applications of meteorology, taking into account new developments in the relevant scientific and practical fields and the development of the agricultural meteorological services of Members through the transfer of knowledge and methodologies and by providing advice. CAgM, which meets approximately once every four years, has to date held fourteen sessions since 1951 (WMO, 2006). The technical work of the Commission is performed mainly by working groups appointed at the sessions and these groups undertake their work between sessions. At its thirteenth session, held in Ljubljana, CAgM adopted a new structure of Open Programme Area Groups, Implementation Coordination Teams and Expert Teams.

WMO recognizes 22 Regional Training Centres (RTCs) around the world which provide training facilities for Members in various fields of meteorology, including agricultural meteorology and in various languages. The WMO RTCs offering courses in agricultural meteorology are located in Algeria, Argentina, Barbados, Brazil, China, Egypt, India, Iraq, Islamic Republic of Iran, Israel, Kenya, Niger, Nigeria and the Philippines.

The International Society for Agricultural Meteorology (INSAM) was founded in 2001 to promote the science and applications of agricultural meteorology at the international level. Currently, INSAM is a Web-based society and membership is free of charge. INSAM serves as a clearing house for information on agricultural meteorology worldwide and all agrometeorologists are encouraged to become members. All national societies for agricultural meteorology are invited to become members of INSAM so as to provide strong leadership to develop agricultural meteorology in the future.

2.3 EVOLUTION OF AGRICULTURAL METEOROLOGY – THE EARLY HISTORY

Prior to the Vedic and pre-Vedic period in India (3500 BC), there had been a system of monsoon forecasting based on the original texts of the songs sung by Thiru Idaikkadar Swamigal. There are also reports that the annual cycle of crop cultivation was based on careful observation of phenological phenomena by Chinese farmers some 4 000 years ago. In the first century BC, a Chinese agronomist, Fan Sheng-Chih, was reported to have said that: "after thawing, the breath of earth comes through so the soil breaks up for the first time. With the summer solstice, the weather begins to become hot and the yin breath strengthens" (Shih, 1974).

In western literature, the first reference to agricultural meteorology was reported to have been made by Aristotle: "Wind is more influential than sun in evaporating water". Prior to 1900, seasonal and diurnal variations in temperature, humidity and wind were measured and summarized. Analytical descriptions of the basic understanding of heat exchange and diffusion were made by Wollny (1878, 1883).

2.4 EVOLUTION OF AGRICULTURAL METEOROLOGY – TWENTIETH CENTURY

In the early 1900s in North America, it was recognized that the year-to-year variations in yields and regional commodity production were associated with variations in climate (Decker, 1994). Statistical analysis of correlations between yields and monthly rainfall (Smith, 1914) and a book on agricultural meteorology by Smith (1920) provide evidence pointing to the enormous interest in this subject at that time. A year later, in 1921, R.H. Hooker, the President of the Royal Meteorological Society, referred to the fact that a few writers in continental Europe, particularly in Italy, were making contributions to the general subject of agricultural meteorology (Hooker, 1921). Fisher (1925) was the first person to evaluate the relationship between yields and rainfall using multiple correlation.

The general response of biological organisms to variations in the weather and climate was a subject that stimulated a great deal of interest. An example of the estimates of the rate of development of maize seedlings under varying temperature conditions was provided by Lehenbauer (1914). At many laboratories and experimental fields in the United States, Europe and the Asian subcontinent, the measurement of microclimate characteristics continued during the first half of the 1900s (Geiger, 1927; Ramdas and others 1935). Studies on the links between soil physical properties, the heat exchange and water movement then started to receive greater attention (Russell and Keen, 1938).

From 1920 to 1960, agricultural meteorology and micrometeorology took root and began to flourish after the Second World War in several European countries, North America, Australia, India, China and Japan. Barger and Thom (1949) developed a method for estimating the deviations of yield from the average on the basis of the probability of precipitation amounts.

An important stimulus was the emergence of new instrumentation for measuring and recording the physical environments of both crops and livestock and their responses to microclimate. In the 1920s and 1930s, in central and eastern Europe, systematic instrumental observations of the microclimate and its effects on plant growth were made, as well as insightful interpretations of causes, effects and interactions. Naegeli carried out studies on windbreak microclimate in Switzerland. In the United States, the Missouri Climatic Laboratory was set up to study the physiological response and production of dairy cattle in relation to variations in temperature, wind and radiation loads (Brody, 1948). The establishment of the Earhart Plant Research Laboratory in California to quantitatively document biological response to varying environmental conditions (Went, 1950, 1957) served as the model for the development of growth chambers and Climatrons.

From the 1940s to the 1960s, a number of renowned agrometeorologists, including Thornthwaite, Holtzman, Penman, Monteith, Priestley, Tanner, Cocheme, Franquin, Shaw and others, carried out methodical studies on a number of agrometeorological aspects (Rosenberg, 1989), thus contributing to our understanding of the following:

- Why crops and forests grow in specific places;
- How their growth is affected by weather, climate and microclimate;
- How alterations in the Earth's surface change the balance of radiation and energy and hence the microclimate, climate and weather;
- How identified scientific principles can be applied to improve the management of fields and forests.

2.5 TOPICS AND TRENDS IN AGRICULTURAL METEOROLOGY IN THE SECOND HALF OF THE TWENTIETH CENTURY

One of the many accomplishments of CAgM was to provide the stimulus for the establishment of the first periodical devoted exclusively to research and development in agricultural meteorology. This periodical was first published in 1964 as a journal with the title *Agricultural Meteorology*. In 1984, the journal broadened its scope and became *Agricultural and Forest Meteorology*.

The titles of the papers published in the journal provide a good indication of the topics and trends in the science of agricultural meteorology. In an analysis of the papers published in the journal from December 1964 to June 1972 and from June 1966 to June 1998, Monteith (2000) concluded that some early papers were characteristic of the descriptive and statistical phases of agricultural meteorology; but, over the years, a third mechanistic phase became dominant, stimulated by the development of accurate instrumentation both for recording and processing data.

An analysis was made of all the papers published in *Agricultural and Forest Meteorology* from 1985 to 2002 to identify the major topics receiving attention and key trends. From the list of major topics (Table 1.1), it can be seen that 21.3 per cent of all published papers were on the subject of water relations, while the topic of energy balance/heat transfer was the second most important subject, representing 16.8 per cent of the papers published on this topic. Papers on forest growth and yield covered 5.5 per cent of those published, a trend that is consistent with the broadening of the scope of the journal to forestry in 1984. Equally consistent was the greater attention paid to the subject of climate change, with 76 papers, or 4.6 per cent of the total number of papers, published. Given the interdisciplinary nature of agricultural meteorology, it is not surprising that some 38 papers published covered the subject of integrated pest management and 23 papers were on remote-sensing.

Table 1.1. Major topics in agricultural meteorology summarized from the papers published in Agricultural and Forest Meteorology *from 1985 to 2002*

Major topic	*Number of papers*	*Percentage*
Water relations	354	21.3
Energy balance/heat transfer	280	16.8
Solar radiation	213	12.8
Crop growth and yield	166	10.0
Other variables	105	6.3
Forest growth and yield	92	5.5
Photosynthesis	79	4.7
Climate change	76	4.6
Temperature	54	3.2
Rainfall	46	2.8
Climatic analysis	43	2.6
Integrated pest management	38	2.3
Phenology	31	1.9
Remote-sensing	23	1.4
Future direction/general	21	1.3
Shelter belts	9	0.5
Livestock	8	0.4
Automatic weather stations	5	0.3

To elicit the trends, the papers published were categorized based on whether studies were conducted in the field, used simulation/models, or used mathematical formulae/estimation methods. The other categories were forestry studies, primarily instrumentation development/calibration, and greenhouse studies. It can be seen (Table 1.2) that the major trend (26.9 per cent of the papers published) was towards field studies. Papers based on simulation/models covered 22.1 per cent of all the papers published, reflecting clearly the importance of this area of work in agricultural meteorology. Some 320 papers, or 19.3 per cent of all the papers, covered mathematical formulae/estimation studies. Studies on forestry are a growing trend and represented 17.3 per cent of all the papers. Papers addressing primarily aspects of instrumentation covered 8.1 per cent of papers, while 3.3 per cent of the papers published were based on greenhouse studies.

Table 1.2. Major trends in agricultural meteorology summarized from the papers published in Agricultural and Forest Meteorology *from 1985 to 2002*

Major trend	*Number of papers*	*Percentage*
Field studies	445	26.9
Simulation/models	367	22.1
Mathematical formulae/estimation	320	19.3
Forestry studies	286	17.3
Instrumentation	134	8.1
Greenhouse studies	55	3.3

When tracing the evolution of agrometeorological science and applications over the past several decades, the following aspects can be identified as having contributed most to its development:
(a) Advanced instrumentation;
(b) Modern data management systems and procedures;
(c) Advances in research;
(d) Simulation modelling;
(e) Agrometeorological adaptation strategies for coping with climate variability and climate change;
(f) Improvements in information dissemination;
(g) New environmental conventions and opportunities;
(h) Education and training.

2.6 FUTURE CHALLENGES FOR AGRICULTURAL METEOROLOGY

Agricultural meteorology faces the following future challenges:

- Significant increases in per capita production must be obtained in all developing countries if hunger is to be eradicated and poverty alleviated for their rapidly increasing populations.
- Cropping must be expanded to marginal semi-arid areas where water resources are limited and droughts are likely to occur.
- In humid-tropical and sub-tropical areas, the introduction of clean-weeded, cash-crop-oriented agrosystems has often exposed the soils to the phenomena of leaching, water erosion and high-temperature effects.
- In the industrialized world, and in some parts of the newly industrializing world, intensive agriculture, in some cases including animal husbandry, has an increasing, cumulative and deteriorating effect on the environment in which agricultural production takes place and on soil, air and water quality.
- In the developing world, spreading and intensifying environmental hazards pose new challenges with agrometeorological components, for example, the increased effects of climate variability, deforestation, wind erosion and desert encroachment, and water erosion.
- For many farmers, in developing and developed countries alike, the cost of providing energy inputs (for land preparation, weeding, ridging, fertilizer application, plant and animal protection, harvesting, transport and storage) is prohibitive unless there is a guarantee that the return from these inputs will be high.

2.7 NEED FOR A FUNDAMENTALLY DIFFERENT APPROACH TO WEATHER AND CLIMATE ISSUES THAT HAVE AN IMPACT ON AGRICULTURE

The following elements highlight the need for a fundamentally different approach to such issues:

- Traditionally, agricultural ministries and the research community viewed Meteorological Services as providers of data on weather and climate as and when needed.
- Many treat the weather and climate as hazards that must be addressed.
- Climate variability is referred to from the perspective of its negative impacts.
- Today, the agricultural research community's challenge is to balance the continuing need for increased productivity with new and growing concerns about climate change, climate variability and the associated environmental impacts.
- There is a need for a greater understanding of weather and climate, including the nature of inherent variability and methods for dealing with the projected impacts of climate change.
- There is much to be gained from looking at the climate not only as a hazard, but also as a "resource".
- Resources must be identified, assessed in quantitative terms and properly managed if they are to be used in a sustainable manner, and climate is no exception.

Hence, it is clear that a fundamental change is required in the way weather and climate are viewed relative to agricultural production.

2.8 NEEDS AND PERSPECTIVES FOR AGRICULTURAL METEOROLOGY IN THE TWENTY-FIRST CENTURY

In February 1999, WMO organized the International Workshop on Agrometeorology in the Twenty-first Century: Needs and Perspectives, in co-sponsorship with a number of national, regional and international organizations, which was held in Accra. Stigter and others (2000) summarized the needs and perspectives for agricultural meteorology in the twenty-first century under two major headings:

(a) Agrometeorological services for agricultural production;
(b) Agrometeorological support systems for such services:
    - Data
    - Research
    - Policies
    - Training/Education/Extension

Agricultural production issues were categorized according to the following classic themes: (a) land use, as a strategic issue; (b) choices of farming and cropping system details; and (c) decisions on day-to-day operations, as tactical issues. For an extensive discussion on the various important needs and perspectives in agricultural meteorology under the two major headings, the reader is referred to the paper by Stigter and others (2000).

2.9 CONCLUSIONS

Agricultural meteorology has advanced during the last 100 years from a descriptive to a quantitative science using physical and biological principles. The agricultural community is becoming more aware of the fact that the use of climate and weather information will improve its profitability, and this will no doubt increase the demand for agrometeorological services. Hence, it is timely that the needs and perspectives for agricultural meteorology in the twenty-first century are grouped under two major headings: (a) agrometeorological services for agricultural production; and (b) agrometeorological support systems for such services. Emphasis must be placed on the components of such support systems comprising data, research, policies and training/education/extension. As Monteith (2000) mentioned, food supplies ultimately depend upon the skill with which farmers can exploit the potential of good weather and minimize the impact of bad weather. Recent developments in instrumentation, data management systems, climate prediction, crop modelling, dissemination of agrometeorological information and so forth provide agrometeorologists with the necessary tools to help the farmers improve such skills. The future for operational applications of agricultural meteorology appears bright, and such applications could contribute substantially to promoting sustainable agriculture and alleviating poverty.

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CHAPTER 3

AGRICULTURAL METEOROLOGY OVER THE YEARS AND NEW PRIORITIES AND CONSEQUENCES FOR CURRICULA

3.1 ABSTRACT

From an elementary historical perspective, additional priorities arose in the undercurrent of agricultural meteorology when its applications widened in developing countries. This has largely been missed by training, education and extension, particularly in developing countries. In a simple diagnostic and conceptual framework, support systems guided by needs assessments in terms of the livelihood of farmers are required. Some consequences for applied agricultural meteorology in university curricula are discussed, including the issue of training extension intermediaries to liaise between developers of agrometeorological products and end users.

3.2 INTRODUCTION

A recent WMO publication, *Commission for Agricultural Meteorology (CAgM): The First Fifty Years* (WMO, 2006), indicates that agricultural meteorology as an accepted term is only about 80 years old. During the first half of this period, it was developed in the Western world, Japan, India and China. Agricultural meteorology was able to develop as a science during its first 40 years because of the evolving possibilities for quantification of the physical aspects of the production environment (WMO, 2006). The same applies to the responses of the different forms of agriculture-related biomass to that same environment. However, for a long time these studies took place in growth chambers and were carried to field conditions only later on (WMO, in preparation).

This developed into a valuable set of actual support systems that keep agricultural meteorology operational, particularly in industrialized countries. In the summary and recommendations of the International Workshop on Agrometeorology in the Twenty-first Century: Needs and Perspectives, which was held in Accra in 1999 (Stigter and others, 2000), four kinds of support systems were identified: data, research, education/training/extension and policies. Data support systems have grown enormously in importance, particularly in applications in the industrialized world. The same applies to research. Training, education and extension followed these developments; however, they followed other developments that took place to a lesser extent.

3.3 WIDENING REGIONS AND PRIORITIES

In the past 40 years, the regions where agricultural meteorology is applied grew extensively, although water balances and evaporation in more temperate climates became and remained the single most treated subject (WMO, 2006). With an increasing rate of application in the developing world, the definition of agricultural meteorology had to be widened to accommodate the conditions in developing countries, with their more abundant weather and climate disasters, and their endangered environments. This was the first gradual widening of priorities in agricultural meteorology.

Society and economics do not equate to agricultural meteorology, but the consequences and use (that is, management) of water, radiation/heat and air in society and economics, as far as the agricultural production environment is concerned, slowly became an undercurrent in agricultural meteorology (WMO, 2006). Translated to poorer countries, the socio-economic aspects of elements such as irrigation, storage, agroforestry, floods, drought, erosion and desertification, frost, wind protection, simple artificial growth conditions, sustainable farming and related farmers' income became additional priorities in the undercurrent of agricultural meteorology. This was a second gradual widening of the subjects associated with agricultural meteorology.

The widening of the definition of agricultural meteorology and the second widening of the scope of related subjects have largely been missed by training and education, and more so in developing countries. This can be explained through a simple conceptual and diagnostic framework (Figure 3.1) that was recently published as a guest editorial in the journal *Agricultural and Forest Meteorology* (Stigter, 2007) and is also used in the third edition of the *Guide to Agricultural Meteorological Practices* (WMO-No. 134).

3.4 WHAT GUIDES THE SUPPORT SYSTEMS?

In Figure 3.1, the progression from the C-domain to the B-domain involves an upgrading of the operationability of the scientific support systems. This upgrading is driven by general agrometeorological action support systems for mitigating the impacts of disasters (E1). However, problem solving in terms of the livelihood of farmers necessarily requires another increase in the operational use of knowledge, by applying the mixture of the B-domain into actual agrometeorological services supporting the decisions and actions of producers (E2). Of course, in each of the three domains use is made of data, research, education/training/extension and policies; however, only in the C-domain are they to be considered as being purely supportive in nature. In the B- and A-domains and in E2 and E1 they are (or should be) used/carried out in action.

This essential difference is often not recognized, because, following advances in developed countries, attention is focused on methodologies and science. The

Figure 3.1. Conceptual and diagnostic framework picturing the generation and transfer of agrometeorological information in an end-to-end system from basic support systems to the livelihood of farmers

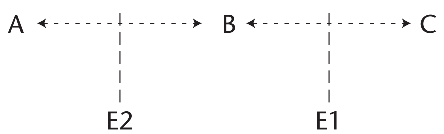
A = Sustainable livelihood systems

B = Local adaptive strategies (knowledge pools based on traditional knowledge and indigenous technologies)

+ Contemporary knowledge pools (based on science and technology)

+ Appropriate policy environments (based on social concerns and environmental considerations, scientifically supported and operating through the market where appropriate)

C = Support systems for agrometeorological services: data + research + education/training/extension + policies



E1 = Agrometeorological action support systems on mitigating the impacts of disasters

E2 = Agrometeorological services supporting actions of producers closest action is most often in the E1 domain. These actions are the bulk of the measures aimed at mitigating the impacts of disasters and using the four support system ingredients in applications in the real world.

Unfortunately, they have little to do with the needs of the A-domain, in which agrometeorological services should deliver support for farmer decisions/actions. E2-supporting actions are actual agrometeorological services that relieve the constraints associated with the livelihood conditions of local farmers. This means that needs assessments with respect to agrometeorological services for farming systems should come first. The matrix of Figure 3.1 shows the three domains and the various farming systems. However, the pushing/guidance goes from right to left.

Is it possible to have the guidance/pushing from left to right? This can first be exemplified from the change in relations between industry (as an A-domain of applied sciences) and physics (as a C-domain of support systems) in the 1950s and 1960s. This progression thrived on the results obtained in theoretical and experimental physics. However, when the author studied physics in Amsterdam in the 1950s and 1960s, physicists working in the industry, for example at the Philips Physics Laboratory, guided/pushed developments in experimental and related theoretical physics, which has been reflected in teaching. This is exactly what happens today in Europe in order to remain competitive with the United States (Shannon, 2007).

An illustrative example from agricultural production may be taken from plant breeding. The green revolution was largely driven by scientific developments. These were important and led in certain parts of India to faster economic growth in the 1980s, but their limitations became quickly clearer because of the high input requirements (for example, Sachs, 2005). Presently, breeding research is driven by the needs of poor people and targets, for example, disease or drought or lodging resistance and increased vitamin A content in seeds, which is a guidance from the A-domain towards the C-domain.

This should become more and more the horizontal situation in agricultural meteorology as well. Among others, the research of the winners of the International Society for Agricultural Meteorology (INSAM) contests of the best examples of agrometeorological services illustrates that this is a very strong possibility (INSAM, 2008). This analysis has serious consequences for training, education and extension, as it therefore does for curricula. This applies most strongly to developing countries or tropical studies elsewhere.

3.5 CONSEQUENCES FOR CURRICULA

High-quality C-domain basic syllabuses in agricultural meteorology exist (for example, see the *Guide to Agricultural Meteorological Practices* (WMO-No. 134)). As also indicated in the third edition of the Guide, the previous analysis shows the necessity of additions to the overall curricula. Training programmes at all levels must be adapted to national and regional needs. Some additions for applied agricultural meteorology result from our analyses thus far, as follows.

National framework of agricultural meteorology

Teaching is enlivened if national frameworks of agricultural meteorology can be set, showing local applications, developments and needs. PhDs in Sudan, Nigeria and Kenya in the Traditional Techniques of Microclimate Improvement African Network project (Stigter and Ng'ang'a, 2001) have all used their local results and those of the supportive MSc students in their teachings together with the literature examples they collected.

International framework of agricultural meteorology

The history of progress in international agricultural meteorology and more recent developments show where the national framework of agricultural meteorology can be further widened. This is illustrated by the complementary developments in the Commission for Agricultural Meteorology and INSAM, as widely published on their Websites. It is one of the tasks of such organizations to translate these developments towards education.

Training in multidisciplinary problem solving

Stigter (2006) provides two examples of such training. Free State University, Bloemfontein, South Africa, offers a course on the influence of climate on agricultural practices which adopts a very original style and uses the problem-based learning method. The subjects used as examples are numerous and can easily vary to fit student needs. This is the first course wherein fresh research results obtained by the lecturers, or under their supervision (or even relevant problem-focused results obtained elsewhere in Africa), could be worked into the curriculum in the course of time. Cases of local farming problems raised, tackled and (partially) solved would be the best choice.

Operational agricultural meteorology is another original course and attempts to familiarize final year BSc students with how to communicate with those in farming, those providing basic information and data and those who can use the research results. In this process, information detection skills, professional analytical skills and information transfer/communication skills are developed, while the outcome reflects the level of success achieved. This is another course into which the problems brought up by African farmers as well as recently solved problems in the day-to-day management of farm operations in Africa and in long-term farm planning could be integrated as scenarios.

Projects and seminars on specific regional agrometeorological problems and interests

At all levels of teaching in agricultural meteorology, projects and seminars on local problems and fields of specific interest to local development strengthen the national framework of agricultural meteorology. A multidisciplinary approach, also showing relations between agrometeorological components and components of other fields of applied science in problem solving, should be developed in this area.

Case studies of agrometeorological services, study tours and examples of their applications

Particularly at the advanced levels of courses, attention to agrometeorological services developed through the B-domain for the A-domain of the livelihood of farmers, and field studies thereof, will show students where the needs lie in agricultural production and how agricultural meteorology can contribute to relieve constraints.

3.6 UNIVERSITY CURRICULA AND THE TRAINING OF INTERMEDIARIES

A last subject is whether curricula at the postgraduate and lower levels should pay attention to the training needs of agrometeorological extension personnel at the intermediate level between the developers of agrometeorological products (national weather services, universities, research institutes) and end users. A first reason for the scant use of agrometeorological services is a lack of cooperation between the institutions providing information and relevant advisories and those responsible for their transfer to the farming community. A second reason for this scant use of agrometeorological services is insufficient education and training among the user community, including the farm advisory services that provide specific agricultural advice from general weather information (Lomas and others, 2000; Stigter, 2003).

In non-industrialized countries, the training of extension intermediaries would go a long way in solving these problems for various groups of all but the richest and best educated farmers. In recent operational developments, this includes developing extension around the establishment of agrometeorological services. Particularly in the poorest countries, intermediaries should be the people in direct contact with the agricultural communities.

A 2006 World Bank report on poverty in Indonesia (World Bank, 2006), which received glowing reviews, refers to the change that happens when intermediaries (such as NGOs) get involved to help the poor. This definitely also applies to intermediaries in the field of agricultural meteorology. Owing to the above, postgraduate and other curricula should focus on what intermediaries should be taught to assist farmers with agrometeorological services. This would enable all students to become familiar with practising agricultural meteorology fully in its ultimate applications. Elsewhere in these Guidelines an introduction is given to a possible approach and related agrometeorological syllabuses for the in-service training of such extension intermediaries in agricultural meteorology and closely related fields.

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CHAPTER 4

SUMMARY OF THE EXPERT MEETING ON REVIEW OF CURRICULUM IN AGRICULTURAL METEOROLOGY

4.1 INTRODUCTION

The Expert Meeting on Review of Curriculum in Agricultural Meteorology was held at the National Academy of Agricultural Sciences of India in New Delhi from 14 to 16 March 2007. Sixteen experts from Austria, Brazil, Canada, India, Indonesia, Italy, the Netherlands, the United States of America and Zimbabwe attended the meeting (Annex I).

The Meeting was organized in six sessions, including an opening session. The following is a short summary of each of the sessions.

4.2 OPENING SESSION

In this session welcome addresses were given by the representatives of the four co-sponsors of the Meeting: Mr M.V.K. Sivakumar from the World Meteorological Organization (WMO); Mr J.L. Hatfield, President of the American Society of Agronomy in 2007; Mr S. Orlandini from the Accademia dei Georgofili of Italy; and Mr V.P. Gupta from the National Academy of Agricultural Sciences of India.

4.3 AGRICULTURAL METEOROLOGY OVER THE YEARS

(session 2: chairperson: Mr J. Eitzinger; rapporteur: Mr J. Mukherjee

The first technical session reviewed the developments made in agricultural meteorology over the years with presentations on agricultural meteorology at the global level by Mr M.V.K. Sivakumar, and on agricultural meteorology over the years and new priorities and consequences for curricula by Mr C.J. Stigter. The full texts of these two papers appear as Chapters 2 and 3, respectively, of this supplement.

4.4 CURRENT STATUS OF CURRICULUM IN AGRICULTURAL METEOROLOGY

(session 3: chairperson: Mr C.J. Stigter; rapporteur: Mr V.R.K. Murthy)

In the first presentation, Mr B. Chipindu, of University of Zimbabwe, talked in detail about the MSc in Agricultural Meteorology offered as a Southern African Development Community regional programme. According to the university rules and regulations concerning admissions, applicants must have a good BSc degree in physical sciences/agricultural sciences/biological sciences or equivalent qualification as approved by the University's AGMET board. The course has a biennial intake and lasts for two years. The first year (August–May) comprises two semesters of course work. During the second year (June–May), the students undertake research projects. Students are also allowed to carry out their projects at institutions outside the university, subject to satisfactory supervisory arrangements by the AGMET board. The first semester consists of courses such as meteorology for agriculture; agricultural systems of Africa; soil properties and processes;

environmental crop physiology; climatic physiology of animals; environmental physics; instruments and observations; and statistics for agricultural meteorology. In addition, certain specialized and specifically designed courses, namely climate–weather and crops; water resources assessment and management; agricultural microclimatology and meteorology; and agricultural hazards, are offered in the second year. It was also mentioned that infrastructure facilities such as the following were available: lecture rooms and a laboratory; library resources and a study area; a computer laboratory with software packages and climatic database; and a wide range of instruments. The presentation also covered issues like staff availability; employment opportunities for graduated students; and future challenges for the curricula in detail.

In the second presentation, the current status of curricula in agricultural meteorology at Brazilian universities was dealt with at length by Mr P.C. Sentelhas of the University of Sao Paulo. The presentation began with an introduction on undergraduate and graduate programmes in agricultural meteorology. It was pointed out that at the undergraduate level that subject was taught as a compulsory course in more than 50 universities for those students opting for degrees in agronomy. Also, the subject of agricultural meteorology was a compulsory course at six universities that awarded degrees in meteorology. In addition, the subject was mandatory for students pursuing degree programmes in crop science, agricultural engineering and so forth. It was mentioned that the geographical distribution of the programmes was irregular/asymmetrical. The research areas covered by graduates were also presented. At the Federal University of Rio Grande do Sul (UFRGS), the Federal University of Santa Maria (UFSM), the Federal University of Campinas (UNICAMP), the Agronomic Institute of Campinas (IAC), the Federal University of Viçosa (UFV) and the University of Sao Paulo (USP) the research programmes were developed in a systematic way to meet the demands of farmers. The striking features of the courses offered in Brazil were the division of course content into basic and applied aspects; their direct link with project work at the field level; and their links with the other programmes in agriculture, such as irrigation, drainage and farm implements. The presenter stressed that there was an urgent need to revive and revise the curricula in agricultural meteorology in Brazil to meet the country's fast changing agricultural scenario.

According to Mr J.L. Hatfield, the President of the American Society of Agronomy in 2007, agricultural meteorology courses in the United States were distributed across a number of universities. The presentation focused on providing an explanation of similarities and differences in terms of the curricula of agricultural meteorology. There were many similarities in the courses on offer, in that the courses and their contents were almost uniform in all the universities teaching environmental biophysics and meteorological instrumentation. Similarly, the contents of courses on subjects such as climate change, agricultural climatology and general climatology were similar across the universities that offered agricultural meteorology programmes in the United States. In contrast, the differences between universities were detectable in the number of courses taught at specific institutions. For example, some universities offered a wide range of courses, while others offered a single course. The courses taught at universities in the United States depended on the availability of experts in agricultural meteorology and the needs of the end users in general and farmers in particular. One major lacuna identified by Mr J.L. Hatfield was the lack of coordination among the universities that offered agricultural meteorology as a major programme, which was delaying the expansion of teaching in all universities. It was also stressed that the linkage between agricultural meteorology and plant protection sciences (entomology, plant pathology, and so on) was at the time non-existent; it was hoped that a well-defined and most deserving linkage with those subjects would make the agricultural meteorology programme much stronger to meet the challenges in the field of risk management in agriculture.

The presentation given by Mr R. Desjardins focused on curriculum development to meet the challenges in the near and far future. He also reviewed very briefly some of the basic curricula in agricultural meteorology in Canada, which were offered at four universities. It was mentioned that the latest technologies for the collection and analysis of data must form part of new curricula in agricultural meteorology. Some courses on subjects such as: (a) quantifying the reduction of greenhouse gases; (b) tools for estimating the flux of trace gases; (c) management effects on C sequestration; (d) downscaling climate data; (e) footprint considerations; (f) quantifying agroecosystem biosphere–atmosphere interaction; and (g) estimating uncertainties in environmental modelling were suggested as a way to meet the new challenges of the next decade.

Mr R. Boer explained that the University of Bogor, in Indonesia, had established the Department of Agricultural Meteorology back in 1978, and that the actual study programme had been initiated in 1984. A major programme in applied climatology would be offered from 2007. Typically, the course structure had a few compulsory subjects, some supporting courses, and again a few optional courses, which were similar to other university curricula in the Asian region. The unique way in which each course was designed, with balanced content covering “Basics–Applications–Analysis”, appealed to the audience. Most contemporary courses such as satellite climatology, applied climatology and advanced hydro-ecosystems were offered at Bogor University at the PhD level. While providing details on the syllabus for each course, it was mentioned that the course content on risk management and crop insurance attracted the attention of private companies, and that it was interesting for all to learn that private companies offered jobs to graduates in sectors such as weather-based insurance for crops.

Mr J. Eitzinger from Austria stated that agricultural meteorology was taught at the University of Natural Resources and Applied Sciences (BOKU) as a 20 credit-hour course in one semester for MSc and PhD students. A few complementary courses, such as ones on agrometeorological instrumentation and measurement and the simulation of the soil–crop–atmosphere system, had been introduced recently to meet the emerging and new challenges in agricultural production systems in Europe in general and Austria in particular. Also, agrometeorological aspects were taught to undergraduate students as interdisciplinary courses, in five of which biometeorology and meteorology formed a major component. However, the main syllabus in each course revolved around basic and applied modules that comprised physics and meteorology. The research projects given to students are on: (a) the impact of climatic parameters on crops; (b) the stress phenomenon (drought, frost, heat, and so on); and (c) the applications of remote-sensing in agriculture, among others. It was observed that curriculum development in agricultural meteorology in Austria faced two challenges: (a) to distinguish between high- and low-input farming in applied agricultural meteorology; and (b) to highlight the possibilities of increasing the sustainable and effective use of agroecosystem resources.

Mr S. Orlandini of the University of Florence, in Italy, informed the meeting that in his country the three plus two year system had been introduced recently for undergraduate students. Only a few of the 24 faculties of agriculture offered courses in agricultural meteorology. A Masters programme in applied meteorology was offered in Florence and Bologna. A PhD programme in ecophysiology and agricultural meteorology was offered at the University of Sassari in Sardinia. A round table had been organized by the Accademia de Georgofili in Florence to introduce agricultural meteorology to university teaching.

Table 4.1. Summary of total credits and major courses for Masters and doctoral programmes in agricultural meteorology at five universities in India

	University				
	TNAU	*PAU*[a]	*AAU*	*ANGRAU*[b]	*IARI*
Total credit for MSc	48	60	50	56	45
Main courses	13	17	35	36	18
Optional/Minor	9	10			9
Supporting	12	8			–
Seminar	2	1	–	–	1
Research	12	25	15	20	–
Total credit for PhD	70	60	50	75	36
Main courses	9	10	25	30	18
Optional	9	9			9
Supporting	0	6			–
Seminar	2	1	–	–	1
Topical research	2	–	–	–	–
Research	48	35	25	45	–
Main courses	Fundamentals of meteorology and climatology Principles of agrometeorology Applied agrometeorology Micrometeorology Research methodology	Fundamentals of agroclimatology Agrometeorological instrumentation Micrometeorology Applied agrometeorology *Advanced synoptic meteorology* *Weather and climate modification* *Advanced micrometeorology* *Agroclimatic models*	Fundamentals of meteorology Fundamentals of climatology Micrometeorology Agrometeorological instrumentation	Agrometeorology Crop micrometeorology and weather modifications Environmental physiology Radiation and the surface energy balance The soil and its heat balance Water and the hydrological cycle in agriculture Small-scale climate, representativity, and their dependence on topography Agrometeorological management at the microscale and toposcale Weather hazards adversely affecting agricultural output Operational agrometeorology Agrometeorological instruments and observation	Fundamentals of meteorology and climatology Physics of radiation interactions in agriculture Crop micrometeorology Evapotranspiration Satellite agrometeorology

Table 4.1. (Continued)

	University				
	TNAU	*PAU*[a]	*AAU*	*ANGRAU*[b]	*IARI*
Optional/Suggested courses	Agroclimatic analysis and drought meteorology Crop weather models Evapotranspiration and hydro-meteorology	Weather forecasting and weather modification Remote-sensing for agricultural resource management Measurement of evapotranspiration Agroclimatic analysis and crop modelling Hydrometeorology and water budgeting	Evapotranspiration Agroclimatic analysis Crop weather models Water budgeting and drought meteorology Applied agrometeorology Weather and agriculture Hydrometeorology Weather modification Principles of remote sensing and its applications in agriculture Air pollution meteorology Mathematics in agriculture and biology Animal and farm house meteorology		Fundamentals of crop–weather–pest–disease interactions Weather aberrations and risk management

[a] The courses indicated in italics are offered to PhD students.

[b] ANGRAU does not specifically divide the courses into the three categories.

4.5 CURRENT STATUS OF CURRICULUM IN AGRICULTURAL METEOROLOGY IN INDIA

(session 3 (continued): chairperson: Mr L.S. Rathore; rapporteur: Mr R. Boer)

Agricultural meteorology programmes for Masters and doctoral degrees are offered at a number of universities in India. Presentations were made by Messrs R. Jagannathan, J. Mukherjee, V. Pandey, V.R.K. Murthy and N.V.K. Chakravarthy on the current status of course curricula in agricultural meteorology at the following universities, respectively:

(a) Tamil Nadu Agricultural University (TNAU);
(b) Punjab Agricultural University (PAU);
(c) Anand Agricultural University (AAU);
(d) Acharya N.G. Ranga Agricultural University (ANGRAU);
(e) Indian Agriculture Research Institute (IARI).

In general, courses offered by Indian universities can be divided into three categories: main (core) field courses, optional/minor courses and supporting courses/specific courses. The main field courses must be taken by all students who undertake a study programme in agricultural meteorology. The optional/minor courses are supplementary courses. Most optional/minor courses are still related to climatology. The total number of credits to be taken by students of Masters and doctoral programmes varies depending on the university. A summary of the total credits and the main courses and optional/minor courses offered by the universities is presented in Table 4.1.

TNAU is now in the process of proposing new courses related to agricultural meteorology which include the following:

- Weather forecasting for farming decisions
- Operational/Applied agrometeorology
- Hydrometeorology and drought meteorology
- Agrometeorology of protected agriculture
- Harvesting of natural energy resources
- Remote-sensing applications in agricultural meteorology
- Climate variability and change, its vulnerability and mitigation
- Eco-physiology of crops
- Computer applications in agricultural meteorology

These new courses may be included in the new curricula if approved by the curriculum commission. For the academic year 2007/08 the following three courses were planned to be offered:

(a) Principles of agronomy, including agricultural meteorology;
(b) Agrometeorology and crop modelling;
(c) Surveillance and forewarning of pests and diseases.

The following important issues and comments were raised during the meeting:

- There are some important subjects that need to be included in current curricula or form part of course content. These include weather-based farming courses on subjects such as weather/climate forecasting for farming decisions, climate risk management, crop insurance based on weather and climate, local/regional climate-related problems, and methods for data quality checking.
- Job opportunities for graduates in agricultural meteorology are another issue. At present, the demand for agricultural meteorology graduates in some countries, for example Indonesia, is not high, as most of the graduates work in areas that are not related to the field. Most of the graduates who still make use of their expertise work in education or research agencies. However, in India, graduates from institutes such as the IARI are being absorbed by the private sector.
- The guidance for curriculum development in the filed of agricultural meteorology should not be limited to postgraduate courses; it should also include undergraduate courses and a training curriculum for intermediaries. The guidance may also need to consider research Masters and PhDs wherein students are not obliged to take courses.

- Livestock population is larger than the human population and may be vulnerable to climate change and variation. Increases in temperature will affect livestock productivity. This is one issue that attracts most of our attention. More attention should be given to livestock breeding (resistance to heat stress), and so on. Another issue that does not receive adequate attention is the impact of climate change on weeds, insects and diseases.
- Agricultural meteorology curricula should have an end-to-end structure (science to farmers). This means that graduates should be capable of identifying climate problems and developing the appropriate tactical and strategic actions or programmes to cope with them.
- The existing group of experts should have regular meetings to discuss the provision of strategies for policymakers in the process of developing curriculum in agricultural meteorology, and to determine how funding agencies could be influenced to increase their funding for conducting research in this area, and so on.

4.6 OVERALL PROGRAMME FOR POSTGRADUATE EDUCATION IN AGRICULTURAL METEOROLOGY

(session 4:
chairperson: Mr J.L. Hatfield;
rapporteur: Mr R. Jagannathan)

During this session, an open discussion was held on the overall programme for postgraduate education in agricultural meteorology, and the participants were divided into two groups for developing proposals for (a) basic courses; and (b) applied courses. The composition of the two groups was as follows:

Basic courses group	*Applied courses group*
L.S. Rathore	M.V.K. Sivakumar
S. Orlandini	C.J. Stigter
B. Chipindu	J.L. Hatfield
P.C. Sentelhas	J. Eitzinger
R. Desjardins	R. Boer
V. Pandey	V.R.K. Murthy
N.V.K. Chakravarthy	R. Jagannathan

The groups met separately and developed course proposals. The proposals of each individual discussion group were subsequently presented and discussed at the plenary session. The group then finalized the courses to be included in the curricula and these are given in Chapter 5.

4.7 PROPOSALS FOR REVISED CURRICULUM

(session 5:
chairperson: Mr R. Desjardins;
rapporteur: Mr V. Pandey)

Following the development of the three categories of courses (Chapter 5), the responsibilities for developing the detailed syllabuses for different courses were assigned to different meeting participants.

It was agreed that, where necessary, for example in the applied courses and for each of the topics in a given course, curricula would include both elementary and advanced issues. This would allow the teaching faculty the flexibility to design the course according to the needs and priorities identified in a given region.

CHAPTER 5

COURSE PROPOSALS

5.1 INTRODUCTION

The meeting proposed agricultural meteorology courses for undergraduate programmes and postgraduate programmes as well as some courses for the intermediaries involved in communicating information to farmers.

5.2 PROPOSALS FOR THE UNDERGRADUATE PROGRAMME

In order to train undergraduate students and to motivate them to enrol for postgraduate studies in agricultural meteorology, it was decided to propose courses for teaching at the undergraduate level where agricultural and other allied programmes were offered. These include a course on climate change and its impacts on society in response to the increased attention society is giving to this topic.

5.3 PROPOSALS FOR THE POSTGRADUATE PROGRAMME

Meeting participants discussed the course requirements expected of postgraduate students taking the agricultural meteorology option without any regional specifications. The issue of which deficiency courses should be taken by students who have not acquired the basic requirements for pursuing a postgraduate degree in agricultural meteorology was discussed. Since the curricula at the undergraduate level at universities around the world vary greatly, it was decided that each university should determine its specific approach to deficiency courses.

The postgraduate programme will include a set of core courses to provide students with a basic understanding of the major subjects as well as a set of applied courses. The applied courses aim to prepare students to be able to define and design tactical and strategic uses of weather and climate information and also to enable them to understand risk management strategies and their applications.

The group decided to present a basic framework for applied courses because the agrometeorological applications in respect of the regions offering these courses differ greatly, given that the basic emphasis in agriculture itself varies and includes crop cultivation, horticultural production and animal production. The courses should emphasize applied aspects in which the case studies must be formulated based on the regional requirements and the expertise available at the university.

5.4 PROPOSALS FOR TRAINING INTERMEDIARIES

There is an acute need for developing explicit education and training in the extension-focused B- and A-domains (see Chapter 3, Figure 1) for the various fields of agrometeorological services. This would indeed be a new approach if the results were worked back as case studies into the education of the C-domain, particularly in developing countries. The latter domain could become better focused on the E1-domain and the connection between the E1- and E2-domain guidance, in order to enhance the operational qualities and the educational exercises in agricultural meteorology (Stigter, 2007).

Such an approach would require changes in the classic education and training in agricultural meteorology, making agrometeorological students and trainees much more aware of application needs and the actual applications of services developed with the methodologies they learn so much about. It would also require such changes when paying more attention to agricultural meteorology in other agricultural curricula and in any in-service training of agrometeorological personnel and agrometeorological intermediaries.

5.4.1 IMPLICATIONS FOR EXTENSION AGRICULTURAL METEOROLOGY

It has been proposed that education and training for intermediaries in agrometeorological extension be conducted in two steps for two kinds of agrometeorological extension intermediaries (AEIAs and AEIBs, Stigter, 2003). The first kind of agrometeorological extension intermediary (AEIB, Stigter, in preparation) would be close to the centres generating agrometeorological information that is useful for decision-makers in agricultural production. They should in essence be specially trained members of staff from national weather services, from extension departments of universities and from research institutes.

Weather and climate forecasts, monitoring and early warning products for drought, floods and other calamities and advisories for agrometeorological services that could increase the preparedness of the population long in advance must be made into client-friendly products that can be absorbed. This must be done in the B-domain. Such AEIBs require training in farmers' needs as well as in how agricultural meteorology can be implemented in the A-domain, using information from the B-domain. They should themselves work in the B-domain, preparing E2-domain guidance (Stigter, 2007).

The second kind of agrometeorological extension intermediary (AEIA, Stigter, in preparation) should be closest to the farmers and operate exclusively in the A-domain, using E2-domain guidance. They should learn to better articulate the needs of farmer communities and seek agrometeorological components that require attention. They should match this with what is, or should become, available as E2-domain services, in close contact with the AEIBs, but not with the generators of the raw weather/climate products and raw advisories.

5.4.2 EDUCATIONAL CONSEQUENCES

In this two-step intermediaries approach, meeting points for the two kinds of intermediaries have to be created in educational undertakings by the government or by non-governmental organizations (NGOs). National Meteorological and Hydrometeorological Services (NMHSs) should liaise with universities and research institutes on contact with the AEIBs. The existing extension services, the government or NGOs should organize the AEIAs and their contact with farmers. Enough research has been conducted for such approaches (for example, Boer, 2006; Saleh, 2007).

The education and in-service training of these two kinds of agrometeorological extension intermediaries are an essential part of the new approach that appears necessary in education, training and extension in agricultural meteorology. Their successes, failures and experiences need to be reintroduced into the curricula for agrometeorological personnel at NMHSs and into those at vocational schools and universities in order to enlighten the classic C-domain training and strengthen its usefulness, because technological advances also require effective education and policymaking (for example, Sachs, 2006).

The proposals for the intermediary courses are expected to attract the attention of those policymakers who could consider providing funding for such a programme for the in-service training of these groups.

5.5 PROPOSED COURSES IN EACH OF THE THREE CATEGORIES

5.5.1 UNDERGRADUATE PROGRAMME

The following are proposed for the undergraduate programme:
(a) Introductory agricultural meteorology;
(b) Climate change and its impacts on society.

5.5.2 POSTGRADUATE PROGRAMME

The following courses are proposed for the postgraduate programme:

5.5.2.1 Basic courses

(a) Fundamentals of meteorology and climatology;
(b) Weather, climate and crops;
(c) Weather, climate and livestock;
(d) Meteorological hazards in agriculture;
(e) Agrometeorological measurements and instrumentation;
(f) Micrometeorology;
(g) Analytical tools and methods for agricultural meteorology.

5.5.2.2 Applied courses

(a) Strategic use of climate information;
(b) Coping with climate variability and climate change;
(c) Coping with extreme meteorological events;
(d) Tactical decision-making based on weather information;
(e) Development of risk management strategies.

5.5.3 TRAINING INTERMEDIARIES

The following are proposed for training intermediaries:
(a) An agricultural meteorology-related syllabus for the in-service training of AEIAs;
(b) An agricultural meteorology-related syllabus for the in-service training of AEIBs.

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CHAPTER 6

DETAILED SYLLABUSES FOR THE COURSES

Undergraduate courses

Postgraduate basic courses

Postgraduate applied courses

Training intermediaries

6.1 UNDERGRADUATE COURSES

6.1.1 INTRODUCTORY AGRICULTURAL METEOROLOGY

The introductory agricultural meteorology course comprises the following:

(a) Agricultural meteorology: introduction, definition and scope;
(b) Introduction to the physics of the atmosphere with emphasis on laws of radiation, solar and terrestrial radiation, surface and atmospheric energy balances, precipitation formation, and atmospheric optical and electrical phenomena;
(c) Agrometeorological variables and their measurements;
(d) Vertical distribution of temperature: lapse rate and stability conditions;
(e) Elements and factors of climate;
(f) Weather and climate effects on agricultural production;
(g) Effect of weather on crop growth and development, and introduction to crop-weather modelling;
(h) Weather aspects of pest and disease management;
(i) Role of weather in determining risks and hazards and the use of weather data in planning and decision-making;
(j) Agroclimatic indices and their application;
(k) Climatic classification and its application in agriculture;
(l) Weather forecasting for agriculture.

Core competency

The course will provide information on various basic aspects of agricultural meteorology, in particular on the atmosphere, weather and climate and how the different weather elements affect crop growth, development and yield.

6.1.2 CLIMATE CHANGE AND ITS IMPACTS ON SOCIETY

The course on climate change and its impacts on society comprises the following:

(a) Weather and climate in different parts of the world;
(b) Principles governing the Earth's climate system, biogeochemical cycles and their interaction with the physical climate system;
(c) An introduction to the elements of the climate system, including the El Niño/La Niña cycle and monsoons;
(d) An overview of the natural variability of climate on interannual and interdecadal scales;
(e) The atmosphere and greenhouse effect;
(f) Evidence of climate change and the anthropogenic role in climate change;
(g) Climate change scenarios, and the major impacts of climate change on natural resources and the environment;
(h) Possible occurrence of extreme weather events and droughts caused by climate change;
(i) Impact of climate change on diseases and human health, agriculture and the economy;
(j) Steps to reverse human-induced climate change;

(k) Possible mitigation measures;
(l) Preparedness and policy options;
(m) Role of institutes in students' countries in terms of climate change research.

Core competency Understanding the Earth's climate and being able to visualize climate change and its triggering factors. The course will inculcate students with knowledge of the impacts of climate change on society and its economics and lead to an understanding of climate change impacts in various sectors and the possible policy options for mitigation and preparedness.

6.2 POSTGRADUATE BASIC COURSES

6.2.1 FUNDAMENTALS OF METEOROLOGY AND CLIMATOLOGY (3 lectures + 1 practical per week)

The course on the fundamentals of meteorology and climatology comprises the following:
(a) The Earth and atmospheric composition;
(b) Vertical structure of the atmosphere;
(c) Variation in temperature with height;
(d) Sun, the Earth and seasons;*
(e) Solar radiation and laws of radiation;
(f) Heat balance of the Earth and atmosphere;*
(g) Hydrological cycle;
(h) Climate change and global warming;*
(i) Instruments for the measurement of meteorological elements;
(j) Variation in pressure;
(k) Hydrostatic equation;
(l) Vapour pressure, saturation deficit and the psychrometric equation;
(m) Potential temperature and pressure gradient;
(n) Cyclones and anticyclonic motions;
(o) Air masses and fronts: types and properties;*
(p) Atmospheric moisture;
(q) Clouds and their classification;
(r) Precipitation processes and artificial rain making;
(s) Thunderstorms and duststorms, haze, mist fog and dew;
(t) Weather charts;
(u) Atmospheric moisture;
(v) Forecasting methods: short-, medium- and long-range forecasting techniques, recent models used in forecasting and their limitations in, and impact on, agriculture;
(w) Numerical weather prediction;
(x) El Niño and the Southern Oscillation;*
(y) Environmental indicators of weather changes;
(z) Local wind systems: land and sea breeze circulation, and mountain and valley winds;
(aa) Seasonal distribution of climatological elements over latitudes;
(bb) Climatic classification: Koppen and Thornthwaite systems;
(cc) Types of climate: humid and dry climates;
(dd) Climate change and global warming;*
(ee) Agroclimatic indices and different agroclimatic zones;
(ff) Frequencies of disastrous weather events in different regions;
(gg) Atmospheric and soil drought;
(hh) Monsoons and elements of monsoon meteorology;
(ii) Rainfall variability;
(jj) Climatology of specific countries.

*Students are given assignments so that they can understand the topics in detail.

Core competency The purpose of this basic course is to prepare students for more advanced courses in agricultural meteorology through a thorough discussion on the fundamental aspects of meteorology and climatology. The assignments given to the students throughout the period of the course will help them to develop a better appreciation of the applications of the different concepts taught during the course.

6.2.2 WEATHER, CLIMATE AND CROPS (hours: 3 + 1)

The course on weather, climate and crops comprises the following:
(a) Weather, climate and crop production: how weather and climatic factors affect plant growth and development;
(b) Climatic water budget as a tool for agroclimatic analysis;
(c) Basic concepts of climate data use for crop planning and climatic risk assessment: crop zoning;
(d) Basic concepts of weather data use for decision-making in relation to agricultural operations: operational agricultural meteorology;
(e) Weather/climate and crop yield relationship, and an introduction to crop-weather modelling;
(f) Introduction to weather hazards and their impact on crop production;
(g) Weather-related aspects of pest and disease management;
(h) Agrometeorological information systems: the use of weather forecasts in agriculture.

Core competency

The objective of this course is to describe the interactions between weather/climate and agriculture for both crop production and agricultural practices, thus enabling students to understand that the agricultural sector is weather/climate dependent. Also, this course will put emphasis on understanding and exploiting climatic resources for the benefit of agriculture, considering that agrometeorological information plays an important part not only in making daily and seasonal farm management decisions, but also in risk management associated with weather and climate variability.

6.2.3 WEATHER, CLIMATE AND LIVESTOCK

The course on weather, climate and livestock comprises the following:
(a) Climatic factors (temperature, radiation, humidity, wind) affecting the thermal balance in animals;
(b) Animal energy exchange processes and the need for the maintenance of thermal balances in animals;
(c) Thermal indices for animal studies and management;
(d) Physiological and productive consequences of environmental stresses and extreme weather events: loss of water from the body, growth rate and body weight, food intake, milk production, and so on;
(e) Adaptive capacity for the alleviation of climatic stress in livestock;
(f) Contribution of animal husbandry to climate change and adaptation strategies to reduce the resulting effects.

Core competency

Students will develop an understanding of the interactions between climate and animal production. They will develop a capacity to recommend improved animal husbandry management.

6.2.4 METEOROLOGICAL HAZARDS IN AGRICULTURE

The course on meteorological hazards in agriculture comprises the following:
(a) Drought
- Definitions; economic and social impacts; statistical climatology of droughts; causes; forecasting droughts (analogue, statistical, physical);
- Coping with drought through early warning and monitoring; planning; reduction of vulnerability; compilation of natural resources inventories; information exchange; use of geographical information systems to improve prediction, and so on;
- Artificial simulation of precipitation: principles and practices of cloud seeding; problems of evaluation of experimental and operational programmes;

(b) Hail
- Definitions; damage; spatial and temporal distribution; growth of ice particles; hail growth models; hail suppression concepts and prediction;
- Aspects of hail insurance;

(c) Frost
- Definitions; types; formation mechanisms; large-scale and local factors affecting the frequency and severity of frosts; methods of frost protection;
- Mitigation of frost impacts using climatology and forecasting;

(d) Floods
- Definitions; causes; statistical climatology of floods; short- and long-term impacts;
- Extreme value analysis; use of unit hydrographs and probable maximum precipitation;
- Meteorological and hydrological forecasting of floods and use of catchment runoff models;
- Mitigation of impacts through forward planning and flood warnings;
- Flood insurance;

(e) Pests and diseases
- Factors controlling migrant pests, including desert and red locusts and army worms; role of meteorology in crop protection, including spraying operations and integrated pest management;
- Climatic factors affecting the spread and survival of pests and pathogens;
- Control methods;

(f) Storage losses
- Climatic conditions affecting storage losses; loss reduction methods;

(g) Fires
- Effects of controlled and uncontrolled burning; fire risk assessment schemes;

(h) Wildfires
- Definitions; damage; role of weather in the occurrence and severity of wildfires; mitigating impacts; fire danger estimates;

(i) Extreme temperatures
- Effects of high temperatures on crop and animal production;

(j) Winds
- Effects of wind on crop production;

(k) Tsunamis
- Causes and the effects on animals and crops.

Core competency

Students will understand the meteorological and climatological factors affecting the frequency and severity of a wide range of hazards faced by agricultural production. They will be able to advise farmers on planning that may mitigate some effects. They will also be aware of the methods used to predict hazards and their reliability, and will be able to interpret forecasts and issue advisory warnings.

6.2.5 AGROMETEOROLOGICAL MEASUREMENTS AND INSTRUMENTATION

The course on agrometeorological measurements and instrumentation comprises the following:

(a) Fundamentals of measurement techniques;

(b) Theory and working principles of various instruments: theoretical and practical aspects of electronic circuits and various sensors and equipment used in agrometeorological research and applications (barometers, thermometers, thermographs, psychrometers, hair hygrometers, thermo hygrographs, raingauges, self-recording raingauges, Duvdevani dew gauges, sunshine recorders and pyranometers, lysimeters, open-pan evaporimeters, anemometers, wind vanes, anemographs, soil thermometers);

(c) Soil heat flux plates and instruments for measuring soil moisture;

(d) Albedometers, photometers, spectroradiometers and quantum radiation sensors;
(e) Ceptometer, pressure bomb apparatus, porometer, photosynthesis systems and infra-red thermometers;
(f) Discussions on instrument selection, sensor deployment and data acquisition;
(g) Automatic weather stations and other electronic instruments;
(h) Data logger and data transmission systems;
(i) Measurement of surface energy fluxes;
(j) Remote-sensing measurements by radar and satellite;
(k) Working with the above instruments in the meteorological observatory, taking observations of relevant parameters and computation and interpretation of the data;
(l) Techniques for data verification and validation;
(m) Methods for data quality assurance and data quality control in automated systems;
(n) Missing data generation;
(o) Visit to a centre equipped with an advanced instrumentation facility not available at the students' institutes.

Core competency Students will learn how to measure the various weather parameters required for agrometeorological activities. They will be taught the working principles and accurate measuring techniques. This teaching will help in understanding the computation and interpretation of data.

6.2.6 MICRO-METEOROLOGY

The course on micrometeorology comprises the following:
(a) Detailed study of turbulence mechanisms and characteristics to evaluate exchanges of momentum, energy and mass in the atmospheric boundary layer;
(b) Evaluation of the structure, dynamics and processes of diffusion and turbulent transfer using exchange models;
(c) Evaluation of the turbulent kinetic energy, stratified flows and stability parameters required to estimate coupled momentum and energy and mass exchanges;
(d) Turbulence and wind profiles near the Earth's surface;
(e) Influence of changing soil surface properties on wind flow dynamics;
(f) Measurement and empirical relationships of wind and temperature profiles over different surfaces;
(g) Control of the physical environment through irrigation, windbreaks, frost protection, manipulation of radiation and water use through intercropping systems;
(h) Simulation of boundary layer structure and dynamics;
(i) Micrometeorology of crop canopies and animal environment: distribution of radiation, temperature, humidity, vapour pressure, wind and carbon dioxide.

Core competency Students will gain an understanding of the role of wind movement and the dynamics of wind flow over different surfaces in energy and mass exchanges. They will learn how to apply diffusion and turbulent transfer as a component of energy and mass exchanges as affected by different surface structures. Students will learn to collect and evaluate wind-flow data and how to estimate the boundary structure and dynamics for use in multiple applications, for example, pollen transport, spore dispersal, and particle and gas movement.

6.2.7 ANALYTICAL TOOLS AND METHODS FOR AGRICULTURAL METEOROLOGY

The courses on analytical tools and methods for agricultural meteorology comprises the following:

Theory

(a) Review of agroclimatic methods;
(b) Characterization of agroclimatic elements;
(c) Atmosphere sampling; temporal and spatial considerations; micro, meso and macro climates;

(d) Network spacing; spatial and temporal methods;
(e) Geographical information system fundamentals and applications;
(f) Numerical characterization of climatic features;
(g) Crop response to climate, time lags, time and distance constants and hysteresis effects;
(h) Influence of climate on stress-response relations;
(i) Thermal time approach in agroclimatology: heat and radiation use efficiency in crop plants;
(j) Applications for insect–pest development and prediction;
(k) Comfort indices for humans and animals;
(l) Instrumentation and sampling problems;
(m) Design of agrometeorological experiments;
(n) Impact of natural and induced climate variability and change on crop production;
(o) Basic knowledge of computer use in agriculture; the theory of programming languages: BASIC, FORTRAN, C, C++ and Visual Basic;
(p) Empirical and statistical crop weather models and examples of their application;
(q) Incorporating weather, soil, plants and other environment-related parameters as subroutine and remote-sensing inputs in models;
(r) Growth and yield prediction models; crop simulation models; forecasting models for insects and diseases.

Practicals

(a) Calculation of the continentality factor;
(b) Climatic indices and Climogram;
(c) Agrometeorological indices: degree-days, photothermal units, heliothermal units and the phenothermal index;
(d) Heat and radiation use efficiency and other crop indices;
(e) Crop growth rates;
(f) Analysis of thermograms, hygrograms, hyetograms, sunshine cards, and so on, streamlines and wind roses and the statistical analysis of climatic data;
(g) Working with statistical models: crop yield forecasting, crop–weather relationships and insect and disease forecasting models;
(h) Working with crop simulation models and programme writing in programming languages such as BASIC, FORTRAN, C, C++ and Visual Basic; geographical information systems.

Core competency

In order to provide the user community in different parts of the world with agrometeorological services, strong support systems are required. This course places emphasis on training the students in the use of different analytical tools and methods. On completing this course, students should be able to apply the tools in preparing different agrometeorological products for use by the farming community.

6.3 POSTGRADUATE APPLIED COURSES

6.3.1 STRATEGIC USE OF CLIMATE INFORMATION

Elementary

The course on strrategic use of climate information comprises the following:
(a) Increasing awareness of potential climate hazards and mitigation
- History of climate-related disasters (hazards and vulnerabilities) suffered in the continent/region/country/subregion concerned and their documented or remembered impacts (with emphasis on the last two decades).
- Hazards and their link to agricultural production risks (intra-annual and interannual); efforts made in mitigating impacts of (future) disasters – prevention; discernable trends in the occurrence and character of disasters, if any (practicals are possible on the last subject).

Advanced

- Expectations concerning future disasters.
- Further efforts that could be made to mitigate the impacts of disasters (prevent what can be prevented) and related policy developments.
- Systematic and standardized data collection on disasters and the role of science in combating them; agrometeorological services to increase farmers' awareness of climate-related disasters and potential mitigation (practicals are possible on the last two subjects).

(b) Selection of appropriate land-use and cropping patterns

Elementary

- Types and drivers of agricultural land-use and cropping patterns (regionalized, by definition).
- History of main present land-use and cropping patterns in the continent/region/country/subregion concerned in relation to environmental issues (including traditional techniques, yet with emphasis on the last two decades).
- Successes and difficulties experienced by farmers with present land-use and cropping patterns.
- Outlooks for present land-use and cropping patterns and possible alternatives from an environmental point of view.
- Recent trends in land-use and cropping patterns (practicals are possible on the last subject).

Advanced

- Land-use and cropping pattern impacts on agroecosystem resources (process-oriented view).
- Outlooks for alternative land-use and cropping patterns and what influences decision-making on such alternatives.
- Policies to protect viable land-use and cropping patterns and support for appropriate alternatives.
- Systematic and standardized data collection on (changes in) land-use and cropping patterns and the role of science in the selection processes.
- Agrometeorological services to increase farmers' design abilities in terms of land-use and cropping patterns (practicals are possible on the last two subjects).

(c) Adoption of preparedness strategies

Elementary

- Priority setting for preparedness strategies in agricultural production.
- Preparedness for meteorological disasters in development planning.
- Permanent adaptation strategies that reduce vulnerability to hazards.
- Preparedness as a coping strategy (practicals are possible on the last subject).

Advanced

- Preparedness for the reception of contingency responses.
- Preparedness as a community approach.
- Policies that enhance preparedness strategies.
- Systematic and standardized data collection on actual preparedness strategies adopted in agricultural production and the role of science in their selection.
- Agrometeorological services to increase farmers' preparedness for climate disasters and their awareness of potential mitigation (practicals are possible on the last two subjects).

(d) Making more efficient use of agricultural inputs

Elementary

- Agrometeorological aspects of agricultural production inputs and their history.
- Determination of input efficiencies.
- Other factors determining inputs and input efficiency.
- Actual use of inputs in main land-use and cropping patterns of the region (practicals are possible on the last subject).

Advanced
- Improvement of input efficiencies in agricultural production.
- Policies that enhance increased input efficiencies.
- Systematic and standardized data collection on agricultural inputs, their efficiencies and their relation to climate.
- Role of science in more efficient use of agricultural inputs.
- Agrometeorological services to increase farmers' abilities for more efficient use of inputs (practicals are possible on the last three subjects).

(e) Selection of livestock management

Elementary
- History of livestock management patterns in the continent/region/country/subregion concerned in relation to environmental issues (including traditional techniques, yet with emphasis on the last two decades).
- Successes and difficulties experienced by farmers with present livestock management strategies.
- Outlooks for present livestock management strategies and possible alternatives from an environmental point of view.
- Recent trends in livestock management strategies (practicals are possible on the last subject).

Advanced
- Outlooks for alternatives in livestock management and what influences decision-making on such alternatives.
- Policies to protect viable livestock management strategies and to support appropriate alternatives.
- Systematic and standardized data collection on (changes in) livestock management patterns and the role of science in selecting them.
- Agrometeorological services to increase farmers' design abilities in terms of livestock management strategies (practicals are possible on the last two subjects).

(f) Adoption of microclimate modification techniques

Elementary
- Review of microclimate management and manipulation methods (for example, Stigter's review tables in Griffiths (1994)).
- History of microclimate modification techniques practised in the continent/country/subregion concerned (including traditional techniques, yet with emphasis on the last two decades).
- Possible improvements in the adoption of microclimate modification techniques, given increasing climate variability and climate change.
- Local trends in the adoption of such techniques (practicals are possible on the last subject).

Advanced
- Outlooks for improved microclimate modification techniques.
- Policies to support the introduction and extension of appropriate microclimate management and manipulation.
- Systematic and standardized data collection on (changes in) microclimate modification patterns and the role of science in their development.
- Agrometeorological services to increase farmers' design abilities in terms of appropriate microclimate modification patterns (practicals are possible on the last two subjects).

(g) Protection measures against extreme climate

Elementary
- History of protection measures against extreme climate in the continent/region/country/subregion concerned (including traditional techniques, yet with emphasis on the last two decades).
- Successes and difficulties experienced by farmers with present protection measures.

- Outlooks for present protection measures and possible alternatives.
- Trends in protection methods against extreme climate (practicals are possible on the last subject).

Advanced

- Outlooks for improved or alternative protection measures and what influences decision-making on such alternatives.
- Policies to safeguard viable protection measures and to support appropriate alternatives.
- Systematic and standardized data collection on (changes in) protection measures against extreme climate and the role of science in their design.
- Agrometeorological services to increase farmers' design abilities in terms of such protection measures (practicals are possible on the last two subjects).

Core competency

Elementary

- Having a historical view of the strategic use of climate information in the areas concerned, and being able to assess the present situation and its potential.

Advanced

- Having an outlook on the strategic use of climate information in the near future for the areas concerned, with a good understanding of the difficulties likely to be encountered and their possible solutions.

6.3.2 COPING WITH CLIMATE CHANGE AND CLIMATE VARIABILITY

The course on coping with climate change and climate variability comprises the following:

(a) Increase capacity in using climate forecast information

Elementary

- History of the dissemination of climate forecast information in the continent/region/country/subregion concerned and its documented or remembered uses and impacts (with emphasis on the last two decades).
- Factors determining the demand, release and use of climate forecasts for/in agricultural production (practicals are possible on monitoring the present release and actual use of certain climate forecasts).

Advanced

- Required improvements in climate forecasting.
- Improvements needed in issuing climate forecasts.
- Improvements required in the assimilation and use of climate forecasts in all agricultural production.
- Systematic and standardized data collection on issuing, assimilating and using climate forecast information in agricultural production and the role of science in improving them.
- Agrometeorological services to increase farmers' awareness of climate forecast information, their assimilation potential and their use of such information (practicals are possible on the last two subjects).

(b) Develop the sustainable use of agroecosystem resources

Elementary

- History of the use of agroecosystem resources in the continent/region/country/subregion concerned and their documented or remembered sustainability, or the lack thereof (with emphasis on the last two decades).
- Factors determining the sustainable development and use of agroecosystem resources (practicals possible on the actual use of such resources).

Advanced

- Improvements needed in the sustainable development and use of agroecosystem resources.
- Policies to support such development and use.
- Systematic and standardized data collection on agroecosystems and the role of science in their sustainable development and use.

- Agrometeorological services related to farmers' sustainable use of agroecosystem resources (practicals are possible on the last two subjects).

(c) Heighten awareness of increasing climate variability and climate risks

Elementary

- History of increasing climate variability in the continent/region/country/subregion concerned and its documented or remembered elevated risk (with emphasis on the last two decades).
- Factors determining the awareness of increasing climate variability and climate risk, with examples of such increased awareness or lack thereof in agricultural production (practicals are possible on examples of increased awareness, or lack thereof).

Advanced

- Outlooks for improved awareness of increasing climate variability and climate risk and factors determining such improvements in agricultural production.
- Policies to increase such awareness.
- Systematic and standardized data collection on (changes in) awareness of increasing climate variability and climate risk and the role of science in the detection and awareness of such matters.
- Agrometeorological services related to an increase in farmers' awareness of the same (practicals are possible on the last two subjects).

(d) Increase understanding of climate change adaptation strategies

Elementary

- History of climate change adaptation strategies for agricultural production in the continent/region/country/subregion concerned (with emphasis on the last two decades).
- Documented or remembered understanding of such strategies, or lack thereof.
- Factors determining the understanding of such adaptation strategies.
- Examples of increased understanding or lack thereof in agricultural production (practicals are possible on such examples).

Advanced

- Outlooks for an improved understanding of climate change adaptation strategies and factors determining the increase of such understanding in agricultural production.
- Policies to increase such understanding.
- Systematic and standardized data collection on (changes in) climate change adaptation strategies and their understanding and the role of science in such matters.
- Agrometeorological services related to an increase in farmers' understanding of such adaptation strategies (practicals are possible on the last two subjects).

Core competency

Elementary

- Understanding the characteristics of climate variability and climate change and how farmers can adapt to them when using agroecosystem resources, with and without the use of climate forecast information.

Advanced

- Understanding the problems and solutions when designing, issuing and applying climate forecasts for coping with climate variability and climate change and the role played by policies, science and agrometeorological services in assisting farmers to adapt to these changes.

6.3.3 COPING WITH EXTREME METEOROLOGICAL EVENTS

The course on coping with extreme meteorological events comprises the following:

(a) Develop understanding of extreme meteorological phenomena, impacts, actions, problems, solutions, policies and the remaining challenges based on case studies

Elementary

- Description and characterization of selected extreme meteorological events and of the impacts of these phenomena on agricultural production and infrastructure.
- Case studies to illustrate the events and impacts suffered by farmers.
- Action strategies available to farmers to counter similar impacts.
- Case studies of such action strategies and challenges remaining (practicals are possible on the collection of local case studies).

Advanced

- Case studies of problems encountered locally by farmers and solutions they developed in coping with extreme meteorological events.
- Case studies of such solutions developed elsewhere for similar problems.
- Role of policies in promoting viable solutions to remaining problems.
- Scientific components of problems and solutions for coping with extreme meteorological events and the remaining challenges for the use of science to contribute to conducting problem analyses and designing viable solutions.
- Agrometeorological services to improve farmers' design abilities in terms of solutions for coping with extreme meteorological events (practicals are possible on the last two subjects).

(b) Capacity to develop and implement effective early warning systems

Elementary

- History of early warning systems for extreme meteorological events and their efficiencies in the continent/region/country/subregion concerned (including traditional techniques, yet with emphasis on the last two decades).
- Bringing such early warnings to users for discussion.
- Successes and difficulties experienced by farmers with present early warning systems.
- Outlooks for present early warning systems, their effectiveness and possible alternatives.
- Trends in early warning systems and their use (practicals are possible on the last subject).

Advanced

- Outlooks for early warning system alternatives and the influences on decision-making concerning such alternatives.
- Policies to promote efficient early warning strategies and to support appropriate alternatives.
- Systematic and standardized data collection on (changes in) early warning strategies and the role of science in designing and selecting them and increasing their efficiencies.
- Agrometeorological services to increase farmers' assimilation of warnings and their actual use (practicals are possible on the last two subjects).

Core competency

Elementary

- Understanding the characteristics of extreme meteorological events and the ways in which farmers cope with them, with and without the use of early warning systems.

Advanced

- Understanding the problems and solutions in designing, issuing and applying early warnings for extreme meteorological events and the role played by policies, science and agrometeorological services in helping farmers to cope with these issues.

6.3.4 TACTICAL DECISION-MAKING BASED ON WEATHER INFORMATION

The course on tactical decision-making based on weather information comprises the following:

(a) Develop an understanding of the weather phenomena, short- and medium-range weather forecasts, impacts, actions, problems, solutions, policies and the remaining challenges based on case studies

Elementary

- Description and characterization of selected weather phenomena, their impacts on agricultural production or their use therein.

- Data assimilation and retrieval for tactical decisions.
- Use of mesoscale models in farm decision-making, satisfying the lead-time requirement.
- History of short- and medium-range weather forecasting and its documented uses and impacts (with emphasis on the last two decades).
- Case studies to illustrate weather phenomena and tactical decision-making to make use of or cope with these phenomena.
- Possible roles of improved short- and medium-range weather forecasting (practicals are possible on the collection of local case studies).

Advanced

- Action strategies available to farmers to improve the use of or to cope with selected weather phenomena requiring tactical decision-making, where necessary/possible making use of (improved) short- and medium-range weather forecasting.
- Local case studies of such action strategies or similar strategies developed elsewhere and the challenges remaining.
- The role of policies in promoting viable solutions to the remaining problems.
- Scientific components of problems and solutions in terms of using and coping with weather phenomena requiring tactical decision-making, and the challenges remaining for the use of science to contribute to problem analysis and to design viable solutions, where necessary/possible making use of short- and medium-range weather forecasting.
- Agrometeorological services to improve farmers' abilities to design solutions in terms of using or coping with such weather phenomena (practicals are possible on the last two subjects).

(b) Capacity to develop tactical applications for agricultural management (for example, in the fields of pests, diseases and animal husbandry)

Elementary

- Optimum weather requirements for various field operations and animal maintenance and crop yields.
- History of selected weather-related tactical applications for agricultural management and their efficiencies in the continent/region/country/subregion concerned (including traditional techniques, yet with emphasis on the last two decades).
- Bringing such tactical applications to users for discussion.
- Case studies of successes and difficulties experienced by farmers with present weather-related tactical applications (seed sowing, fertilizer application, irrigation scheduling, harvest, crop drying, labour utilization, controlling pests and diseases affecting crops, animal protection requirements for optimum growth and production).
- Outlooks for present tactical applications, their efficiencies and possible alternatives.
- Trends in such tactical applications and their use (practicals are possible on the last subject).

Advanced

- Outlooks for alternatives to present weather-related tactical applications for agricultural management and the influences on decision-making concerning such alternatives.
- Policies to promote efficient tactical applications and to support appropriate alternatives.
- Systematic and standardized data collection on (changes in) such tactical applications for agricultural management and the role of science in designing and selecting them and increasing their efficiencies.
- Agrometeorological services to increase farmers' actual use of tactical applications for using or coping with weather phenomena (practicals are possible on the last two subjects).

Core competency

Elementary

- Understanding the characteristics of relevant weather phenomena and the ways in which farmers use them or deal with their impacts by tactical decision-making, with and without the use of short- and medium-range weather forecasting.

Advanced

- Understanding problems and solutions in designing, issuing and applying weather-related tactical applications for agricultural management and the role played by short- and medium-term weather forecasting, appropriate policies and the use of science and agrometeorological services in assisting farmers in tactical decision-making.

6.3.5 DEVELOPING RISK MANAGEMENT STRATEGIES

The course on developing risk management strategies comprises the following:

(a) Risks in agricultural production

Elementary

- History of weather and climate as accepted agricultural risk factors in the continent/region/country/subregion concerned and the related documented risk concepts (including traditional concepts, yet with emphasis on the last two decades).
- History of and trends in defence strategies towards such risks in the same continent region/country/subregion.
- Preparedness for weather and climate risks (practicals are possible on the last subject).

Advanced

- Weather- and climate-related risk managers and those who have to cope with weather- and climate-related risks in agriculture.
- Management and coping strategies for such risks, and the related trends.
- Policies to enhance and improve such strategies.
- Systematic and standardized data collection on weather- and climate-related risks in agriculture and the role of science in defining, managing and coping with such risks.
- Agrometeorological services to increase abilities to design risk management strategies and strategies to cope with risks (practicals are possible on the last two subjects).

(b) Risk characterization

Elementary

- Definitions and classifications of risks.
- Characterization of weather- and climate-related risks in agriculture.
- Water-related risks.
- Radiation/heat-related risks.
- Air and its movement-related risks.
- Biomass-related risks.
- Social and economic risk factors related to weather and climate (practicals are possible on local recognition of the various risks).

Advanced

- Quantification approaches of weather- and climate-related risks in agricultural systems.
- Successes and difficulties in using scales and other tools for weather- and climate-related risk quantification.
- The role of science in developing such scales and tools.
- Policies to stimulate a quantitative and scientific approach to risk characterization.
- Challenges remaining (practicals are possible on the applications of some scales and other tools).

(c) Approaches and tools for dealing with risks

Elementary

- History of methods for weather- and climate-related risk assessment in the continent/region/country/subregion concerned and their documented evidence of application to agricultural/farming systems.

- Strategies for dealing with risks: mitigating practices before the event.
- Preparedness for the inevitable.
- Contingency planning and responses.
- Disaster risk mainstreaming (practicals are possible on local recognition of the last strategies).

Advanced

- Modelling risk assessments.
- Application of methods that enable the incorporation of weather and climate factors determining risks.
- Using short- and medium-range weather forecasting in risk assessment approaches.
- Using seasonal and long-term climate forecasts in risk assessment approaches.
- Systematic and standardized data collection on weather- and climate-related risk assessments in agricultural production, and the role of science in improving such assessments.
- Agrometeorological services to increase risk assessment design abilities (practicals are possible on the last two subjects).

(d) Outlook for farm applications

Elementary

- Farm applications not yet dealt with, such as making risk information products more client friendly and the transfer of risk information products to the primary and secondary users of such information.
- Heterogeneity of rural populations in the areas of education, income, occupation and information demands and the consequences for risk information products and their transfer.
- Livelihood-focused support, participation and community perspectives (practicals are possible on local recognition of the mentioned heterogeneity and its consequences).

Advanced

- Case studies of farm applications of risk information products, including traditional technologies.
- Improvements needed in the farm applications of such products and the policies required to foster improvements, including the use of intermediaries.
- Role of science in designing and communicating improvements in the farm applications of risk information products.
- Agrometeorological services to increase the assimilation and use of risk information products in farming (practicals are possible on the last two subjects).

(e) Challenges in terms of developing coping strategies, including risk transfer through insurance schemes

Elementary

- Challenges faced by coping strategies: combining challenges with disaster risk mainstreaming, mitigation practices, contingency planning and responses and basic preparedness.
- Preparedness approaches to reduce emergency relief necessities.
- Role played by insurance in risk spreading and transfer (practicals are possible on the last two subjects).

Advanced

- Challenge implementations: adaptation strategies, relief responses, impact reductions, the many faces of preparedness.
- Policies to better meet the challenges.
- Systematic and standardized data collection on coping strategies for weather- and climate-related risks in agricultural production and the role of science in improving such coping strategies, including the improved use of insurance approaches.

- Agrometeorological services to foster the design, assimilation and use of such coping strategies (practicals are possible on the last two subjects).

(f) Quantification of risks in agricultural systems associated with weather and climate

(g) Risk assessment methods and their application to agricultural systems of local and regional interest

(h) Application of risk management approaches to weather- and climate-related problems

(i) Application of methods enabling the incorporation of seasonal and long-term forecasts into risk assessment models

Core competency

Elementary

- Understanding weather and climate as risk factors in agricultural production and knowing the essence of risk management strategies and risk coping strategies.
- Understanding the many faces of preparedness for risks and problems, with the transfer of risk information products to various users.

Advanced

- Understanding risk assessment methods that are particularly suited to climate- and weather-related risks in agricultural production, as well as scales and other tools for risk quantification.
- Understanding challenges faced by coping strategies, including an approach based on adaptation, risk mitigation and insurance.

6.4 TRAINING INTERMEDIARIES

6.4.1 AN AGRICULTURAL METEOROLOGY-RELATED SYLLABUS FOR THE IN-SERVICE TRAINING OF AEIAs (A-DOMAIN AGROMETEOROLOGICAL EXTENSION INTERMEDIARIEs)

Elementary

The elementary components of this syllabus comprise the following:

(a) Review of local context concerning administrational issues: functions and responsibilities;
(b) Review of local climate issues, including traditional knowledge;
(c) Review of farming systems in the subregion/country/region/continent concerned;
(d) Production constraints within the farming systems reviewed;
(e) Fields of agricultural meteorology relevant to local agriculture;
(f) Agrometeorological components of identified production constraints;
(g) Assessment of needs identified by the farmers in the various systems.

Practicals with farmers are possible on the last two subjects, and additional ones with AEIBs (B-domain agrometeorological extension intermediaries) (Stigter, in preparation) as indicated below. The results of such practicals should be discussed with AEIBs in joint classes.

Advanced

The advanced components of this syllabus comprise the following:

(a) Review of processes of change (economic, social, environmental, and so on) taking place in the subregion/country/region/continent concerned;
(b) Extension approaches suitable in the farming systems reviewed for the production constraints identified;
(c) Policies of existing extension and their decentralization;
(d) Extension agricultural meteorology locally available to meet assessed needs;
(e) Agrometeorological services already applied or tried;
(f) New extension agricultural meteorology possible;
(g) Constraints in applying extension agricultural meteorology through agrometeorological services and their relief solutions.

Practicals with farmers are possible on the last three subjects and additional ones with agrometeorological extension intermediaries as indicated below. The results of such practicals should be discussed with AEIBs in joint classes.

6.4.2 AN AGRICULTURAL METEOROLOGY-RELATED SYLLABUS FOR THE IN-SERVICE TRAINING OF AEIAs (B-DOMAIN AGROMETEOROLOGICAL EXTENSION INTERMEDIARIEs)

Elementary

The elementary components of this syllabus comprise the following:

(a) Needs assessments concerning the agrometeorological products required by farmers and farming systems;
(b) Products available from weather services, research institutes and universities directed at farming systems in the subregion/country/region/continent concerned;
(c) User friendliness of those products, as assessed by clients;
(d) Documented or remembered use of such products and their successes and failures and assessment of their causes.

Practicals are possible together with the AEIAs on the last two subjects. The results should be discussd in joint classes.

Advanced

The advanced components of this syllabus comprise the following:

(a) Needs for additional products from weather services, research institutes and universities;
(b) How to commission these organizations to provide such products;
(c) How to make such products as user friendly as possible for the farming systems concerned;
(d) Discussions on potential new products with prospective users;
(e) Bringing new products to new or existing agrometeorological services.

Practicals are possible together with the AEIAs on last two subjects. The results should be discussed in joint classes.

REFERENCES

Griffiths, J.F.,1994 — *Handbook of Agricultural Meteorology*. Oxford University Press, Oxford.

Stigter, K. (ed.), in preparation — *Applied Agrometeorology*. Springer, New York.

CHAPTER 7

CONCLUSIONS

Agricultural meteorology is a relatively new term that has been in existence for about 80 years. During this time, the discipline has rapidly evolved from a descriptive science to a very quantitative approach to the interactions between physical processes and biological systems. Emerging global issues require a different understanding of the interactions between weather and climate and biological systems which can help quantify the risks associated with natural disasters, increasing occurrences of pests and diseases, variations in crop production and yield, and impacts on animal production and stress. In order to address these issues, students should be prepared to understand how to balance increasing weather and climate variation with biological response and be able to provide information to producers and policymakers about the implications of these changes.

In order to address these challenges it is necessary to develop curricula for agricultural meteorology that can provide a strong foundation for achieving increases in per capita production in developing countries; stabilize production in marginal semi-arid areas with limited and variable water resources; sustain the soil resources in humid and tropical climates where they are exposed to water erosion and high temperature effects; and reduce the impact of agricultural production on soil, water, and air quality in industrialized countries. There is also a need to develop effective systems around the world to cope with climate variation, deforestation, wind erosion, desertification and water erosion, and to enhance the efficiency of plant production by optimizing the use of inputs. These may seem like daunting requirements for any curriculum, but it is necessary to develop a programme that will provide a strong foundation for students to address these challenges.

One of the guiding principles for agricultural meteorology curricula is the need to ensure a seamless transition between the sustainability of agricultural systems and the need for support systems that can enhance research, education, training, extension and policy information needs. To address this need, courses are developed to address local requirements, an international communication and information exchange system, and a foundation in multidisciplinary problem solving. These are underpinned through the development of special topics on specific regional problems, case studies and potential study tours.

To address these requirements a proposal for courses was developed in three areas: the undergraduate programme, the postgraduate programme, and the training of intermediaries. The undergraduate programme consists of two core courses: (a) introductory agricultural meteorology; and (b) climate change and its impact on society. The postgraduate programme consists of basic courses (fundamentals of meteorology and climatology; weather, climate, and crops; weather, climate and livestock; meteorological hazards in agriculture; agrometeorological measurements and instrumentation; micrometeorology; and analytical tools and methods for agricultural meteorology) and applied courses (strategic use of climate information; coping with climate variability; coping with extreme meteorological events; tactical decision-making based on weather information; developing risk management strategies). The training of intermediaries consists of an agricultural meteorology-related syllabus for the in-service training of AEIAs (A-domain agrometeorological extension intermediaries) and an agricultural meteorology-related syllabus for the in-service training of AEIBs (B-domain agrometeorological extension intermediaries) (Stigter, in preparation). For each of these courses there is an outline to define the course structure and to provide a definition of the core competencies to be gained. These courses have been developed by an expert panel of agricultural meteorologists concerned with the future training of students to equip them with the necessary tools to meet the diverse challenges in worldwide agriculture.

These courses are being defined in detail to assist instructors throughout the world with guidance on agricultural meteorology curricula and the minimum materials required for training. These courses and their content will be revisited as courses are adopted to evaluate whether changes should be made to increase their effectiveness and impact on the worldwide community.

REFERENCE

Stigter, K. (ed.), in preparation: *Applied Agrometeorology*. Springer, New York.

ANNEX I

LIST OF PARTICIPANTS OF THE EXPERT MEETING ON REVIEW OF CURRICULUM IN AGRICULTURAL METEOROLOGY

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ANNEX II

PROGRAMME OF THE EXPERT MEETING ON REVIEW OF CURRICULUM IN AGRICULTURAL METEOROLOGY

PROGRAMME

(Venue: National Academy of Agricultural Sciences, NASC Complex DPS Marg, Pusa)

National Academy of Agricultural Sciences

EXPERT MEETING ON
REVIEW OF CURRICULUM IN
AGRICULTURAL METEOROLOGY

WORLD METEOROLOGICAL ORGANIZATION

AMERICAN SOCIETY OF AGRONOMY

ACCADEMIA DEI GEORGOFILI

(14–16 March 2007, New Delhi, India)

Tuesday, 13 March 2007

Participants arrive in New Delhi

Wednesday, 14 March 2007

Session 1 Opening of the Meeting

09:00 hrs Welcome
Ved Prakash Gupta
National Academy of Agricultural Sciences (NAAS)

09:10 hrs Welcome
M.V.K. Sivakumar
Chief
Agricultural Meteorology Division
WMO

09:20 hrs Welcome
L.S. Rathore
Vice President
Commission for Agricultural Meteorology, WMO

09:30 hrs Welcome
J.L. Hatfield
President
American Society of Agronomy
USA

09:40 hrs Welcome
S. Orlandini
Accademia dei Georgofili
Italy

10:05 hrs Group Photo

10:10 hrs Tea/Coffee Break

Session 2 Agricultural Meteorology over the Years

(Chair: **Josef Eitzinger**
Rapporteur: **Joydeep Mukherjee**

10:30 hrs Agricultural Meteorology at the Global Level
M.V.K. Sivakumar
WMO

11:00 hrs Agricultural Meteorology over the years and new priorities and consequences for the curricula
C.J. Stigter
Netherlands

11:30 hrs General Discussion

12:00 hrs Lunch

Session 3 Current Status of Curriculum in Agricultural Meteorology

(Chair: **C.J. Stigter**
Rapporteur: **Vasiraju Murthy**)

13:00 hrs University of Zimbabwe
Mr Barnabas Chipindu
Zimbabwe

13:30 hrs University of Sao Paulo
Dr Paulo Cesar Sentelhas
Brazil

14:00 hrs Universities in USA
Jerry Hatfield
USA

14:30 hrs Universities in Canada
Raymond Desjardins
Canada

15:00 hrs Tea/Coffee Break

15:30 hrs University of Bogor
Rizaldi Boer
Indonesia

16:00 hrs University of Vienna
Josef Eitzinger
Austria

16:30 hrs University of Florence
Simone Orlandini
Italy

17:00 hrs General Discussion

17:30 hrs Adjournment

18:00 hrs Workshop reception

Thursday, 15 March 2007

Session 3 Current Status of Curriculum in Agricultural Meteorology *(contd)*

(Chair: **L.S. Rathore**
Rapporteur: **Rizaldi Boer**)

09:00 hrs Tamil Nadu Agricultural University
R. Jagannathan
India

09:30 hrs Punjab Agricultural University
Raj Kumar Mahey
India

10:00 hrs Anand Agricultural University
Vyas Pandey
India

10:30 hrs ANGR Agricultural University
Vasiraju Radha Krishna Murthy
India

11:00 hrs Tea/Coffee Break

11:30 hrs General Discussion

12:30 hrs Lunch

Session 4 Overall Programme for Post-Graduate Education in Agricultural Meteorology – Open Discussion

(Chair: **Jerry Hatfield**
Rapporteur: **R. Jagannathan**)

13:30 hrs Overall programme for Post-Graduate Education in Agricultural Meteorology

14:45 hrs Leave for IARI Auditorium

15:00 hrs Risks in crop production induced by water and nitrogen interactions
Jerry Hatfield
President
American Society of Agronomy

16:30 hrs Return to NAAS

16:45 hrs Overall programme for Post-Graduate Education in Agricultural Meteorology

17:30 hrs Adjournment

Friday, 16 March 2007

Session 5 Proposals for Revised Curriculum – Discussion

(Chair: **Raymond Desjardins**
Rapporteur: **Vyas Pandey**)

9:00 hrs Synthesis of the Overall Programme for Post-Graduate Education in Agricultural Meteorology

10:00 hrs Proposal (1)
(title to be confirmed)

10:30 hrs Tea/Coffee break

11:00 hrs Proposal (2)
(title to be confirmed)

11:30 hrs Proposal (3)
(title to be confirmed)

12:00 hrs Proposal (4)
(title to be confirmed)

12:30 hrs Lunch

Session 6 Discussion on a Hand Book on Curriculum in Agricultural Meteorology at the Post-Graduate Level

(Co-Chairs: **J.L. Hatfield and M.V.K. Sivakumar**)

13:30 hrs Open Discussion

15:30 hrs Tea/Coffee break

16:00 hrs Vote of thanks
Ved Prakash Gupta
National Academy of Agricultural Sciences (NAAS)

16:10 hrs Vote of thanks
M.V.K. Sivakumar
WMO

16:20 hrs Meeting closure