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THE PRESENT AND POTENTIAL USE OF CLIMATE INFORMATION BY THE UNITED STATES PRIVATE AGRICULTURAL SECTOR

By

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Final Report
NSF ATM 81-16615

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TABLE OF CONTENTS

ABSTRACT

This study seeks to identify the climate information uses and needs of agribusiness decision makers in the United States. It was conducted in three phases: (1) a nationwide mail questionnaire survey for which usable responses were obtained from 107 individuals involved in nine types of agribusiness activity; (2) a two-day Workshop at which the primary participants were 14 of the questionnaire survey respondents; and (3) individual day-long post-Workshop discussions with several of the Workshop attendees. Four types of climate information are considered (historical data, year-to-date accumulations, now-only conditions, climate predictions).

Climate information is currently being extensively used by agribusiness decision makers. This usage has increased substantially in recent years, and occurs in (1) the design and planning of ongoing and future operations, (2) the monitoring of in-season conditions, and (3) the model-based prediction of crop yields. It is particularly characteristic of integrated pest management consultants, the grain trade, the seed production and food processing industries, and professional farm managers, and involves a relatively wide range of meteorological parameters. This situation is probably little recognized by the atmospheric science community. Its implications for the United States National Climate Program, the World Climate Programme, agribusiness, and the provision of climate services are discussed.

The present non-use of climate information is found to stem from reservations about the availability, utility, cost, value, and (in the case of climate predictions only) accuracy of that material. In order to remove those impediments it will be necessary to mount substantial initiatives in the areas, of data acquisition/assembly, scientific research, information generation and dissemination, and user education. An in-depth consideration of these needs is presented. It includes an assessment of the most appropriate roles for federal and state government agencies, universities, private meteorological companies, and agribusiness itself. The potential exists for a substantial and profitable increase in the utilization of climate information by the private agricultural sector.

ACKNOWLEDGMENTS

This study originated from a December 1980 discussion with Dr. Alan D. Hecht, who was then Director of the National Science Foundation's (NSF) Climate Dynamics Research Program, about the need for interdisciplinary research in the "climate impacts" area. Most of the financial support for the effort was subsequently provided by the aforementioned NSF Program (NSF Grant ATM 81-16615). Dr. Hecht's continued interest in and encouragement of this research after his transfer to the Directorship of the National Climate Program Office (National Oceanic and Atmospheric Administration) is much appreciated, as is the like support given by his NSF successors, Drs. Kenneth H. Bergman and Hassan Virji.

Important additional funding was provided by three agribusiness concerns (Crop-Hail Insurance Actuarial Association, Growmark, Country Companies), the United States Department of Agriculture (World Agricultural Outlook Board), and the State of Illinois. We are particularly grateful for the support and encouragement offered by the following representatives of those organizations: E. Ray Fosse, Leonard Gardner, and Dr. Norton D. Strommen. In addition, we thank Workshop participants Dr. Don Collins (Monsanto), Gail Martell (E. F. Hutton), Lynn Murray (Stokely-Van Camp), Bill Nelson (Control Data), and Doris Sincox (Continental Grain) for continuing to educate us about the the private agricultural sector. Grateful acknowledgment is also made of the valuable Workshop rapporteuring performed by Drs. Phil Garcia and Wayne Wendland and the considerable support work undertaken by Steve Hilberg, Phyllis Stone, Rebecca Runge, and Joyce Cain.

During 1983 we took advantage of the opportunity to make conference and seminar presentations on this research in locations as disparate as Tallahassee (Florida), Fort Collins (Colorado), Washington (D.C.), Rockville (Maryland), Alcabadiche (Portugal), Norwich (England), Oxford (England), and Hot Springs (Arkansas). The reactions, advice, and encouragement of these varied audiences helped us identify the strengths and weaknesses of our effort, and contributed substantially to the shaping of this report.

1. INTRODUCTION

One of the more striking science policy developments of the past decade has been the formulation and partial implementation of large, ambitious, multifaceted "climate programs" at both the national and international levels.

The United States National Climate Program (USNP), for instance, was established by an Act of Congress (September 1978, PL 95-367) to "assist the Nation and the world to understand and respond to natural and man-induced climate processes and their implications" (Section 3), following legislative deliberations during 1975-78. It has three components (National Oceanic and Atmospheric Administration, 1980). A *Climate Impact Assessment* effort is seeking to identify "procedures to evaluate climate's effects on society, the economy, and the environment in order to develop responses and strategies for dealing with climate fluctuations" (National Oceanic and Atmospheric Administration, 1980, p. E-4). *Climate System Research* will attempt to increase the knowledge of global and regional climate and its variation by means of a range of empirical studies and analyses of the climate record, the development of climate simulation and prediction models, and the investigation of climate system processes (e.g., solar and terrestrial radiation, ocean heat storage and transport). The *Data, Information, and Services* component is designed to provide accurate and timely data and information products, and be responsive to Government and private sector needs.

The USNCP is just one of several emerging national programs that are intended to be consistent with a larger World Climate Programme (WCP). The latter was formally established during 1979 by agreement among the World Meteorological Organization, the United Nations Environment Program, the

International Council of Scientific Unions, and the Intergovernmental Oceanographic Commission. It will span the two decades 1980-2000, contains subprograms that parallel the components of the USNCP, and is intended to accelerate progress by serving as a catalyst rather than by providing direct support (World Meteorological Organization, 1979, pp. vii, 709-758). The latter role will involve assisting developing countries to build modern data acquisition and application systems, fostering international cooperation when it is a necessary pre-requisite for research progress (e.g., on the CO- question and ocean heat storage/transport), and other similar activities.

The relatively sudden emergence of these programs is in marked contrast to the situation in the 1950s and 1960s when there was little interest in climate, its vagaries, or their effects. The programs are a response to both the climate system providing an abundance of striking weather extremes and climatic fluctuations during the last 15 years and the wide publicity given to the adverse socioeconomic effects of those episodes by the ever-increasing capabilities of the news media (e.g., White, 1982). In particular, the Sahel drought and consequent famine of the early 1970s forced governmental and scientific communities, on an international level, to recognize that climate does vary on short time-scales and that such variations can have disastrous human consequences. This new awareness has been increasingly reinforced as the 1970s and 1980s have progressed by other pronounced climatic fluctuations and their adverse impacts — the 1976 heatwave, drought, and water shortages in Western Europe; pronounced extremes in Indian monsoon rainfall and their associated flooding and famine; four recent very severe United States winters, including one whose excessive snowfall crippled the Chicago transportation system for many weeks; recurrent poor growing seasons in the Soviet Union; the

1980 central United States heatwave and drought that greatly reduced crop production; and so on. For the United States, the appreciation of climate's central role in human affairs was hastened by the serious economic repercussions of the 1972-73 and 1975 grain sales to the Soviet Union that were at least partly occasioned by that nation's aforementioned climate-induced crop failures (National Oceanic and Atmospheric Administration, 1980, p. E-1).

It is thus very clear that developing climate programs such as the USNCP and the WCP have been conceived and designed to broadly benefit mankind by reducing (enhancing) the adverse (beneficial) socioeconomic consequences of climatic variability, rather than to foster narrow basic research (e.g., see White, 1982). This is why they are dominated by the likes of climate impact assessment, data acquisition and applications, and the provision of information and services; the climate system research they do include would very probably have been supported and pursued, for reasons of scientific curiosity, without the creation of the programs. In fact, it seems fair to assert that the existence of these elaborate, ambitious, and expensive programs is based on the assumption that a substantial reduction (enhancement) of the unfavorable (beneficial) effects of climatic variability is attainable. Whether this is the case has never really been demonstrated, as is clearly acknowledged by the twin program objectives for the USNCP Climate Impact Assessment effort that were quoted above. There is no doubt that the second of these goals (the development of "responses and strategies for dealing with climatic fluctuations") will be much more difficult to achieve than its necessary forerunner (the identification of "procedures to evaluate climate's effects on society, the economy, and the environment").

Our contention is thus that the management strategies necessary to substantially reduce (increase) the unfavorable (advantageous) socioeconomic consequences of climatic variation are presently largely unknown. If this assessment is correct, the aforementioned climate programs constitute something of a risk. However, we believe that this risk is justified, and indeed that the emergence of the climate programs from the public interest generated by the recent climatic vagaries and their impacts (White, 1982) is a desirable development that offers considerable potential and challenge for a broad range of specialists (e.g., atmospheric, agricultural, and social scientists, and economists). Clearly, atmospheric scientists will need the assistance of these other people in tackling the above problem area. However, the other side of the coin is that an inadequate response to this situation will be to the considerable detriment of the atmospheric sciences' reputation among the wider scientific and governmental communities for its ability to "deliver". The fact that early optimism relating to weather modification (e.g., Changnon, 1975, 1980) and numerical weather prediction (e.g., White, 1982) has so far not been anywhere near matched by actual achievement underlines the atmospheric sciences' need for the climate programs to be at least modestly successful. In contrast, since social and agricultural scientists and economists did not initiate the climate programs, they presumably have little to lose (and much to gain) from being actively involved in these endeavors.

The foregoing discussion has the important implication that, in order for the climate programs to ultimately reduce (enhance) the adverse (favorable) socioeconomic effects of climatic variability and hence come to be regarded as successful, considerable *initial* effort must be devoted to understanding the *climate information needs* of decision makers (National Research Council, 1981). It is only from this foundation — one of the appropriate knowledge — that the required management strategies can be developed and deployed. The study reported here sought to identify such information needs for one important group of economic activities — those constituting to the United States private agricultural sector. Climatic variability probably affects agriculture more than any other broad economic sector (e.g., National Research Council, 1976, p. 3; 1982, p. 7). In recognition of the aforementioned need for this type of work to be interdisciplinary, the present project was a fully collaborative undertaking between two atmospheric scientists and an agricultural economist.

2. THE UNITED STATES PRIVATE AGRICULTURAL SECTOR: BACKGROUND AND PRESENT INVESTIGATION

a. Background

While climatic fluctuations impact all economic sectors to some degree, as indicated above the production of food and fiber is perhaps *the* activity most sensitive to these vagaries of Nature (e.g., National Research Council, 1976, p. 3; 1982, p. 7). Most of the recent pronounced climatic variations listed in the preceding section, for instance, substantially reduced agricultural outputs. In view of this situation, one of the better starting points for the investigation of the extent to which the adverse (beneficial) socioeconomic consequences of climatic variability could be reduced (enhanced) is the consideration of the World's most productive agricultural system — that of the United States, and particularly its midwestern heart.

This agricultural system consists not only of the actual producer (grower, farmer, rancher), but also of the large and complex support structure that has evolved to serve the producer. Such a support structure includes the development, production, and distribution of seeds, fertilizers, pesticides, and farm machinery; the provision of rural insurance, financial, farm management, and integrated pest management services; the food processing and brokerage industries; the grain trade; and several other activities. This combination of the producer and the non-farm firms that support the producer constitutes the private agricultural (or "agribusiness") sector. The present inquiry deals with this entire sector. In contrast, there may be a tendency among those people who have little contact with agriculture (e.g., most atmospheric scientists) to equate this sector solely with the producer. In this vein, a well known recent National Research Council inquiry into the use of weather information by United States agriculture was limited to on-farm decision making (National Research Council, 1980a).

There are several reasons why study of the climate information needs of the United States private agricultural sector is expected to be particularly instructive in the above regard. The first relates simply to the size of this sector and its importance to the United States and World economies (National Research Council, 1980b, p. 54; National Defense University, 1983, p. v). The value of the nation's agricultural production in 1981 was $167 billion (United States Department of Agriculture, 1982a). In that same year, the sales by input suppliers to agricultural producers probably totalled around $40-45 billion (Midwest Association of State Departments of Agriculture, 1981), while agricultural exports earned $43 billion (United States Department of Agriculture, 1982b). Such exports typically include approximately 72 percent (45 percent) of the World's total corn (wheat) exports (Cramer and Heid, 1983, chapter 2). The counterpart fraction for soybean meal-equivalent is about 73 percent (Sisson, 1981). Despite its great importance, the sector can be severely impacted by climatic fluctuations, as the enormous crop yield fluctuations of 1979-83 readily attest. Improvements to its efficiency would therefore substantially benefit the consumer of food and fiber both in the United States and throughout the World.

The second reason to investigate this sector stems from its very nature. This overwhelmingly private enterprise (and hence initiative-rewarding) endeavor is endowed with highly fertile soil, generally abundant moisture, the finest available scientific and technological support in the fields of plant breeding, chemical development, pest management, and machinery design, and educated operators who function within the motivating (or perish!) environment of the "farm firm". If the present level of use of climate information by this highly developed sector could be clearly established, and the benefits ascertained, that knowledge would provide incentives and guidelines for the adoption or increased utilization of such practices by less developed agricultural systems. The latter is a goal of the World Climate Programme (WCP). In addition, the aforementioned attributes of the United States private agricultural sector suggest that it may possess the considerable structural and human flexibility that is necessary to provide an agricultural demonstration of the ultimate potential for improved management strategies to reduce (enhance) the unfavorable (beneficial) socioeconomic effects of climatic variation.

The diversity and complexity of this sector provide further incentive for its study in the present context. Because of the differing size and function of the sector's firms, the characteristics of the climate information needed by agribusiness are likely to be quite varied. This hypothesis is offered despite the fact that, for a given commodity, the climatic vagaries which have the greatest effect on production are the same whether the climate information user is an input (e.g., pesticide) supplier, a producer, or an output processor (e.g., food canner). What is likely to vary substantially across the sector, in contrast, is the type of climate information needed, the times at which such material is required, and the decision maker's ability to interpret and use individual information items. This likelihood that the specific characteristics of the climate information needed by each component of the sector could be relatively unique is rather significant, for it offers an opportunity to assess the potential scope and complexity of the general problem of providing appropriate data and information products to the private sector. As was indicated in the Introduction, the latter task is an important. component of the United States National Climate Program (USNCP).

The final reason that this study deals exclusively with the United States private agricultural sector is that this sector has been surprisingly neglected in, and hence had little or no input to, the development of the USNCP. For example, it was not represented at either of the following meetings that were an important part of this development process: (1) the April 1980 "Workshop on the Methodology of Economic Impact Analysis for Climatic Changes" that was sponsored by Resources for the Future (RFF) and the National Climate Program Office (NCPO) and had 43 participants (Resources for the Future, 1980; Smith, 1982), and (2) the June 1981 "Climate Users' Conference" of the Climate Analysis Center (CAC) that was part of the USNCP (National Oceanic and Atmospheric Administration, 1980, p. 25) and had 50 attendees (Climate Analysis Center, 1981). The agricultural perspectives/ positions/interests at these gatherings were instead taken care of solely by government (Federal and State) and academic economists and scientists, i.e., by people with no practical involvement in the United States agricultural system.

While this constitutes an undesirable situation, it may also be one that is understandable on at least two counts. First, atmospheric and other environmental scientists have hitherto shown little interest in the applied aspects of their broad disciplines that relate to agribusiness. This is evidenced by the fact that only ten percent of the papers (14 our of 141) presented at three recent and highly relevant American Meteorological Society meetings dealt with the private agricultural sector. Furthermore, this treatment generally lacked real depth. The meetings concerned were the August 1980

"Conference on Climatic Impacts and Societal Response" at Milwaukee (American Meteorological Society, 1980a), the San Diego "Symposium on the Economic and Social Value of Weather and Climate Information" during January 1981 (American Meteorological Society, 1980b), and the "Sixteenth Conference on Agriculture and Forest Meteorology" held in Fort Collins, Colorado, in April 1983 (American Meteorological Society, 1983). Even important interdisciplinary conferences/workshops on topics such as the likely environmental and societal consequences of climatic change (e.g., United States Department of Energy, 1980) and the use of climate information in decision making (e.g., Pocinki et al., 1980) have given scant attention to the climate information needs of the United States private agricultural sector, despite the latter's aforementioned importance for the global food supply.

The second probable reason for the neglect of this sector in the development of the USNCP is that its actual use (e.g., level, type, methods, etc.) of climate information has been little known to date. This seems to have stemmed from (i) the fact that the climate information suppliers to agribusiness are typically private meteorological consulting firms for whom report writing and conference participation are extremely low priorities; (ii) the obvious need for individual agribusiness concerns to protect their own operating procedures; and (iii) some agribusiness companies not having realized, or alternatively had the time/resources to exploit, the "gold mine" of information they have accumulated (e.g., many years of field trial and operations results obtained under different climatic conditions).

It therefore seems clear that the further shaping and implementation of the USNCP that must occur as the Program enters its critical second five years would benefit from increased exposure to and input from this nation's private agricultural sector. The research project reported here was conceived as an initial contribution to both this end and also the others listed above.

b. Objectives of the Study

As noted in the previous discussion, the motivating force for the recent initiation of several ambitious major climate programs was a belief that at least some of the adverse (favorable) socioeconomic effects of climatic variability can be reduced (enhanced) by means of an increased and improved use of climate information. Although the generation of this information is performed by atmospheric scientists and other specialists, these people are today seldom involved in the decisions relating to the information's actual utilization within a particular economic sector. Those decisions tend to be made by the professionals in the sector concerned, and are influenced by a variety of economic, political, and social forces, in addition to climatic considerations. This situation is unlikely to change very rapidly.

The present study therefore focuses on the United States agribusiness decision maker with the fundamental goal of obtaining an understanding of the factors that determine his use of climate information. It has the following three specific objectives in that regard:

(1) To describe the present level, types, and methods of use of climate information by this sector.

(2) To identify the potentials for and impediments to a fuller use of climate information in the future.

(3) To specify the scientific *research* and data acquisition/ information dissemination *development* thrusts that are necessary before the level of present use can be increased to the maximum that would seem possible, and which would therefore help decision makers reduce the unfavorable effects of climate fluctuations.

c. Components of the Study

This project was conducted in three distinct phases. The first involved a nationwide mail questionnaire survey of agribusiness decision makers. Usable responses were obtained from 107 individuals. The second phase was an intensive two-day Workshop at which the primary participants were 14 of the respondents to the mail survey. Those people were selected because they were already users of climate information and had indicated an advanced interest in this topic in their questionnaire responses. The third phase of our effort has consisted of individual day-long post-Workshop discussions with several of these Workshop attendees.

(i) *Questionnaire survey*

This was administered in the spring of 1982, and its results were analyzed during the rest of that year. It focused strongly on the present use of climate information, with historical data, year-to-date accumulations, and climate prediction (defined in Section 2d) being treated separately. A copy of the 7 page survey instrument appears as Appendix A of this report. The survey was designed by the agricultural economist among us (S. Sonka), and underwent developmental testing within the College of Agriculture at the University of Illinois. It was sent to 125 agribusiness decision makers after they had consented over the telephone to participate in the survey. Where necessary, further telephone contact was used to ensure the return of a completed questionnaire form. This time-consuming procedure proved worthwhile, since it produced an extremely high (86%) response rate — 107 usable responses were obtained. Table 1 indicates the components of the private agricultural sector that were represented in the survey responses, and also

Table 1. Components of private agricultural sector considered in questionnaire survey and number of respondents from each component.

Component	Number of respondents
Agricultural chemical manufacturers	5
Agricultural finance companies	12
Food processing/canning industry	8
Grain trade (merchandisers, brokers, consultants)	19
Integrated pest management consultants	12
Producers	27
Professional farm managers	13
Rural insurance industry	6
Seed production companies	5
TOTAL =	107

the degree of their representation. This background information is extended in Appendix B, which details the title, company, and location of each respondent. That material documents both the generally nationwide character of the survey (to which the producers were an exception, for reasons given below) and the types of professionals from whom we sought information. The latter is important because the information obtained from a given company may not be independent of the role (e.g., marketing versus product development) of the respondent. We were fully cognizant of this issue when identifying potential respondents (see below). Appendix B may also provide useful contacts for other researchers wishing to pursue this and related subjects.

The components of the private agricultural sector identified in Table 1 have vastly differing characteristics. They represent industries as diverse as farm production, with its several million individual operators, and grain merchandising and pesticide manufacture, which are dominated by a relatively small number of multinational companies. In some cases, such as integrated pest management, the industry is very new and the definition of its population is accordingly difficult. For this reason, and also because of the extremely large size of the private agricultural sector, no attempt was made to conduct a fully comprehensive statistical survey. Instead, the role of the questionnaire survey in the total effort (which itself was of an exploratory nature) was to obtain both background knowledge on the present use of climate information and also some initial insight into the potentials for/impediments to a fuller utilization of this material in the future. This information was sought to provide a starting point for the in-depth and more specific investigation of the same topics at the subsequent Workshop.

The names of potential questionnaire survey respondents were assembled using what may be best termed an "informed judgement" approach. For each component of the sector specified in Table 1, a key individual was identified and asked to name those persons whose present positions and performances qualified them to provide the information we sought. These key "nominating" individuals were chosen by the authors (with agricultural economist Sonka providing most of the input) because of either their prominence as agribusiness leaders (e.g., in trade associations) or, in the case of the production component, their role in the Cooperative Extension Service. The non-production nominators, who also consented to participate in the survey themselves, tended to name people from among their peers in other companies. The Extension Agents were asked to nominate producers they considered to be among the most innovative of the many with whom they had contact. In addition, we were able to usefully supplement the list of potential survey respondents developed in this way from our own bank of prior contacts in this sector.

As already implied, a strong effort was made to obtain survey responses from most parts of the nation. For some of the agribusiness components investigated, this goal was made more attainable by the fact that many of the respondents work for national and multinational concerns (Appendix B). Their responses therefore inherently reflected an exposure to the agribusiness practices of a broad geographical area. The very large and extremely diverse production component was an exception to this desired nationwide character of the survey. In order to make its treatment both manageable and (we hoped) informative, respondents were sought from only two, but highly contrasting, regions. These were the unirrigated portions of the humid Upper Midwest and the much drier West Texas. The Midwest respondents were overwhelmingly Illinois cash grain producers, while those from Texas raised cotton and beef (Appendix B). Irrigated production was excluded from the survey because most of the humid Upper Midwest, the nation's premier crop producing region and therefore one we wished to consider, does not usually need or presently utilize irrigation (cf. Great Plains). Since the availability of irrigation as a management tool could be expected to alter an operator's use of climate information, it seemed undesirable to include both irrigated and unirrigated production in this investigation. This situation required that the second and contrasting production system studied also be unirrigated, and Texas dryland farming appeared to have considered potential in this regard. Unfortunately, however, both.the quantity (Appendix B) and quality of the responses obtained from this region were unusually disappointing.

In summary, we believe that the size and scope of the questionnaire survey were adequate for the task at hand.

(ii) *Workshop*

The second phase of our study took place at an intensive two-day Workshop in Door County, Wisconsin, during August 1982. Although this included some further inquiry into the present use of climate information, it was primarily concerned with the second and third of the objectives given above. It was dominated by in-depth considerations of (a) the potentials for and impediments to a fuller use of climate information by agribusiness in the future and (b) the scientific research and data acquisition/information dissemination development thrusts that are necessary before the level of present utilization can be increased to the maximum that would seem possible. The Workshop thus sought to exploit and build on the foundation of the knowledge about the agribusiness use of climate information that was acquired from the earlier questionnaire survey.

The primary Workshop participants were 14 of the 107 questionnaire respondents; one or two of the latter were chosen to represent each component of the private agricultural sector listed in Table 1. They were selected because their questionnaire responses exhibited both an interest in the issue of improved climate information availability and the insight needed to anticipate possible future needs and opportunities in that regard. These people provided the high quality input to the Workshop discussions for which we had hoped. Other Workshop attendees included three people from Federal agencies (United States Department of Agriculture [USDA], National Science Foundation [NSF], National Climate Program Office [NCPO]), a market analyst from the Illinois Agricultural Association (IAA, i.e., the Farm Bureau), and five Illinois State Water Survey/University of Illinois personnel. The NSF, USDA, and IAA participants were representatives of some of the financial sponsors of the project (all sponsors are cited in the Acknowledgments, p. vi, and in Appendix C, p. 134); the NCPO person's attendance was invited because of the study's relevance to that program, as already outlined.

A complete list of the Workshop attendees, along with a copy of the agenda that was followed, appear as Appendix C of this report. For each of the Workshop's three Group Discussions, the participants were divided into the same three groups of seven individuals. Each group included five agribusiness personnel from different components of the sector (one of whom acted as group leader and gave oral summary reports to the entire group at the end of each Discussion Session), one Federal government representative who provided most valuable input from his perspective, and one Illinois person who steered and formally rapporteured the discussions. The two remaining Illinois participants, who later became the senior authors of this report, directed the entire Workshop. In this role they provided introductory "lectures", chaired Plenary Sessions, and observed as much of the Group Discussions as possible (Appendix C). For the purpose of these Group Discussions, the participants from the USDA's Federal Crop Insurance Corporation (FCIC) and the IAA were considered to be from the private sector. This was prompted by the IAA being an advisor to private sector clients and the FCIC's substantial interaction with private insurance companies. Because of the latter circumstance, the FCIC representative had anyhow been one of the questionnaire respondents.

(iii) *Post-Workshop discussions*

The third phase of the project consisted of post-Workshop discussions with several of the Workshop participants from the private sector. These were conducted on an individual (as opposed to group) basis, were generally daylong, and occurred at both the Illinois State Water Survey and private company locations. The discussions have concentrated particularly on the third of the objectives listed earlier — the specification of the scientific research and data acquisition/information dissemination development thrusts that are necessary before the level of present use of climate information by this sector can be increased to the maximum that would seem possible. The agribusiness personnel involved in these discussions were chosen because of the potential importance of climate information to their (generally large) companies, and because their contributions to the earlier Workshop discussions suggested they could be of further help in the above regard. This interaction proved to be most beneficial.

d. Types of Climate Information Treated

Four types of climate information are considered in this investigation. The questionnaire survey dealt with three of these — historical data, year-to-date accumulations, and climate predictions. These information categories were also treated at the Workshop, along with the fourth type (now-only conditions). Our use of the term "climate information" thus includes climate data, a practice that has not always been followed recently (e.g., National Research Council, 1981, p. 2; 1982, p. 4). The contrasting nature of these climate information types needs to be clearly established before the results can be discussed in detail and appreciated fully.

The term *historical data* refers to the very large bank of all instrumental measurements (e.g., of temperature and precipitation) made since the inception of such observations, which was between 30 and 100 years ago at many locations in the United States. These point data are available as averages (e.g., of temperature) and totals (e.g., of precipitation) for individual years, seasons, months, and shorter time periods, and can also yield important information on the past variability of climate (e.g., frequency of occurrence of extreme daily and monthly values). It is from these data that the well known standard climatic "normals" (i.e., monthly means for the most recent three-decadal period, currently 1951-80) are computed, and from which alternative shorter-period normals (e.g., Lamb and Changnon, 1981) and a wide range of other information, including some that is highly user-specific, can readily be obtained.

Year-to-date accumulations , on the other hand, consist of summations of the daily values of actual weather parameters (e.g., precipitation) and derived quantities (e.g., growing degree days, which are obtained from temperature records) through any point in a given year. While such accumulations are generally made and used in a real-time operational mode (or something close to it) for the present year, this use could reasonably involve the comparison with counterpart values for earlier years or averages for longer periods (e.g., the 1951-80 normal). The latter would of course be derived from the bank of historical data discussed above. Year-to-date accumulations thus provide integral-type measures of relevant aspects of the climate of a given year; they contribute, usually on a collective rather than individual basis, to agriculturally important *now-only* conditions such as (for the Midwest) late-April soil temperature and mid-July soil moisture. For the case of mid-July soil moisture, the more important controlling factors include year-to-date precipitation (the moisture input) and year-to-date solar radiation, growing degree days, and wind run (all of which influence the drying of soil). A subtle difference therefore exists between year-to-date accumulations and now-only conditions. The latter will not be treated until chapter 4, whereas the other climate information types are considered in both chapters 3 and 4.

A *climate prediction* is a statement of the expected general character of the weather for a period in the future whose length may be a part of a season (e.g., one or two months), a season, a year, a decade, or even longer. One month is the shortest period for which a climate prediction should be made. The present investigation is concerned only with the shorter-term climate predictions (those for one-month to one-year periods) that could potentially be incorporated into the decision making process relating to annual agricultural production. Longer-term climate predictions are much less likely to have such utility in the foreseeable future. The short-term predictions are generally only made for the mean temperature and total precipitation for the period concerned (the prediction period), and tend to be expressed in such extremely qualitative terms as "above normal", "near normal", "below normal", and "indeterminate" for temperature, where "normal" has the meaning given above, and "heavy", "moderate", and "light" for precipitation. A prediction period (e.g., July-August) can be somewhat ahead of the date the prediction is issued (e.g., 1 May). This time difference is termed the "lead time" of the prediction. While longer lead times (e.g., 3-6 months) presumably offer the greatest potential for the use of short-term climate predictions as planning instruments, this is presently offset by such predictions being less reliable than those with shorter lead times. Short-term climate predictions are in pronounced contrast to the short-period weather forecasts for up to 1-2 days into the future with which most people are so familiar. The latter have lead times of only 0-1 day, and cover a wider range of parameters in a much more quantitative manner (e.g., daily maximum and minimum temperatures, probability of occurrence of precipitation, wind speed and direction, sky cover, etc.). It is unlikely that such detail will ever appear in short-term climate predictions.

3. RESULTS OF QUESTIONNAIRE SURVEY

a. Background

The questionnaire survey constituted the means by which the overall project was launched,, and by which we began to acquire information. Since previous work in this field was meager, we started from a position of near-zero knowledge for which there was minimal available guidance. The role of the questionnaire survey was therefore to provide background knowledge — but in a quantitative way — on the present general use of climate information by the United States private agricultural sector. It was intended to form the foundation for the subsequent and more specific components of the study that were identified above. The first results presented accordingly summarize the valuable information obtained from the analysis of the questionnaire survey responses.

b. Extent of Use

The questionnaire respondents were first asked whether or not they/their company utilized any of the three types of climate information under consideration (Appendix A). Probably the most important single finding of the entire survey is that climate information is now being extensively used by agribusiness decision makers in the United States. This situation is documented in Tables 2-8, in which historical data, year-to-date accumulations, and climate predictions are treated separately. Table 2 indicates that almost three-quarters of the respondents use historical precipitation data, and that nearly as many use historical temperature records. A lesser fraction, but still a majority, use year-to-date accumulations and climate predictions. The

Table 2. Summary of extent of present use of climate information by entire private agricultural sector.

Type of climate information	Percent of respondents who use each type of information	
	Precipitation	Temperature
Historical climate data	74	70
Year-to-date accumulations	64	51
Climate predictions	64	60

aggregation of the results across the entire private agricultural sector in Table 2, while providing an informative starting point for this discussion, masks the considerable and highly important intrasectoral variation in the use of climate information. This variation is fully revealed in Tables 3-8.

(i) *Historical climate data*

From Table 3, for example, it is readily seen that producers, agricultural finance companies, and the rural insurance industry are relatively low users of both historical temperature and historical precipitation data. At the other extreme, pest management consultants, the chemical, seed, and grain industries, and (to a lesser degree) farm managers, utilize this type of climate information to a very considerable extent. The types of specific use involved are summarized in Table 4. This information is offered primarily as background material at the present time, and is little discussed in this chapter. The specific uses of all types of climate information were investigated more fully at the Workshop, and are accordingly treated in greatest detail in the next chapter. A perusal of Table 4, however, quickly shows that the agribusiness use of historical climate data largely occurs in a pre-season planning-type mode.

Interestingly, the canning industry results in Table 3 do not fall into either of the above two extreme categories. While they indicate a very substantial use of historical temperature data on the one hand, they also suggest that this component of the private agricultural sector has a somewhat weaker current interest in the historical precipitation records. This industry's response to our inquiry about the types of specific decisions that are influenced by historical climate data (Table 4) sheds some light on the foregoing

Table 3. Intrasectoral variation in extent of use of historical climate data.

Component of sector (number of respondents in parenthesis)	Percent of respondents who use this type of information: Precipitation	Temperature
Agricultural chemical manufacturers (5)	100	100
Agricultural finance companies (12)	50	25
Food processing/canning industry (8)	63	88
Grain trade (19)	100	95
Integrated pest management consultants (12)	100	100
Producers (27)	44	37
Professional farm managers (13)	85	77
Rural insurance industry (6)	67	50
Seed production companies (5)	100	80
Average for entire sector (107) (from Table 2)	74	70

Table 4. Intrasectoral variation in types of specific use of historical climate data, as revealed by responses to question 3 of Quest lonnai re Survey (Appendix A). This question did not seek an explicit differentiation between the uses of precipitation and temperature data. The table is simply a listing, and makes no attempt to indicate how frequently a particular use was cited.

Component of sector	Types of specific use
Agricultural chemical manufacturers	Design of application instructions on product labels; *a posteriori* defense of alleged product liability; ore-season location and post-season evaluation of product trials; development of marketing strategies; study of pesticide residues in soil.
Agricultural finance companies	Derivation of basis of loan volume predictions (from duly and August rainfall); establishment of framework for feedlot performance projections (temperature).
Food processing/canning industry	Pre-season general decisions relating to the location, planning, and scheduling of contract production from planting to harvesting; assessment of snimg and autumn frost risks.
Grain trade	Development of basis of analog approach to crop yield estimation (identifies and uses earlier years with similar climate to present year); construction and refinement of quant i tative crop yield models; analysis of supply-demand relationships, development of general marketing, trading, jnd hedging strategies and recommendations (including aforementioned analog method); quantification of effects of past extreme climatic fluctuations.
Integrated nest management consultants	Pre-season general recommendations of crop planting dates and densities and hybrid selections; estimation of timing/length of pol l inat ion periods at planting; general planning of scouting for insect presence/damage and probable pesticide and herbicide application schedules; pre-season decisions on fertility goals and fertilizer type and application rate; scheduling of autumn application of nitrogen fertilizer; planning of consultants' own field activities.
Producers	Pre-season general planning of planting schedules and herbicide applications; anticipation of timing of possible insect infestations (degree-day correlation); planting-time projection of first autumn freeze; estimation of harvest dates and final yields.
rofessional faim managers	Pre-season consideration of crop and variety options; preliminary estimation of planting and harvesting times and plant populations; assessment of in-season climatic risk probabilities, and probable pest control and land requi rements; general scheduling of borrowing/investing, land purchases, and commodity marketing.
Kural insurance industry	Promulgation and verification of rates; analyzing prior yield fluctuations; claim analysis for past years.
Seed production companies	Pre-season choice of seed production areas; calculation of likely hybrid maturity times for those areas; general crop planning for coming season — estimation of probable planting dates, desirable plant population levels, autumn freeze likelihoods, and facilities needed to harvest seed crop.

discrepancy, even though our question failed to seek an explicit differentiation between the uses of temperature and precipitation information. We found that historical climate data are primarily used by canning companies in their pre-season location and planning (as opposed to in-season direction) of contract production. Since these pre-season activities involve decisions that are obviously strongly thermally influenced — site selection, expected planting and harvesting dates, assessment of spring and fall frost risk, and the choice of seed variety that is contingent upon all of the foregoing — it is probably not surprising that the canning industry makes a greater explicit use of historical temperature data than the latter's precipitation counterparts. However, it seems likely that some historical type precipitation information is *implicity* "factored" into this decision making, at least to the extent that particular crops (or varieties of crops) are grown in only those areas for which the decision maker's experience suggests the moisture supply is usually adequate. This feeling is reinforced by the fact that the seed production companies, which evidently use historical climate data in a very similar manner to the canning industry (Table 4), reported a much greater dependence on this type of precipitation information (Table 3). Furthermore, it is distinctly possible that some research will be needed before the potential utility of historical precipitation data can be fully appreciated by the canning industry (see chapter 5).

A particularly striking feature of Table 3 is its suggestion that the use of historical climate data is much more extensive among farm managers than producers. This result is probably rather surprising, at least on the surface, given that these two groups have production and marketing decisions that should be quite similar. The latter belief is supported by the fact that our probing of the specific uses of historical climate data (Table 4) yielded very similar results for farm managers and producers. These uses are dominated by the pre-season planning decisions relating to crop and variety selection, the estimation of likely planting, pollination, and harvesting times and desirable planting densities, the assessment of in-season climatic risk probabilities and likely pest control and land (e.g., to work, rent, etc.) requirements, and the scheduling of financial borrowing/investing, land purchases, and commodity marketing.

The substantially greater use of historical climate data in this context by farm managers than producers probably results from the scale and nature of their respective operations. Since farm managers tend to direct the operation of several (or sometimes many) farms that can have quite disparate locations, they likely need to utilize historical climate data (among other information) to gain a full understanding of the production potentials and problems of the varied tracts of land under their control. The individual producer, on the other hand, should be quite familiar with his own land base, especially if he or his family has worked it for many years. In that case there would be little need for the producer to use historical climate data in the above manner, since he would have assimilated the climate history they contain into his own experience. A continuation of the current trend away from the relatively small family farm to larger production units that are professionally managed from remote locations, which seems highly likely (Schertz, 1979), will therefore very probably be accompanied by an increased need for/use of historical climate data. The implications of this situation are considered in chapter 5.

(ii) *Yeav-to-date accumulations*

Table 5 documents the intrasectoral variation in the extent of use of year-to-date accumulations, a climate information type that Table 2 suggested is on the whole somewhat less exploited (especially in the case of temperature) than the historical climate data considered above. The variation evident in Table 5 is at least as pronounced as, and in many cases very similar to, that found characteristic of the use of historical data (Table 3). However, the extent of use results for these two information categories include some interesting differences that are discussed below. For information on the types of specific use of year-to-date accumulations, reference is made to Table 6. This is patterned after Table 4's treatment of historical data and, like that display, is offered primarily as background material at the present time. As already indicated, the main discussion of the specific agribusiness uses of climate information occurs in the next chapter. For now, however, it should be pointed out that this sector's utilization of year-to-date accumulations largely occurs in an in-season operational-type mode (Table 6). The latter often builds on the pre-season planning that was found to depend strongly on historical climate data (Table A).

The heaviest users of both year-to-date rainfall and temperature accumulations are pest management consultants and the seed and canning industries (Table 5). All three of these components of the private agricultural sector are required to make production decisions during the growing season. Their monitoring of the evolution of the present year's climate through these accumulations apparently enables them to better anticipate the growth processes of the crops and the possibility of insect infestations (Table 6). While the seed industry year-to-date results in Table 5 are unchanged from those

Table 5. Intrasectoral variation in the extent of use of year-to-date accumulations. Note that a very small number of respondents did not supply this information (cf. Table 1).

Component of sector (number of respondents for each parameter in parenthesis)	Percent of respondents who use this type of information	
	Precipitation	Temperature
Agricultural chemical manufacturers (5)	40	40
Agricultural finance companies (12)	50	25
Food processing/canning industry (8)	75	88
Grain trade (19/16)	74	50
Integrated pest management consultants (9/11)	88	91
Producers (27)	52	33
Professional farm managers (13)	85	69
Rural insurance industry (6/5)	17	0
Seed production companies (5)	100	80
Average for entire sector (104/102) (from Table 2)	64	51

Table 6. IntTasectoral variation in types of specific use of year-to-date accumulations, as revealed by responses to question 16 of Questionnaire Survey (Appendix A). This question did not seek an explicit differentiation between the uses of precipitation and temperature accumulations. The table is simply a listing, and makes no attempt to indicate how frequently a particular use was cited.

Component of sector	Types of specific use
Agricultural chemical manufacturers	Final decisions on planting options (crop, variety) and in-season decisions on pesticide applications for product trials; following in-season performance of product trials; field research testing; study of pesticide residues in soil.
Agricultural finance companies	Loan volume predictions (from July and August rainfall) and feedlot performance projections (from temperature) for present year.
Food processing/canning industry	Finalizing of planting schedules; in-season forecasting of insect control needs, spray dates, and likely harvesting times for specific crops and varieties.
Grain trade	Hre-season projection of subsoil moisture for next crop (autumn and winter) and in-season assessment of growing conditions (spring and summer); in-season estimation of likely crop production over wide areas and resultant crop prices and marketing patterns (especially timing of latter); assessment of possible future climato-induced crop and market conditions; development of current year marketing, hedging, inventory, and transportation decisions and strategies.
Integrated pest management consultants	Final decisions on crop planting dates, hybrid selection, and population rates; scheduling of in-season scouting for specific insect pests and development of predictions for outbreaks of their occurrence; timing of in-season applications of hoibicidos, insecticides, and supplemental fertilizers; in-season projections of crop development (including recovery from hail, wind, and frost damage), maturation and harvest times, and yield potentials; marketing and hedging advice; pesticide carry-over risk evaluations.
Producers	Final decisions on crop planting dates,-hybrid selection, and population rates; in-season projections of pollination periods, harvest times, crop yields, and marketing options; in-season assessment of likely timing of insect infestations; real-time decisions on livestock numbers and associated acquisition/shipping considerations.
Professional farm managers	Finalizing of crop and variety choices and planting times and densities; in-season scheduling of pesticide spraying; in-season projections of crop development, maturation and harvest times, and yield potentials; planning for subsequent crops; farm valuation and investment analyses; development of marketing strategies.
Rural insurance industry	In-season estimation of insurance losses; investment guidance.
Seed production companies	Final decision on planting date; in-season prediction of detasseling periods (corn); monitoring of crop progress and formulation of production decisions/recommendations; in-season prediction of effects of extremes (e.g., of high temperatures on pollination and of freeze damage on yields).

obtained for historical climate data (Table 3), and the pest management ones are also quite similar, a particularly interesting difference is apparent for the canning results. Whereas this industry's use of historical data (primarily for pre-season planning purposes, Table 4) was found to be much more extensive for temperature than precipitation (Table 3), that contrast is not nearly so characteristic of its utilization of year-to-date accumulations (Table 5). Once the growing season has commenced, the canning companies evidently find the guidance to production decision making (Table 6) offered by that year's cumulative precipitation to be almost as valuable as that provided by temperature-based accumulations such as growing degree days. This difference between the canning industry results in Tables 3 and 5 seems intuitively reasonable.

The other agribusiness activites that extensively utilize year-to-date accumulations are farm managing and grain merchandising (Table 5), both of which were also found to be heavy users of historical climate data (Table 3). In contrast to the latter situations, however, the utilization of year-to-date information is more widespread for precipitation than temperature, particularly in the grain trade. Since these users find year-to-date accumulations valuable when making in-season assessments of both the yield potentials of diverse areas and their market implications (Table 6), it is clear that growing season precipitation is perceived to be the most critical determinant of the likely production of major crops such as corn, soybeans, and wheat. While this belief probably holds true for most years, it is distinctly possible that a detailed analysis of the climate-crop interactions that occurred during the disastrous 1983 midwestern growing season (Illinois State Water Survey, 1984) will identify a more important role in this calamity for prolonged excessive temperature than for deficient moisture. Such a finding would provide a timely reminder to the above agribusiness activities of the need for full cognizance of temperature conditions in the present context. Table 5 also suggests that the use of year-to-date information by the grain trade is much less widespread than is true for historical climate data (Table 3). This difference is surprising and would seem to be to the disadvantage of that industry.

The same difference is even more characteristic of the chemical industry results in Tables 3 and 5. Whereas this component of the private agricultural sector is an exceptionally heavy user of historical climate data, its utilization of year-to-date accumulations is evidently rather restricted. This implies that chemical manufacturers are less concerned with making in-season adjustments to their field trials in response to the evolving climate (Table 6), than they are with both the pre-season planning of these trials and the post-season evaluation of product performance in relation to the overall growing season climate (Table 4). Such evaluations may involve the intercomparison of several years of trial/climate data, which in turn could well include the retrospective use of year-to-date accumulations. In this case, however, the year-to-date information would be drawn from the historical data bank. Since the chemical industry's interest in yield maximization is limited to the *future* contribution of its own products to that end, which is in strong contrast to the dominating real-time concern with yield maximization that is characteristic of most of the other activities being considered (Table 6), its foregoing use of year-to-date accumulations seems entirely rationale.

Table 5 indicates that producers, agricultural finance companies, and in particular the rural insurance industry are low users of year-to-date accumulations of both precipitation and temperature. These agribusiness activities were also found to make the least utilization of historical climate data (Table 3). However, while the producer and finance company year-to-date results in Table 5 essentially duplicate those obtained for historical data (save a somewhat lower use of year-to-date temperature accumulations), the insurance industry is shown to be much less dependent on year-to-date information than on historical data. In fact, Table 5 suggests that this industry makes little, if any, use of year-to-date temperature accumulations. At the present time, insurance companies clearly do very little in-season monitoring of their likely losses (Table 6) from this type of climate information. Such knowledge is instead largely acquired via field scouting of affected areas, the locations of which may be at least partly identified from now-only-type climate information (defined in Section 2d). However, the present trend towards "all-weather peril" insurance (as opposed to solely hail insurance) could make this industry more reliant on year-to-date information.

Finally, it should also be noted that the fact that producers make much less use of year-to-date accumulations than professional farm managers (Table 5) parallels the situation identified for historical climate data (Table 3). This difference presumably has at least partly the same origin as that suggested above for the historical data case. Whereas a remotely located farm manager probably needs formal year-to-date accumulations to make in-season production and marketing decisions (Table 6) for his disparate and possibly contrasting units, the on-site producer is much more likely to have assimilated the year's climate into his own experience and so not need such formal guidance for his decision making. In addition, economies of scale in information acquisition and interpretation may be working against the producers' use of this information type. Professional farm management concerns (along with seed and grain companies), being larger entities (Appendix B), can probably better justify the cost of acquiring this derived-type information and/or hiring specialists to perform (sometimes internally) the necessary data reduction and interpretation, than can individual producers. The aforementioned present trend towards larger production units that are professionally managed from remote locations (Schertz, 1979) implies that there will be an increased need for/use of year-to-date accumulations in the future. A similar projection was made above for the case of historical climate data. Furthermore, if the efficiency of food and fiber production by individual operators would be enhanced by their having improved access to year-to-date accumulations, there is a need for an infrastructure that will deliver an interpretive treatment of this derived information at reasonable costs. This situation is further considered in chapter 5.

(iii) *Climate predictions*

The intrasectoral variation in the extent of use of climate predictions is summarized in Table 7. This climate information type is on the whole exploited to about the same degree as the year-to-date accumulations just discussed, and somewhat less extensively than the historical data base considered earlier (Table 2). The variation evident in Table 7 includes both interesting similarities to and differences from that noted above for the two other types of climate information being considered (Tables 3 and 5). These will be discussed below. Table 7 is supplemented by Table 8, which summarizes the types of specific use of climate predictions by the private agricultural sector. The latter display is a companion to Tables 4 and 6, being offered primarily as background at this juncture. More in-depth discussions of climate predic-

Table 7. Intrasectoral variation in extent of use of climate predictions. Note that a very small number of respondents did not supply this information (cf. Table 1).

Component of sector (number of respondents for each parameter in parenthesis)	Percent of respondents who use this type of information	
	Precipitation	Temperature
Agricultural chemical manufacturers (5)	40	40
Agricultural finance companies (12)	33	25
Food processing/canning industry (7)	43	43
Grain trade (19/18)	89	89
Integrated pest management consultants (12/11)	75	73
Producers (27/25)	63	60
Professional farm managers (13/12)	77	67
Rural insurance industry (5)	60	60
Seed production companies (5)	40	40
Average for sector (105/100) (from Table 2)	64	60

Table 8. Intrasectoral variation in types of specific use of climate predictions, as revealed by responses to question 31 of Questionnaire Survey (Appendix A). This question did not seek an explicit differentiation between the uses of precipitation and temperature predictions. The table is simply a listing, and makes no attempt to indicate how frequently a particular use was cited.

Component of sector	Types of specific use
Agricultural chemical manufacturers	Estimation of potential sales and production requirements; capital investment considerations; general planning of field research; plant growth legulator applications.
Agricultural finance companies	Loan volume forecasting and general business planning; extension of credit (risk management) considerations.
Food processing/canning industry	Tentative general planning of planting, spraying, and harvesting schedules; harvest prediction.
Grain trade	Preliminary estimation of crop planting times and yields; marketing, hedging, inventory, and transportation decisions.
Integrated pest management consultants	Tentative general planning of crop production advice — crop/variety types and acreages, pesticides choices and application rates and timing, scheduling of particular field activities; preparation of marketing and hedging advice.
Producers	Tentative general planning and design of crop production activities such as cultivation, crop and variety mix selection, pesticide applications, and harvesting; estimation of labor requirements; preparation of marketing strategies.
Professional farm managers	Tentative general planning and design of crop production activities such as planting, crop and variety choices, pesticide applications, and harvesting; preliminary estimation of crop yields; planning of marketing strategies.
Rural insurance industry	listabl l.shing coverages and rates; investment planning; estimating likely insurance experience for coming season.
Seed production companies	Tentative general planning of planting, spraying, and harvesting schedules and strategies.

tion uses and needs appear in subsequent chapters. An inspection of Table 8, however, clearly reveals that the agribusiness use of climate predictions occurs in a tentative general planning type mode, both in and out of the actual growing season.

Climate predictions are utilized most extensively by the grain trade, pest management consultants, and farm managers (Table 7). All of these activities show a similar interest in both temperature and precipitation predictions, an interest that is apparently motivated by the need to plan production schedules (or, in the case of the grain trade, anticipate them) and develop marketing strategies (Table 8). While these components of the private agricultural sector were also heavy or relatively heavy users of historical climate data and year-to-date accumulations (Tables 3 and 5), the extent to which the grain trade exploits the availability of climate predictions (Table 7) contrasts somewhat with its dependence on those other types of climate information. This activity's use of climate predictions is more extensive than its recourse to year-to-date accumulations, and almost as widespread as its utilization of historical data. This finding, which is perhaps surprising, is particularly characteristic of the temperature results. It was not clearly detected for either farm managers or pest management consultants (Tables 3, 5, and 7).

Producers and the insurance industry utilize climate predictions to a moderate extent (Table 7). Both of these activities evidently consider this type of climate information to have a value equal to or greater than either historical data or year-to-date accumulations (cf. Tables 3, 5, and 7). The insurance industry's increased use of climate predictions, relative to its minimal exploitation of year-to-date accumulations, is especially marked.

This points to general planning being of some concern to insurance companies (Table 8), and perhaps more so than the monitoring of in-season developments (Table 6), at least to the extent that the latter is based on formal climate information (see earlier comment). The level of use of climate predictions by producers is closer to that of farm managers than was found characteristic of other information types. Since the specific uses involved are once again highly similar for these two groups — in this case the planning of production and marketing (Table 8) — the above difference may reflect that fact that (a) a climate prediction is less likely to be part of a producer's experience than the information contained in historical data and year-to-date accumulations and (b) climate predictions are more readily available and in an easier-to-use format (e.g., by subscribing to a small brochure published twice-monthly by the National Weather Service, and from many newspapers) than these other climate information types.

Perhaps the most striking feature of the climate prediction results in Table 7 is the rather limited use of this information type by the chemical, seed, and canning industries. In contrast, all of these activities were found to be very heavily dependent on historical data (Table 3), and only the chemical manufacturers do not make extensive recourse to year-to-date accumulations (Table 5). Clearly, these components of the private agricultural sector do not consider climate predictions to be particularly valuable to the general planning of their operations (Table 8). Given the extreme vulnerability of these operations to climatic fluctuations, it would seem that predictions of such vagaries, if considered to be in a usable format and of sufficient reliability, ought to be one of the more important management tools utilized by the foregoing industries. The fact that this is not the case (Table 7) suggests that climate predictions are poorly regarded on these (and possibly other) grounds. This hypothesis was therefore chosen for in-depth testing at the Workshop, the results and implications of which are fully reported in the next two chapters.

Finally, it should be noted that the use of climate predictions among agricultural finance companies is even less widespread than in the canning, chemical, and seed industries just considered (Table 7). The type of planning undertaken by finance companies, some of which is summarized in Table 8, is at present apparently not thought to greatly need or benefit from the available information on the likely future climate. This component of the private agricultural sector was also found to be a low user of historical data and year-to-date accumulations.

c. Some Characteristics of Uses

The questionnaire respondents who indicated that they/their company utilized climate information were asked several subsequent questions designed to reveal some of the characteristics of that use (see Appendix A). All three categories of climate information under consideration were treated similarly in this regard. The results are presented in Tables 4, 6, and 8-11.

(i) *Specificity of use*

This line of inquiry began with the issue of the specificity of the use of climate information. The respondents were first requested to indicate whether such material was utilized as general background information, or whether it was required for specific decisions, or both. Table 9 clearly

Table 9. Ceneral versus specific uses of climate information. Percent.of respondents utilizing climate information who also indicated they used it as general background (GB) and/or for specific decisions (SI)).

Component of sector (number of respondents for each information type in parenthesis)	Climate information type: Historical data		Year-to-date accumulations		Climate predictions	
	CB	SD	GB	SD	GB	SO
Agricultural chemical manufacturers (5.2,,2)	100	80	100	100	50	100
Agricultural finance companies (6,6,4)	100	17	100	17	100	50
Food processing/canning industry (7,7,3)	86	43	86	86	100	67
Cram trade (19,14,17)	100	53	100	43	100	53
Integrated pest management consultants (12,10,9)	100	75	90	90	100	67
Producers (12,14,17)	100	42	100	43	88	82
Professunonal farm managers (11,11,10)	100	64	100	55	90	80
Kural insurance industry (4,1,3)	75	100	100	100	100	100
Seed production companies (5,5,2)	100	00	100	60	100	50
Average for entire sector (81,70,67)	98	57	97	57	94	70

indicates that the need for guidance of a general background type is one motivation for almost all agribusiness users of climate information. This result varies little either across the sector or between information types. Indeed, it is not possible to identify with certainty either a minimum user or the least valuable information type for this mode of utilization. Interestingly, the exploitation of year-to-date accumulations and climate predictions as general background *among actual users* is essentially as great as that of historical data (Table 9), despite the opposite being true of the *overall* agribusiness recourse to these categories of information (Table 2).

Table 9 also indentifies the fraction of climate information users for whom this use occurs during the making of specific decisions. This mode of utilization is less prevalent than the general background one considered above. Only 57 percent of the users permit historical data and year-to-date accumulations to influence specific decisions, while 70 percent do likewise for climate predictions. It is perhaps surprising that climate predictions are exploited in this way by a higher percentage of users than make a counterpart recourse to the two other types of climate information.

The specific decision results in Table 9 contain much greater intrasectoral variation than those pertaining to the utilization of climate information as general background. The rural insurance industry, agricultural chemical manufacturers, and integrated pest management consultants make the greatest use of climate information during specific decision making, while agricultural finance companies are the least active in this regard. Although the remaining agribusiness activities are, on the average, only moderately dependent on climate information when making specific decisions, some clearly find one information type to be much more helpful in that context than the other types. Examples of information categories that are of particular specific decision value to individual components of the sector are year-to-date accumulations for the food canning industry and pest management consultants, and climate predictions for producers and professional farm managers (Table 9). The grain trade's relatively low incorporation of climate information into its decision making process is one of the most surprising results in Table 9. A comparison of that display with Tables 3, 5, and 7 reveals no clear relation between the extent of an agribusiness activity's *overall* recourse to climate information and the degree of exploitation of this material during the making of specific decisions by the activity's *actual users.*

This inquiry into the characteristics of the agribusiness use of climate information continued with a request that the respondents whose decision making is influenced by such information list the types of specific decisions involved (see Appendix A). Complete summarizations of the results of this survey, as functions of information type and agribusiness activity, have already been presented in Tables 4, 6, and 8. Readers with an interest in the details of this use are referred to those displays, which are much more comprehensive than any textual discussion could be. Brief treatments of these tables appeared earlier in this chapter; in summary, they stressed that historical data are largely exploited in a pre-season planning-type mode, that the utilization of year-to-date accumulations tends to occur during in-season operations, and that climate predictions are used (tentatively) for general planning purposes, both in and out of the growing season. As already indicated, the main discussion of the specific agribusiness uses of climate information appears in the next chapter.

Another aspect of the specificity of the use of climate information to be investigated was the extent to which such material is inserted into mathematical equations and formulae that aid decision making (see Appendix A). The results are summarized in Table 10, which indicates that this highly quantitative exploitation of climate information is only weakly characteristic of the private agricultural sector. In fact, little more than one-third of climate information users presently utilize historical data and year-to-date accumulations in this way, while the counterpart fraction for the use of climate predictions is an even lower 22 percent. The comparison of Tables 9 and 10 clearly establishes that much of the agribusiness dependence on climate information *during the making of svecifio decisions* does not go to the quantitative extreme of introducing this material into mathematical equations or formulae. This is especially true of the recourse to climate predictions.

Of the agribusiness activities studied, pest management consulting makes the greatest use of climate information in mathematical equations and formulae (Table 10). This result is probably not surprising, given that the component concerned has emerged as a consistently strong utilizer of climate information throughout the study thus far (Tables 3, 5, 7, and 9). The insertion of historical climate data and year-to-date accumulations into mathematical equations and formulae is also moderately characteristic of the food canning, agricultural chemical, and seed production industries, while rural insurance companies apparently make a similar level of such use of the historical data bank (Table 10). Other interesting features of Table 10, particularly in relation to certain findings discussed earlier, include the relatively low utilization by the grain trade (in similarity to Tables 5 and 9), the greater use by producers than professional farm managers (in contrast to Tables 3, 5,

Table 10. Percent of respondents using climate in founation for whom this involves the input of-such information into mathematical equations or formulae that aid decision making.

Component of sector (number of respondents for each information type in parenthesis)	Climate information type		
	Historical data	Ycar-to-date accumulations	Climate predictions
Agricultural chemical manufacturers (5 2 2)	40	50	0
Agricultural finance companies (6,6,4)	17	17	25
food processing/canning industry (7,7,3)	43	57	33
Grain trade (19,14,17)	26	21	24
Integrated pest management consultants (12, 10, 9)	58	70	44
Producers (12,14,17)	33	43	18
Professional farm managors (11,11,10)	27	18	10
Rural insurance industry (4,1,3)	75	0	33
Seed production companies (5,5,2)	40	40	0
Average for entire sector (81,70,67)	38	37	22

7, and 9), and the very low utilization by agricultural finance companies (consistent with all previous results).

(ii) *Focus, resolution, and source of information*

This inquiry into the characteristics of the agribusiness use of climate information then turned to the focus and resolution, both temporal and spatial, of the information being utilized (see Appendix A). The respondents were requested to indicate the likes of the seasons and area sizes (e.g., from "smaller than a county" to "larger than a state") involved, the lengths of the prediction and data summary periods (e.g., daily, weekly, monthly, seasonal, annual) used, whether or not comparable information was utilized for regions outside the United States, and the source(s) of their information. Table 11 provides an aggregation of the results for the entire private agricultural sector as a function of information type. While the original data analysis for Table 11 also differentiated betweeen the use characteristics of individual agribusiness activities, the intrasectoral variation that emerged was considered insufficient to warrant the cumbersome display needed to convey that information. However, the most outstanding aspects of this variation are mentioned in the ensuing discussion of Table 11.

It is clear from Table 11 that climate information pertaining to the spring and summer seasons is currently being exploited much more than that for the other half-year. The interest in winter conditions is especially poorly developed. Very similar sector-aggregated results were obtained for all three information types. The only moderate anomalies in this regard (i.e., relative to the recourse to the other information for the same seasons) are the greater use of autumn climate predictions and the lower exploitation of historical

Table 11. Sumary of some characteristics of the use of climate information, aggregated across the entire private agricultural sector. The lesults given are the percent of respondents using climate information who do so for a particular season, for certain data summary/prediction period lengths, and for regions of varions sizes, and who obtain that information from several different possible sources. The number of respondents for each information type is given in parenthesis.

	Climate information type		
Characteristic	Historical data (81)	Year-to-date accumulations (70)	Climate predictions (67)
Season			
Spring	72	91	97
Summer	73	91	97
Autumn	49	53	70
Winter	22	31	33
Data summary/prediction period length			
Daily	52	--	73
Weekly	47	--	72
Monthly	63	--	48
Annual	28	--	22
Region size			
Smaller than a county	28	24	22
County	51	56	58
Crop reporting district	42	41	37
Stale	38	38	45
Larger than a state	21	16	27
Part of foreign country	27	29	30
Information source			
Directly from National Weather Service	62	61	78
Other government agency	54	61	40
Private consultant	28	29	46
Other	28	36	43

data for spring and summer. Whereas the results obtained for pest management consultants, producers, and farm managers conform very closely to the pattern depicted in Table 11 for the entire sector, those for the other agribusiness activities include some interesting departures from that pattern (not shown). For example, while the chemical and canning industries apparently make absolutely no use of winter climate information, the grain trade is abnormally dependent on this material. The latter is also true of the small fraction of agricultural finance companies that utilize any climate information (cf. Tables 3, 5, and 7). This result probably stems from the fact that the operations (and hence cognizance of climatic influences?) of these two agribusiness activities are year-round. Finally, the seed industry was found to be an especially strong user of autumn climate information. This is consistent with that activity's paramount need to bring in an undamaged harvest. The same finding was not obtained for the canning companies, despite most of the foregoing seed and canning results being very similar (Tables 3-10). This contrasting recourse to autumn climate information probably stems from the canning industry being dominated by crops that generally mature faster than those grown for the seed companies.

For the sector as a whole, historical data with a monthly temporal resolution receive the greatest utilization (Table 11). While daily and, to a lesser extent, weekly historical data are exploited to a moderate degree, annual historical data are apparently considered to be of little value. Our analysis of the use characteristics of individual agribusiness activities revealed that the grain trade and seed industry make particularly extensive recourse to daily, weekly, and monthly historical data, and that the canning industry is very heavily dependent on daily historical data (not shown). The latter activity makes surprisingly little use of weekly and (especially) monthly information of this type.

Since the time-scale of the data used in year-to-date accumulations by definition needs to be daily (see Section 3a), the questionnaire survey (Appendix A) did not consider this subject. However, that instrument did make a preliminary inquiry into the lengths of the prediction periods that are characteristic of the climate (and also, for comparative purposes, weather) predictions that are currently being used. Definitions of these and related terms were given in Section 2d. It is clear from Table 11 that the agribusiness use of monthly climate predictions is not nearly as widespread as this sector's dependence on daily and weekly weather forecasts. Furthermore, climate predictions for entire calendar years receive substantially less use than their monthly counterparts. While the grain trade, pest management consultants, and professional farm managers all make a moderate level of recourse to monthly climate predictions, only the insurance industry currently exhibits any real interest in annual predictions (not shown).

Table 11 reveals that the "county" is the United States areal unit for which climate information is most frequently compiled and used at present. The level of utilization of both historical data and year-to-date accumulations declines as the unit size increases from county to crop reporting district to state. These information types are seldom compiled and used for areas that are either smaller than a county or larger than a state (Table 11). The results obtained for climate predictions differed from the above only slightly — in this case, the state is apparently a more useful unit than the crop reporting district (Table 11). While the canning and seed industries, chemical manufacturers, and pest management consultants emerged as the heaviest users of climate information compiled for counties, it was the grain trade that showed the strongest interest in such material for the larger spatial units (not shown). The latter activity also makes by far the greatest use of climate information pertaining to countries outside the United States (not shown). This use approaches the grain trade's recourse to domestic climate information (not shown). For the sector as a whole, however, the utilization of foreign climate information is rather restricted (Table 11).

It is clear from Table 11 that a majority of the climate information currently used by agribusiness is obtained directly from the National Weather Service (or other National Oceanic and Atmospheric Administration agencies). This is particularly true of climate predictions. For historical data and (especially) year-to-date accumulations, other government agencies are collectively of equal or almost equal importance in this regard. Private consultants play a much greater role in the provision of climate predictions than the two other information types (Table 11). The most prominent intrasectoral variation in the source of information results was the strong dependence of the grain trade on private consultants (not shown). In addition, the canning, chemical, and insurance industries were found to be unusually reliant on information supplied by the National Weather Service, while farm managers and pest management consultants are similarly dependent on other government agencies.

d. General Reasons for Non-Use

The questionnaire respondents who indicated that they/their company did not currently utilize climate information were subsequently asked to choose among several possible reasons for this non-use (see Appendix A). A slightly different set of possible reasons was offered for each information type. It should be noted that these reasons were, by design, rather general. This portion of the questionnaire was intended only to furnish the background knowledge needed to focus the in-depth discussion of the same topic at the subsequent Workshop, the findings of which are fully detailed in the next chapter. It should also be emphasized that the questionnaire responses obtained on this subject are in fact largely perceptions, and that such views may be at variance with reality, sometimes considerably so. The extent and significance of this discrepancy will be fully treated in the two remaining chapters, for they are highly germane to the third objective of this study — the determination of how the level of present use of climate information can be increased to the maximum that would seem possible (see section 2b).

In the meantime, Table 12 provides an aggregation of the aforementioned questionnaire results for the entire private agricultural sector as a function of information type. In similarity to the genesis of Table 11, the original data analysis for Table 12 differentiated between the reasons for non-use offered by individual agribusiness activities. While the sample sizes involved and intrasectoral variation detected were considered insufficient to warrant the latter's inclusion in Table 12, the most prominent aspects of that variation are mentioned below. The two most cited reasons for the non-use of historical data are the perceptions that (i) this information is not available and (ii) that it has no value even when believed to be available (Table 12). By comparison, relatively few respondents considered data processing costs to be high enough to dissuade their utilization of this information type. Agricultural finance companies in particular doubt the value of historical data to their operations, while producers were found to be the strongest believers

Table 12. Percent of respondents who do not use climate information for whom this non-use is due to the listed individual reasons. The number of respondents for each information type is given in parenthesis. Note that some respondents gave more than one reason for their non-use of a particular information type.

Type of information	Reason for non-use	Percent
Historical data (26)	Data have no value	42
	Data not available	65
	Too costly to convert data to a usable form	19
	Other	12
Year-to-date accumulations (37)	Mo need for it	54
	Not available	43
	Too costly	8
	Not available when needed	27
	Other	0
Climate predictions (40)	No need for information	28
	Present forecasts are not sufficiently accurate	73
	Present forecasts are not available soon enough	13

that this information was not available (not shown).

The year-to-date accumulation results in Table 12 are very similar to those just discussed for historical data. Again, reservations about the availability and utility of the information emerge as the major impediments to its greater exploitation. In this case, however, a sizeable fraction of the respondents who believe that year-to-date accumulations become available in due course do not consider this process to occur quickly enough for the information to be useful (Table 12). Approximately half of the *entire* set of questionnaire respondents indicated (question 26, Appendix A) that year-to-date accumulations need to be updated on a weekly basis to have real utility; much smaller fractions favored daily or monthly updating (not shown). The belief that this type of climate information is not available or not available when needed was found to be strongest among producer and agricultural finance company non-users (not shown). The latter group, along with representatives of the grain trade and chemical industry, was also found to be among the agribusiness personnel most influenced by the notion that year-to-date accumulations have little value (not shown). Like some previous grain trade results [Sections 3b (ii), 3b (iii), and 3c (i)], this one is probably also rather surprising.

The principal reason for the non-use of climate predictions is doubt about their accuracy (Table 12). This concern was found to be widespread throughout the sector (not shown). These findings greatly clarify the preliminary discussion of the possible reasons for the non-use of climate predictions that appeared in Section 3b (iii). In this regard, it is of further interest to note that three-quarters of the respondents to question 45 of the questionnaire survey (Appendix A) indicated that climate predictions would "have to be approximately correct" 70-80 percent of the time before they could be incorporated into their decision making process. In contrast, there seems to be much less concern about the zero or very short lead times (defined in Section 2d) that presently characterize most of these predictions (Table 12). Furthermore, reservations about the utility of this type of climate information are evidently less prevalent among its non-users than is true of the non-users of the other information types considered above (Table 12). Only among agricultural finance and chemical companies is there any real tendency to not use climate predictions because of doubts on this score (not shown).

4. RESULTS OF WORKSHOP

a. Background

As was indicated in Section 2c, the Workshop sought to exploit and build on the foundation of the knowledge about the agribusiness use of climate information that was acquired from the foregoing questionnaire survey. In particular, it attempted to provide the detail, specificity, and clarity concerning the climate information uses and needs of this sector that inherently could not be obtained from the questionnaire survey. Although the Workshop (Appendix C) was primarily concerned with the second and third of the three study objectives listed in Section 2b — those dealing with possible future information needs and opportunities, in which regard it constituted an extension of the questionnaire survey — some time was also spent reviewing the survey's results on the present agribusiness use of climate information. The latter represented both a confirmation and extension of the questionnaire survey.

Although the organizational-type aspects of the Workshop have already beeen fully detailed (Section 2c and Appendix C), some comment on the rationale for certain features of that organization is now in order. The decision to include people from five different components of the private agricultural sector in each Discussion Group (Section 2c), as opposed to clustering only participants from the same and closely related agribusiness activities, was made in the hope that their contrasting backgrounds and perspectives would produce a "cross fertilization" of ideas on the subject at hand, and so make the discussions more productive. This goal was largely realized. It was prompted by the questionnaire survey revealing that some components of the sector had potentially similar climate information uses/needs (e.g., the seed and canning industries), that others currently exhibited a surprisingly low level of use of some information types (e.g., chemical manufacturers, grain trade), and that representatives of the latter and other activities would probably benefit from exposure to the philosophy and practices of heavy users such as pest management consultants. The holding of Plenary Sessions (Appendix C), to which groups summarized their discussions, was similarly motivated and equally successful. One of the principal reasons for the success achieved on the above two counts was the participants' ability to accept our "charge", issued very early in the Workshop, to think and speak not so much for themselves or their company, but for the entire agribusiness activity they had been chosen to represent.

The remainder of this chapter is organized into three sections that deal, in turn, with the topics considered in each of the three Group Discussions (Appendix C). In contrast to the quantitative nature of the preceding chapter, this new material is necessarily presented in a qualitative manner. It is primarily the product of a summary and synthesis of the formal reports prepared on the Group Discussions by their rapporteurs from the Illinois State Water Survey and the University of Illinois (see Section 2c). However, it also reflects the responses to the qualitative-type questions in the questionnaire survey (numbers 11-13, 23-25, and 40-44 of Appendix A) that were not considered in the preceding chapter. In contrast, discussion of the significance and implications of some of the most striking material presented during the Workshop's Plenary Sessions (Appendix C) is reserved for the next and final chapter, which focuses on the future.

b. Present Uses of Climate Information

One of the principal reasons for holding Group Discussions on this subject (Appendix C) was the hope that they would permit the identification of broad categories of climate information use. This approach, which offered the chance to focus on the nature of the utilization, is in distinct contrast to that employed in chapter 3's summary of the questionnaire results. The latter was organized by information type and, as such, was almost completely limited to the identification of the extent and characteristics of the use of each of the three varieties of information by individual activities. A sector-wide synthesis was not attempted there, whereas it is in this section.

Our distillation of the reports on the aforementioned Group Discussions identified several major and somewhat overlapping categories of current application of climate information within the private agricultural sector. This not only strongly confirmed the foregoing questionnaire survey results, but also yielded considerable insight into the genesis, context, present limitations, and probable future characteristics of the various types of use. The latter information was, for the most part, not sought by the questionnaire survey. Details follow.

(i) *Design and planning of operations*

One especially important type of agribusiness use of climate information is in the design and planning of ongoing and future operations. This particularly involves the utilization of climate information in the scheduling of field efforts (e.g., tillage, fertilizer and pesticide application, planting, harvesting, etc.) by producers, professional farm managers, chemical manufacturers, food processing organizations, pest management consultants, and seed producers. Furthermore, both the agricultural finance companies that provide capital for borrowing and the agribusiness activities that depend on this service (most of those listed above) utilize climate information during their financial decision making. In the cases of the seed and food processing firms, the planning also involves the climate-based selection of sites for contract production, while for the chemical industry climate information plays a role in the locating of the field trials that are an important part of the product development process.

The above information clearly provides valuable confirmation of many of the questionnaire results summarized in Table 4 (for historical data), and also some of those appearing in Tables 6 (year-to-date accumulations) and 8 (climate prediction). Of even greater importance, however, is the fact that the Workshop setting involved permitted a full appreciation of the considerable ubiquity and value of the foregoing type of reliance on climate information. The latter extends across a considerable fraction of the sector and is clearly an integral and very important part of the decision making processes of the agribusiness activities concerned. Furthermore, there would seem to be some potential for the future enhancement of this mode of utilization of climate information. This theme is developed in the next chapter.

(ii) *Crop yield modeling*

The second prominent category of agribusiness use of climate information to emerge from the Workshop discussions involves the input of this material into the predictive crop yield models that are run routinely during the growing season by some grain merchandisers, commodity brokers, and their consultants. While this activity is in practice clearly not sector-wide, it was selected for treatment in the present context because of its considerable influence on the nation's financial markets and its instructive climate information uses and needs. The latter have important implications that extend beyond this activity; they will be developed further in the next chapter. In addition, since the yields being predicted reflect the efforts and possible uses of climate information by many other agribusiness activities (e.g., utilization of year-to-date accumulations to guide pest management, dependence on climate predictions for seed variety selection), they represent a sector-wide integration of sorts. The ensuing discussion substantially extends the questionnaire-based information on crop yield modeling given in Tables 4 and 6. Again, the Workshop setting permitted the needed in-depth treatment.

The crop yield models currently in use are diverse in their formulation. They range from those that have a sufficiently strong physiological basis to require the input of daily meteorological data (but which are run at intervals of at least a week) through to the more traditional statistical (e.g., multiple regression) varieties that utilize monthly time-scale information. Irrespective of the type of model used, however, these operational crop yield prediction efforts depend on two separate sets of climate information.

The first such set consists of actual data for the entire growing period or year prior to the time of the model run, while the second one contains assumptions about the climatic character of the remainder of the growing season. In some cases, the information of the first type that is currently being fed into the models is interpolated to a much finer spatial resolution (e.g., down to the county-scale) than characterizes the material from which it is derived. The latter is often limited to reports from only the "first-order" National Weather Service (NWS) stations, of which there are presently but five in a state the size of Illinois, for example. Unfortunately, the NWS. "cooperative substation" data that are recorded at many more locations (e.g., approximately 200 in Illinois) and therefore have considerable potential utility in this context, are currently not disseminated to agribusiness with the required speed. The time-lag involved tends to be several months, whereas delays of a few days to a week are probably the longest that most of this modeling can tolerate. The larger issue of which this situation is part — the question of the design of an appropriate climate information "delivery system" for agribusiness — is considered fully both later in this chapter and in the next one.

The foregoing data availability problem increases the relevance to this modeling effort of two fundamental questions that pertain to any endeavor of chat type. The first of these questions concerns the number of versions of a given type of model (the versions may differ from one another only slightly) that are required to adequately treat agricultural areas as large as the North American Great Plains, the Midwest of the United States, and even the portion of southern Brazil that is increasingly being used for soybean production. All of these areas are currently of great interest to grain merchandisers and commodity brokers in the United States. What the latter require in the present context is, in effect, a regionalization of individual such areas into smaller units that are statistically coherent with respect to a given model type's basic characteristics and the objectives with which it would be deployed. While these regionalizations should be developed from historical climate data, they would have to be consistent with the present availability of climate information for the current year in the required real-time operational mode outlined above.

This situation raises the second of the aforementioned questions that stem from the contemporary data availability problem. It relates to the number and location of the stations from which climate information is utilized in operational crop yield prediction. Juxtaposed against the obvious advantages of economy is the need for the design of the station network to be consistent with a regionalization of the type advocated above. The Workshop discussions suggested that the grain trade's crop yield prediction modelers are quite cognizant of the two foregoing problems. The solution of these problems would seem to require considerable *basic* research into the variability of growing season climates in both space and time. An example of the type of work that should prove helpful in this regard is given in the next chapter.

The first of the foregoing problems, which amounted to a need for the delineation of climatic regions, also pertains to the second of the two aforementioned sets of climate information utilized in the operational prediction of crop yields. This information ensemble contains assumptions about the climatic character of the rest of the growing season beyond the time of a given model run. Such assumptions are, in effect, climate predictions (defined in Section 2d). The alternatives currently in use include regarding the standard 30-year normals (Section 2d) as predictors, doing likewise with some shorter period normals (e.g., Lamb and Changnon, 1981), making conditional probability predictions that are derived from the historical climate data (e.g., there is X% chance August will be Y because July was Z), and adopting the more physically-based 30- and 90-day forecasts of the National Weather Service. Not surprisingly, therefore, the people involved in operational crop yield prediction are very much aware of the considerable potential value to them of accurate climate predictions. They are also rather skeptical of the quality of the climate predictions presently available. Balanced against this somewhat harsh opinion, however, is a realization that the prediction of climate is not easy. Some additional aspects of the climate prediction problem are considered both later in this chapter and in the next one.

(iii) *Monitoring of in-season conditions*

A further striking category of climate information use by the private agricultural sector is in the monitoring of in-season conditions. This occurs quite extensively among many of the agribusiness activities considered (e.g., canning industry, seed production companies, pest management consultants, professional farm managers, and to a lesser extent, grain merchandising companies). It permits the timely and productive adjustments to operating practices that are needed because of prior climatic developments. This monitoring also leads to revised estimations of both the procedures that should be used during the rest of the season and their likely outcomes (including yields). Particularly prominent in this regard are decisions relating to seed variety and planting rate, pesticide type and application, and harvesting/processing arrangements.

This category of climate information use involves not only the year-to-date accumulations whose treatment constituted an important part of the questionnaire survey (see preceding chapter), but also the "now-only" conditions (e.g., mid-July soil moisture, late April soil temperature) that are typically contributed to by year-to-date accumulations of several meteorological parameters. An example of the latter process was given in Section 2d. Now-only conditions were not considered in the questionnaire survey and therefore have been totally neglected in the study thus far. One of the most valuable findings of the Workshop **was** its identification of this strong dependence of many agribusiness activities on now-only climate information for the monitoring of in-season conditions.

Finally, the Workshop discussions also revealed that historical climate data yield a range of probability estimates (e.g., of spring and fall frost dates, planting dates, high temperature extremes) that are frequently used as background information for this in-season monitoring.

(iv) *Concluding remarks*

As the foregoing discussion implies, the present application of climate information within the private agricultural sector involves a relatively wide range of meteorological parameters. For some of the parameters, the types of information being utilized are also quite varied.

In the case of temperature, for instance, the use includes the entire historical data bank on seasonal, monthly, and shorter time-scales, daily values for the present season, temporal integrations of interpretive quantities derived from these daily data (e.g., year-to-date accumulations such as growing degree days and other heat units), and information on runs of daily extremes. Precipitation data are utilized in broadly similar forms. With regard to temperature and precipitation, the Workshop was thus able to expand on the information obtained from the questionnaire survey. The latter was restricted to those parameters.

Of greater importance, however, was the fact that the freedom of the Workshop discussions revealed the use and potential value of information on several meteorological parameters that were not treated in the questionnaire survey. For example, many of the Workshop participants stressed that information on cloud amount/sunshine duration/solar irradiance is considered. very useful for photosynthetic and soil moisture considerations, especially when extensive cloudiness persists during important crop growth periods. Interestingly, the participants' appreciation of the potential value of such information was heightened by the fact that considerable cloud cover occurred over the upper Midwest during the middle third of the 1982 growing season (i.e., in the six weeks or so immediately prior to the Workshop!), and caused plant development there to lag considerably behind the stage implied by the accumulated growing degree days. However, as is discussed later in this chapter, the much needed cloud/sunshine/radiation data are not readily available. The other parameters for which climate information is presently being used include wind (relevant to insect pest problems), soil temperature (planting), soil moisture (crop maturation and nitrogen application), and frost occurrence (seed variety selection and overall scheduling). The availability of this information is also considerably less than optimum.

It should also be reported that the Workshop participants expressed the belief that there is presently a relatively high level of climate information use by their sector. This offered valuable conformation of the similar result yielded by the questionnaire survey (Chapter 3). The Workshop discussions also suggested that the major innovative and intensive climate information users are pest management consultants, the highly controlled seed and food canning industries, and *some* grain and brokerage companies. Their use particularly involves the in-season dependence on year-to-date accumulations and now only information. The grain trade's Workshop participants were found to be more dependent on these information types than some of the questionnaire respondents from that activity [see Sections 3b(ii) and 3c(i)]. This difference suggests that the potential exists for a greater exploitation of climate. information by this important component of the sector.

The situation outlined above — the suggested high overall level of use, and the especially strong dependence of some activities on year-to-date accumulations and now-only information — is probably little recognized by the atmospheric science community. Furthermore, it appears that there has been a rapid growth in this utilization in recent years. The Workshop discussions left us with the impression that such enhanced use has occurred in response to several developments — increased financial pressures felt by agribusiness, a perception that such use provides a company with an economic advantage over its competitors, the dramatic improvement in the sector's modeling and information management capabilities that has resulted from the greatly enhanced computer technology, and the financial consequences of the 1972-73 and 1975 grain sales to the Soviet Union. The latter are perceived to have been at least partly climate-induced.

This increased recent use of climate information by agribusiness suggests that the sector employs progressive management practices and that it would accordingly seek to further exploit such information in the future if that possibility existed. We now turn to the issues raised by this situation.

c. Major Impediments to a Fuller Use of Climate Information

A minor objective of the questionnaire survey (Appendix A) was to obtain a preliminary indication of the reasons for the present non-use of climate information. The results were reported in Section 3d and reflect the very general level of that inquiry. The purpose of the latter was simply to gather the background information needed to focus the envisaged in-depth Workshop treatment of the same subject. The resulting Workshop Group Discussion (Appendix C) was therefore aimed primarily at eliciting informative details relative to the questionnaire survey's suggestion that the agribusiness use of climate information is currently most curtailed by reservations about the availability, utility, and (for climate predictions) accuracy of that information. As in the rest of the Workshop, a sector-wide synthesis was sought. The results obtained are summarized below.

(i) *Lack of delivery system*

A principal reason for the present non-use of climate information is the lack of an appropriate delivery system for material that exists, is known to exist, and is desired. This particularly limits utilization of the year-to-date accumulations and now-only information for which preceding discussion noted a substantial need. It is much less applicable to the other information types.

An excellent example of this problem is provided by the NWS cooperative substation data that were mentioned during the discussion of crop yield modeling in Section 4b(ii). This data set contains daily precipitation totals and (to a lesser extent) daily maximum and minimum temperatures for a large number of locations (e.g., approximately 200 in Illinois for rainfall). It is data of this type and resolution that are needed to reliably compute year-to-date accumulations, help identify now-only conditions, and ascertain the important spatial variations of such information. The recordings are made on a daily basis. If they could be transmitted to potential agribusiness users with some urgency (say, within 3-5 days), these observations would doubtless be extensively and profitably utilized for the monitoring of in-season conditions [see

Section 4b(iii)]. However, the current NWS procedures relating to these data delay their availability much longer than can be tolerated by the agribusiness community. These procedures have the station observers mailing a given month's handwritten records (on NWS Form E-15) to the National Climate Data Center (NCDC, Asheville, North Carolina) at the end of the month concerned, the NCDC subsequently performing a quality control of the huge mass of acquired data and then archiving the resulting sanitized sets, after which the latter are published for each state in the series of National Oceanic and Atmospheric Administration (NOAA) pamphlets entitled Climatological Data. Only at the end of this process, which takes 2-4 months depending on the time of year, are cooperative substation data available to agribusiness...by which time they are of no use for in-season monitoring. The next chapter provides an example of the type of initiative that is needed to remove this delay.

In the absence of the delivery system needed to provide the most appropriate climate information (e.g., data from the national cooperative substation network discussed above), the agribusiness community is forced to utilize its own measurements, qualitative field reports of climatic conditions and indicators, data from less appropriate but more accessible national network [e.g., the NWS first-order stations mentioned in Section 4b(ii)l, various other estimates, experience, and instinctive reactions.

(ii) *Perceived comlexity of vvoblem*

A second major impediment to a fuller use of climate information by agribusiness is the perceived complexity of the problem of which climate is but one part. There is wide recognition that the complicated decision making and modeling processes characteristic of this sector have other equally or more important inputs (e.g., economic, social, and political considerations) that are not easily quantified or whose dimensions are imperfectly known. In the face of this situation, there has been a distinct tendency for some agribusiness personnel to see little dividend in the sophisticated use of climate information.

It is important to stress that this view is presently but a perception, and that it may be at variance with reality. The current situation would seem to result from the fact that the benefits to be obtained from the use of climate information have generally not yet been adequately demonstrated, from the existing uncertainty about how this needed demonstration can be accomplished, and probably also from nagging doubts about the sector's ultimate ability to ameliorate (accentuate) adverse (beneficial) climate impacts. Clearly, all of these issues need to be addressed in the very near future. We believe that this task would be best pursued via economic modeling that includes the effects of climate fluctuations, and which is as rigorous and quantitative as possible. This approach, which probably should commence with the treatment of individual components of the sector (e.g., the operation of the farm firm), would open new and professionally rewarding fields for agricultural economists, for instance. If we are to achieve the much needed involvement in this area of specialists other than atmospheric scientists, the work will have to be professionally beneficial for all participants. The next chapter makes reference to a developing interdisciplinary study that is being patterned along the lines just advocated — it deals with the possible use of climate predictions by Midwestern row crop producers, and was partly motivated by the results of the present study.

In conclusion, we wish to emphasize that while the relatively qualitative and survey-type approach adopted throughout this study and also by Glantz (1977, 1979) constitutes an informative way to initiate research into the use of climate information, it is unlikely that it will be of much help in addressing the important issues listed above. As already indicated, future progress would seem to require the use of quantitative economic models.

(iii) *Deliberate non-use*

There is also deliberate non-use of climate information that is known to be available. Such material is either perceived to be of little use, or else its utility is thought to have not yet been demonstrated. The difference between this type of non-use and that discussed immediately above is one of attitude — the non-user is very definite in his view that the information concerned is of questionable utility and does not consider the issue to be clouded by any "complexity of the problem" type arguments.

An excellent example of this type of non-use concerns the monthly and seasonal climate predictions issued by the Climate Analysis Center (CAC) of the NWS. The availability of these predictions, both in many newspapers and by nominal subscription, is apparently very widely known within the agribusiness community. Furthermore, relatively few of the latter's members question the *potential* value of climate predictions — the Workshop discussions offered valuable confirmation of the questionnaire survey's suggestion that this was the case (see Section 3d). The neglect of the CAC predictions by a large majority of agribusiness personnel stems instead from a perception that they are far too unreliable to be useful. This Workshop finding was also foreshadowed by the questionnaire results (Table 12). In addition, the Workshop discussions suggested that the zero lead time (defined in Section 2d), coarse spatial resolution, and open distribution (which gives no individual or company an "edge" over competitors) of these predictions further militate against their use. While the climate predictions that are being increasingly issued by private meteorological consultants do not have the latter disadvantages, the Workshop discussions indicated that their perceived credibility is at least as low as that of the CAC predictions.

The foregoing agribusiness standpoint may not be entirely appropriate. Even though climate predictions have yet to consistently achieve the accuracy levels that most people (including both atmospheric scientists and potential prediction users) think is desirable, they nevertheless may already be reliable enough to be of some economic value to agribusiness. This has proven to be the case for crop-hail insurance (Changnon and Fosse, 1981). There is thus a definite need for the quantitative investigation of the above possibility; it should be pursued using the same economic modeling approach advocated above, for the basic problem is identical. As already indicated, the next chapter makes reference to a developing study that has these objectives with respect to the use of climate predictions by Midwestern row crop producers.

The same general comments and research needs apply to some (but not all) of the other deliberate non-use of climate information. A reasonable fraction of this non-use is, on the other hand, highly rational.

(iv) *Exploitation difficulties*

The capability of the private agricultural sector to fully exploit the climate information currently available is sometimes deficient.

In some cases the limitations are conceptual — for example, the appropriate models do not exist or are thought not to exist. If modeling work of the type advocated above can be developed to at least a moderate extent during the next decade, this type of impediment should be gradually removed. The latter process would be accelerated, particularly for the smaller agribusiness concerns (e.g., pest management consultants, professional farm managers, producers), by an improved diffusion through the sector of information about innovations in the above regard.

In other instances, the present utilization of climate information is limited by physical constraints. The latter include the lack of the requisite organizational support, computational facilities, appropriately trained staff, and financial resources. However, the growing trend towards the provision of electronically generated and transmitted agribusiness information by some large organizations (e.g., grain and brokerage companies, Farm Bureaus) should help overcome these limitations. There is considerable potential for the inclusion of climate information in this supply. The situation should be further eased by the guidance on the accessing and use of electronic information that is becoming available to smaller agribusiness concerns (e.g., Sonka, 1983).

(v) *Other*

The Workshop discussions revealed several other reasons why the present use of climate information does not equal the maximum that would seem possible. These include simple unawareness of the material that is available; the nonexistence/paucity/inaccessibility of some highly desirable information [e.g., cloud/sunshine/radiation, wind, soil moisture, and soil temperature, as was discussed in Section 4c(iv)]; communication problems between scientists and lay users (e.g., the question of what probability predictions mean); the apparently inappropriate formats of some of the present information publications and data tapes; and the notion that the cost incurred in acquiring and processing the information is not justified by the resulting benefits (real or perceived). The implications of some of these findings for the future agribusiness use of climate information are considered in the next chapter.

d. Climate Prediction Needs for the Future

One of the Workshop Group Discussions focused exclusively on this topic (see Appendix C). There were several reasons for this emphasis. First, the questionnaire treatment of the subject was either very cursory (e.g., the limited and very general options offered for the present non-use of climate predictions; Appendix A, question 39) or else yielded disappointingly superficial and undefinitive results (e.g., the responses to our inquiry about future climate prediction needs; Appendix A, questions 40-44). In the latter regard, many respondents offered nothing more informative than the likes of "precipitation, temperature", "drought and extreme wet periods", and "early or late frost" in answer to our request that they indicate the climate events (i.e., meteorological parameter, time period, and area involved) for which they most desire predictions (Appendix A, question 40). We therefore felt a need to capitalize on the opportunity offered by the flexibility of the Workshop setting to explore the above topic in as much depth as possible. This decision was further prompted by our belief that the achievement of a really *substantial* reduction (enhancement) of the adverse (favorable) consequences of climatic variation would seem to require an effective use of skillful climate predictions. The potential benefits to be derived from a fuller utilization of other forms of climate information are, by comparison, inherently more modest.

The Workshop Group Discussions on this subject were prefaced by a lecture ("An introduction to climate prediction") that sought to provide the participants with the background needed to address the issues we wished to have considered (Appendix C). This lecture began with a review of relevant terminology, much of which was covered in Section 2d of this report (e.g., climate-versus-weather prediction, lead time, and prediction period). However, the lecture also sought to differentiate between three additional and potentially confusing terms that are used in relation to climate prediction — "resolution" (whether predictions are expressed in such extremely qualitative terms as "above normal" and "near normal" — defined in Section 3a — or something more precise), "accuracy" (the absolute difference between a predicted value and what actually occurs) and "skill" (the extent to which a given prediction method is more successful than would be achieved by chance or some other standard of comparison that does not require meteorological expertise to produce). The lecture concluded with an outline of the current procedures, format, and skill levels of the NWS CAC climate predictions. It was partially based on Harnack (1981a, b). The participants were then charged with discussing the future climate prediction needs of the agribusiness activity they represented (as opposed to only their own company) with respect to the following parameters — applications, lead times, desired length and timing of prediction periods, weather elements to be treated, resolution, accuracy, and skill.

In general, the Workshop participants found this assignment to be extremely difficult, and did not perform it nearly as well as we had hoped.

These Group Discussions were decidedly less successful, at least in a "positive" sense (i.e., in providing firm results), than their forerunners. Despite the participants' impressive backgrounds and the insight exhibited in their questionnaire responses [Section 2c(ii)], it became very clear that they had never before given this particular subject the serious and rigorous consideration that it apparently requires. It was the latter circumstance, much more than anything else, that reduced the participants' effectiveness in this instance. The same factor presumably also accounts for the aforementioned superficial and undefinitive questionnaire responses obtained on the same topic.

The foregoing situation was deemed useful in a "negative" sense, however, for it provided real-world support for Lamb's (1979, 1981) earlier and somewhat abstract contention that considerable interdisciplinary research is needed to assess whether, where, how, and what type of climate predictions could/should be used. He argued there that the use of climate predictions to minimize the adverse socioeconomic consequences of climatic variation has the following three demanding and reasonably sequential prerequisites: (i) the identification of the human activities most severely impacted by such variations (by geographical region, time of year, and weather parameters responsible), (ii) the determination of which of the most affected regional economies possess the flexibility to adjust or change to an extent that would permit them to capitalize substantially on the availability of skillful climate predictions, and (iii) the development of accordingly focused prediction schemes for the cases for which some skill seems attainable. Partly as a result of the Workshop experience outlined above, this framework is now being used to investigate the possible value of climate predictions for Midwestern row crop producers. The latter study, which has already been alluded to in this chapter, will be considered more fully in the next. Its conduct is being substantially shaped by the Workshop findings.

Despite the participants' general difficulty in dealing with this subject, their efforts did yield three more positive (if rather general) conclusions. The first was that, for many agribusiness applications, a prediction of the likely general character of the late spring and summer conditions would be useful if it was made available during the preceding January-March period (certainly no later than April 10). For example, the forecasting of the late May and June climate with this lead time could potentially influence winter decisions on fertilizer use, insecticide and herbicide choices, and production/sales questions. The important meteorological parameters appear to be temperature, sunshine, and rainfall. Since the early-July through mid-August period is the most critical one for crop growth, a demonstrated capability to successfully anticipate its climatic character six months ahead would affect *all* decisions made during the intervening time. A particularly important issue in this regard is the likelihood of July-August climatic extremes such as the 1980 and 1983 Midwestern heatwaves/droughts and their antithesis. The latter conditions affected Illinois (and also some surrounding states) during its record 1979, 1981, and 1982 growing seasons. The foregoing Workshop results are consistent with the relatively few "quality" responses given to questions 40-44 of the questionnaire survey (Appendix A).

The second important positive conclusion to emerge from these Group Discussions was that the private agricultural sector would welcome attempts to predict September and early October conditions with some lead time. It is particularly interested in the likelihood of the early frost that would damage crops, and also the extended wet and cool period that delays harvesting and. thereby exposes the crop to a range of yield-reducing threats. It appears that predictions of these phenomena would be needed by August 15 to influence late season decisions. These decisions, which of course vary somewhat across the sector, in general relate to harvest scheduling and preparations, yield expectations, grain storage considerations, financial planning, and the development of marketing strategies. It is important to realize that, because of the time of year in question, few of these decisions affect production. Predictions of autumn conditions with much longer lead times would be needed to influence production; this would occur through the selection of seed variety which, in turn, determines maturation time. The foregoing September-October climate prediction needs were only weakly recognized by the question-naire respondents (Appendix A, questions 40-44). Furthermore, the atmospheric science community has probably greatly underestimated this interest in the predictability of autumn conditions.

Finally, the Workshop Group Discussions strongly confirmed the question-naire finding (Section 3d) that the agribusiness community presently *thinks* climate predictions will need to be "highly accurate" before they are taken seriously by this sector. Some of the consequences and implications of this Workshop result have already been treated in the present chapter [Section 4b(iii)]; the comments made there have equal application in the current con-text. For instance, our earlier contention that the above agribusiness stand-point may not be entirely appropriate is supported by the fact the Workshop participants had considerable difficulty dealing with the concepts of skill, accuracy, and resolution. Furthermore, they readily agreed that considerable research and user education will be necessary before an individual or company can properly assess the potential benefits and likely risks involved in using climate predictions, including those expressed in probabilistic terms. This sentiment is also consistent with the earlier ideas of Lamb (1979, 1981). As indicated previously, we believe that a quantitative economic modeling approach can be of decided help in this regard. This theme is further developed in the next chapter.

5. CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

a. Summary of Motivation and Scope

This study has sought to identify the climate information uses and needs of the group of economic activities that constitutes the United States private agricultural sector.

It was undertaken in the belief that it had the potential to be particularly instructive for the sustaining and refinement of a recent and important atmospheric science policy development. The latter has involved the formulation and partial implementation of large, ambitious, multifaceted, national and international "climate programs" (e.g., United States National Climate Program, World Climate Programme) that are intended to broadly benefit mankind by reducing (increasing) the adverse (beneficial) socioeconomic consequences of climatic variability. While these climate programs (World Meteorological Organization, 1979; National Oceanic and Atmospheric Administration, 1980) are predicated on the assumption that such a goal is attainable, whether this is the case has never really been demonstrated. We contended at the outset that the required management strategies are presently largely unknown, and that their development awaits substantial investigation of the climate information needs of decision makers (National Research Council, 1981). It was in this context that we considered the United States private agricultural sector to invite comprehensive investigation.

This viewpoint was prompted by the many and varied characteristics and attributes of that sector. First, not only is agriculture the broad economic activity most affected by climatic variation (National Research Council, 1976, 1982), but the private enterprise production system that has evolved in the

United States is the most developed in the World. This system is accordingly of great importance to the United States and World economies. It is very large, diverse, complex, and technology-based, encompassing as it does the actual producers (growers, farmers, ranchers), the elaborate support structure that provides producers with high quality materials (e.g., fertilisers, seeds, pesticides, machinery) and services (e.g., insurance, finance, farm and pest management), and the grain trade and the food processing and brokerage industries that are concerned with the ultimate outputs of the system. The sector is also endowed with highly fertile soil, generally abundant moisture, the finest available research and development of the materials listed above, and educated operators who function within the initiative-rewarding environment of the "farm firm". However, despite these great strengths, the sector can be severely impacted by climatic fluctuations, as the enormous crop yield variations during 1979-83 readily attest.

An equally important motivation for this study was the dearth of prior knowledge of the climate information uses and needs of the sector concerned. We argued initially that the redressing of this deficiency would likely have several benefits in the foregoing "climate programs" context: (i) the identification of the present level of use and its value might increase the exploitation of such material within less developed agricultural systems, (ii) the diversity and complexity of the system implied that its uses and needs could be varied and therefore offer an indication of the scope and difficulty of providing appropriate climate information products to the United States private sector in general, (iii) the system's considerable structural and human flexibility may provide the possibility for a greatly enhanced use in the future which would in turn offer an agricultural demonstration of the ultimate potential for improved management strategies to mitigate (enhance) the unfavorable (beneficial) socioeconomic consequences of climatic variation, and (iv) the latter would improve the sector's efficiency and thus substantially benefit the consumer of food and fiber both in the United States and throughout the World.

The fundamental goal of the present study has therefore been to obtain an understanding of the factors that determine the use of climate information by agribusiness decision makers in the United States. It has had the following three specific objectives in that regard: (i) to describe the present level, types, and methods of utilization, (ii) to identify the potentials for and impediments to a fuller use in the future, and (iii) to specify the scientific ***research*** and data acquisition/information dissemination ***development*** thrusts that are necessary before the level of present use can be increased to the maximum that would seem possible.

The project has been conducted in three distinct phases. The first involved a nationwide mail questionnaire survey of agribusiness decision makers, from which 107 usable responses were obtained (an 86% response rate). This effort concentrated strongly on the present use of climate information. We believe that the size and scope of the questionnaire survey were adequate for the task at hand. The second phase was an intensive two-day Workshop at which the primary participants were 14 of the respondents to the mail survey. Those people were selected because they were already users of climate information and had indicated an advanced interest in this topic in their questionnaire responses. Although the Workshop made some further inquiry into the present use of climate information, it was dominated by an in-depth consideration of how the sector's profitable utilization of climate information might be increased in the future. Furthermore, this concern with the second and third of the foregoing objectives sought the detail, specificity, and clarity that inherently could not be obtained from a questionnaire survey. The third phase of the project consisted of day-long post-Workshop discussions with several of the Workshop participants from the private sector. These interactions concentrated particularly on the scientific research and data acquisition/dissemination development thrusts that are needed to maximize the agribusiness use of climate information (i.e., the third of the above objectives).

All phases of the project have thus been totally dominated by the extraction of information and opinions from active members of the private agricultural sector. As such, this study has not been at all influenced by atmospheric scientists' perceptions of the climate information uses and needs of that sector. While a study with the latter basis would likely have been easier to undertake, it would also have been of lesser value.

Four types of climate information have been considered. The questionnaire survey dealt with three of these — *historical data* (the very large bank of instrumental measurements made since the inception of such observations), *year-to-date accumulations* (summations of the daily values of actual weather parameters and derived quantities through any point in a given year), and *climate predictions* (statements of the expected general character of the weather for future periods of at least one month in length). These three information categories were also treated at the Workshop, along with a fourth type *(now-only conditions,* such as mid-July soil moisture). The latter tend to be the product of year-to-date accumulations for a range of parameters. More extensive explanations of these contrasting climate information categories appeared in Section 2d.

b. Summary and Implications of Present Use

The present extent and types of use of climate information were treated in Sections 3b and 3c (questionnaire survey results) and 4b (Workshop results). We here attempt to summarize the many, detailed, and somewhat disparate findings reported in those sections. The construction of Table 13 was intended to facilitate this process. That display provides a synopsis of the quantitative/explicit material in Tables 2-8 as well as the qualitative Workshop information contained in Section 4b. It gives a general indication of both the extent and type of use as functions of information category and agribusiness activity. Although the year-to-date and now-only columns of Table 13 contain identical information, we have resisted the temptation to combine them. By keeping them separate we seek to emphasize that, because of the insight obtained from the Workshop discussions, our investigation came to include now-only conditions in addition to the three other information types considered from the outset.

(i) *Summary of extent of use*

One of the most important findings of the entire study is that climate information is now being extensively used by agribusiness decision makers in the United States, and that the utilization has increased substantially in recent years. For example, almost three-quarters of the questionnaire survey respondents were found to use historical temperature and precipitation data (Table 2, p. 23). A lesser fraction of those respondents, but still a majority, indicated that they/their company utilized year-to-date accumulations and

Table 13. Summary of present use of climate information. The upper entry gives the extent of the utilization on a five category basis (VERY CONSIDERABLE, CONSIDERABLE, MODERATE, LITTLE, VERY LITTLE), while the lower entry briefly indicates the type of use involved.

	Climate information type				
Component of sector	Historical data	Year-to-date accumulations	Now-only conditions	Climate predictions	Average of extent of use across all information types
Agricultural chemical manufacturers	VERY CONSIDERABLE Varied (esp. understanding product performance)	LITTLE Monitoring (Adjusting) in-season conditions (operations)	LITTLE Monitoring (Adjusting) in-season conditions (operations)	LITTLE Varied planning (production, sales, investment, trials)	MODERATE
Agricultural finance companies	LITTLE Formulation of operating infrastructure	LITTLE Monitoring of in-season conditions for loan volume predictions	LITTLE Monitoring of in-season conditions for loan volume predictions	LITTLE General planning (esp. loan volume predictions)	LITTLE
Food processing/canning industry	CONSIDERABLE Pre-season operations planning	CONSIDERABLE Monitoring (Adjusting) in-season conditions (operations)	CONSIDERABLE Monitoring (Adjusting) in-season conditions (operations)	LITTLE Tentative general operations planning	CONSIDERABLE/MODERATE
Grain trade	VERY CONSIDERABLE Development of crop yield models and operating strategies	MODERATE Monitoring (Adjusting) in-season conditions (operations)	MODERATE Monitoring (Adjusting) in-season conditions (operations)	VERY CONSIDERABLE Anticipation of growing conditions and operations planning	CONSIDERABLE
Integrated pest management consultants	VERY CONSIDERABLE Pre-season operations planning	VERY CONSIDERABLE Monitoring (Adjusting) in-season conditions (operations)	VERY CONSIDERABLE Monitoring (Adjusting) in-season conditions (operations)	CONSIDERABLE Tentative general operations planning	VERY CONSIDERABLE
Producers	LITTLE Pre-season operations planning	LITTLE Monitoring (Adjusting) in-season conditions (operations)	LITTLE Monitoring (Adjusting) in-season conditions (operations)	MODERATE Tentative general operations planning	LITTLE
Professional farm managers	CONSIDERABLE Pre-season operations planning	CONSIDERABLE Monitoring (Adjusting) in-season conditions (operations)	CONSIDERABLE Monitoring (Adjusting) in-season conditions (operations)	CONSIDERABLE Tentative general operations planning	CONSIDERABLE
Rural insurance industry	MODERATE Insurance history and rate analyses	VERY LITTLE Monitoring of in-season conditions	VERY LITTLE Monitoring of in-season conditions	MODERATE Varied planning (rates, investment) and prediction (insurance experience)	LITTLE
Seed production companies	VERY CONSIDERABLE Pre-season operations planning	VERY CONSIDERABLE Monitoring (Adjusting) in-season conditions (operations)	VERY CONSIDERABLE Monitoring (Adjusting) in-season conditions (operations)	LITTLE Tentative general operations planning	CONSIDERABLE
Average for entire sector	CONSIDERABLE Pre-season operations planning	MODERATE Monitoring (Adjusting) in-season conditions (operations)	MODERATE Monitoring (Adjusting) in-season conditions (operations)	MODERATE Varied (often tentative) planning (esp. operations)	CONSIDERABLE/MODERATE

climate predictions for the same parameters. Furthermore, the Workshop suggested that the recourse to information on now-only conditions is similar to that for year-to-date accumulations [Section 4b(iii)]. In addition, as indicated in Table 13, both the questionnaire survey and the Workshop revealed that there is considerable and highly important intrasectoral variation in the dependence on all of the climate information types considered.

The heaviest users of *historical data* were found to be pest management consultants, the chemical, seed, and grain industries, and to a lesser extent farm managers (Table 13). At the other extreme, producers, agricultural finance companies, and the rural insurance industry make relatively little recourse to this type of climate information. Two especially interesting results were the canning industry's much greater dependence on temperature than precipitation data (presumably because of the more obvious thermal implications for planning) and the clear evidence that the use of this information type is more extensive among farm managers than producers (discussed further below).

The extent of utilization of *year-to-date accumulations* and *now-only information* was found to have both similarities to and differences from that characteristic of historical data (Table 13). The seed industry and pest management consultants were again heavy users, while producers, agricultural finance companies, and (especially) the rural insurance industry were once more found to lie at the opposite end of the extent-of-use spectrum. Agricultural chemical manufacturers also fall into the latter category, in pronounced contrast to their strong need for historical data. Other interesting differences from the historical data results include the canning industry's (grain trade's) more (much less) extensive utilization of precipitation (temperature) information that is in year-to-date form (Table 13). Finally, as for historical data, farm managers were found to be more dependent on year-to-date accumulations and now-only information than are producers (see below).

The intrasectoral variation in the extent of use of *climate predictions* was also found to include both interesting similarities to and differences from that summarized above for the other climate information categories considered (Table 13). Climate predictions are utilized most extensively by the grain trade, pest management consultants, and farm managers. For the grain trade, the dependence is (surprisingly) much greater than on year-to-date accumulations and now-only information. The moderate users of climate predictions (producers and the insurance industry) also regard the value of this information type to equal or exceed that of the other categories. Furthermore, it is only for climate predictions that the extent of utilization by producers approaches that of farm managers (Table 13). A particularly striking feature of the climate prediction results was the rather limited use identified for the chemical, seed, and canning industries, activities that were found to be generally heavily dependent on the other types of climate information. The similarly restricted use of climate predictions by agricultural finance companies, on the other hand, parallels the situation detected for historical data, year-to-date accumulations, and now-only conditions.

(ii) *Summary of characteristics of use*

The questionnaire respondents who indicated that they/their company utilize climate information were asked several subsequent questions designed to reveal some of the characteristics of that use. The results [Tables 4 (p. 26), 6 (p. 31), 8 (p. 37), and 9-11 (pp. 41, 45, 47)] were confirmed by the

Workshop discussions, and are summarized next. First, it is very clear that one motivation for almost all agribusiness users of climate information is the need for guidance of a general background type. The dependence on climate information during the making of specific decisions is, on the other hand, somewhat less prevalent. Furthermore, no clear relation was found to exist between the extent of an agribusiness activity's overall recourse to climate information (summarized above) and the degree of exploitation of this material for specific decision making by the activity's actual users. Apparently, too, much of the agribusiness use of climate information in specific decision making does not yet extend to the quantitative extreme of inserting that information into mathematical equations and formulae.

Both the questionnaire survey and the Workshop clearly established that the utilization of *historical data* largely occurs in the pre-season planning of operations (Table 13). This is rather intriguing given the difficulty of justifying the value of planning (well planned decisions can still turn out to be less than optimum!). Despite the latter circumstance, however, many agribusiness decision makers clearly find this mode of utilization of historical data to be particularly helpful. The major alternative uses of this information type [Tables 4 (p. 26) and 13] occur among agricultural chemical manufacturers (for product label design, defense of alleged product liability, and post-season evaluation of trials) and grain merchandisers (in the important formulation of crop yield estimation procedures).

The questionnaire survey strongly suggested that the utilization of *yeav-to-date acoumulations* largely occurs in an in-season operational-type mode that often builds on pre-season planning formulated with the aid of historical data (Table 13). This finding was firmly supported by the Workshop discussions, which also established that *now-only information* is exploited in the very same manner (Table 13). This use of year-to-date accumulations and now-only information primarily involves the monitoring of the evolution of in-season conditions. It permits timely and productive adjustments to operating practices that are needed because of prior climatic developments, and also leads to revised estimations of both the procedures that should be used during the rest of the season and their likely outcomes (including yields). Particularly prominent in the latter regard is the dependence on these two information types of the predictive crop yield modeling efforts that are routinely conducted during the growing season by some grain merchandisers, commodity brokers, and their consultants (Table 6, p. 31).

The present agribusiness use of *climate predictions* occurs in a general planning-type mode (Table 13), both in and out of the growing season. However, because strong reservations about the current reliability (but not potential value) of such predictions are widespread among decision makers, this utilization is often somewhat tentative in nature. One of the most important — and probably least obvious — specific applications of this type of climate information to emerge from our study is in the aforementioned predictive crop yield modeling efforts undertaken by/for the grain trade [Section 4b (ii)]. This modeling requires an assumption about the climatic character of the growing season beyond the time of a given model run. Such assumptions are climate predictions. Their use in this context also can influence the nation's financial markets.

Our inquiry into the characteristics of the agribusiness use of climate information also yielded considerable insight into the *focus, resolution, and source* of the material being utilized. For example, it is very clear that climate information (all types) pertaining to the spring and summer seasons is currently being used much more than that for the other half-year. The interest in winter conditions is especially poorly developed. Furthermore, the spring and summer use in particular involves a wide range of meteorological parameters — temperature and precipitation information from each of the four categories expressed in a broad variety of forms, wind, soil moisture, soil temperature, and (where available) information on cloud amount/sunshine/solar irradiance.

Historical data with a monthly temporal resolution currently receive greater utilization by the sector as a whole than those with longer or shorter time-scales. However, some agribusiness activities (e.g., grain trade, seed and canning industries) are quite heavily dependent on daily and weekly historical data. Calendar months and 30-31 day intervals running from the middle of one month to the middle of the next are the periods for which climate predictions are now most frequently used.

Concerning the spatial resolution of the information presently being exploited, the "county" is the preferred United States areal unit. The grain trade makes by far the greatest utilization of climate information pertaining to countries outside of the United States; this use apparently approaches that activity's recourse to domestic climate information. Finally, it is clear that a majority of the.climate information currently used by agribusiness is obtained directly from the National Weather Service or other agencies of the National Oceanic and Atmospheric Administration.

The extensive current use of climate information by the United States private agricultural sector that has been summarized above has diverse and important implications.

(iii) *Implications for Climate Programs*

First, the results offer considerable support for the basis and goals of the *United States National Climate Program* (DSNCP). They show that the adverse (beneficial) socioeconomic consequences of climatic variability can indeed be reduced (increased) by the incorporation of climate information into management strategies. This circumstance, in turn, provides encouragement for the long-run success of the USNCF. The extensive use of climate information occurs because the sector's decision makers believe that it is of economic benefit to their organizations; the resulting enhanced efficiency may also be to the advantage of the consumer of food and fiber both domestically and abroad. Furthermore, as noted in Section 4b(iv), it appears that there has been a rapid growth in this utilization in recent years. This entire situation is probably little recognized by the atmospheric science community. An improved appreciation of it would surely elevate the quality of the (proportionately large) atmospheric sciences' input into the refinement and continued development of the USNCF as it enters the crucial second five-years of its existence. Furthermore, it suggests that counterpart investigations for other climate-affected sectors of the United States economy (e.g., transportation, energy, water resources, government) would be especially helpful.

The very positive nature of the present-use results obtained here also suggests that this research effort could be profitably "duplicated" for several foreign countries. The motivation for and objectives of this study would seem to be quite transferable. An obvious starting point would be to consider some of the more developed of the remaining private agricultural sectors — those of Western Europe, Canada, Argentina, Australia, New Zealand, and South Africa would presumably be candidates for selection. However, the most productive state-controlled agricultural systems also invite investigation in this context. Such systems would ideally not only be drawn from the Eastern European and Soviet republics, but also from the Peoples' Republic of China. Perhaps this potential research thrust could be developed under the auspices of the *World Climate Programme* (WCP). Certainly, it is the WCP that must take the lead in the much more difficult task of determining how to pursue this line of inquiry in the developing nations.

(iv) *Implications for agribusiness*

The present-use results also have ramifications for the people whose decisions affect agricultural production in both the United States and a number of foreign countries. For the United States, individuals/companies whose current utilization of climate information is noticeably below the level identified here for their agribusiness activity may have much to gain by increasing their recourse to such material. This comment particularly applies to low usage among pest management consultants, seed companies, farm managers, and the grain trade (Table 13). Several sections noted the surprisingly limited recourse that some grain traders make to year-to-date accumulations and now-only information, especially when making specific in-season decisions.

The results should also provide considerable guidance to decision makers in the foreign private agricultural sectors listed above.

(v) *Implications for climate services*

The considerable intrasectoral variation in the extent and type of use of climate information that has been identified for the United States private agricultural sector confirmed our initial hypothesis that the climate information needs of this complex sector were likely to be quite diverse. This was. particularly exemplified by the aforementioned case of remotely-located professional farm managers making substantially greater recourse to climate information than is characteristic of on-site producers. Farm managers have both a greater need for such material (because of the difficulty of assimilating the climate history of several disparate and possibly contrasting units into their own experience) and stronger present acquisition capabilities (being larger concerns they can better justify the costs involved). The case of the private agricultural system has thus yielded the desired demonstration of the scope and difficulty of providing appropriate climate information products to the United States private sector in general. This circumstance should assist state and federal governments in the formulation and implementation of the needed national system of climate services.

c. Summary and Implications of Present Reasons for Non-Use

The questionnaire survey included a preliminary investigation of this subject, the results of which were reported in Section 3d. That inquiry was intended only to furnish the background knowledge needed to focus the in-depth discussions of the same topic at the subsequent Workshop. The latter were fully documented in Sections 4c-d. We here attempt to summarize the present reasons for the non-use of climate information, and then turn at much greater length to consider how such impediments could be reduced and removed.

The summary of the present reasons for the non-use of climate information appears in Table 14. It is readily seen that this non-use stems from reservations about the availability, utility, cost, value, and (in the case of cli-

Table 14. Summary of present reasons for the non-use of climate Information and the Initiatives needed to reaove those Impediments.

Type of Information	Reasons for non-use	Research/technological Initiatives needed
Historical data	Perceived to be unavailable	Improve awareness, accessibility, and delivery of existing data Improve present data collection networks (especially density) Develop new networks to measure additional parameters
	Perceived to have little value	Develop methods (especially economic models) to define value Demonstrate potential to provide background guidance for the design and use of other climate Information types Communication of above utility and proof of value to users Improve capabilities to exploit data (models, hardware, personnel)
	Considered to be too costly to convert to usable form	Establish (e.g., through modeling) most cost efficient modes of utilization Identify cost/benefit ratios Develop relatively cheap methods of furnishing useful information (e.g., by private consultants)
Year-to-date accumulations	Perceived to be unavailable (especially in the required near real-time)	Improve present data collection networks (especially denalty) Develop new networks to measure additional parameters Establish procedures to rapidly assemble the raw observational data, process them Into the most desirable forma of Information, and deliver that information to users in near real-time
	Perceived to be unnecessary	Perform research (cllmatologlcal, agrometeorologlcal) on historical dats to establlah the most appropriate formats for this lnformstion Develop methods (especially economic mode1S) to define value Communication of most appropriate formats and proof of value to uaers Improve capabilities to utilise this Information (models, hardware, personnel) Hake cost of Information apply aa low ae possible (through prlvste consultants)
Now-only Information	Perceived to be unavailable (especially In the required near real-time)	Improve present data collection networks (especially density) Develop new networks to measure additional parameters Establish procedures to rapidly assemble the raw obaervatlonal data, proceaa them Into the most desirable forms of Information, and deliver that Information to users in near real-time
	Perceived to be unnecesssry	Perform research (cllmatologlcal, agrometeorologlcal) on historical data to establish the scat appropriate formats for this Information Develop methods (especially economic models) to define value Communication of most appropriate formats and proof of value to users Improve capabilities to utilise this Information (models, hardware, personnel) Hake coat of Information apply as low as possible (through private consultanta)
Climate predictions	Perceived to be Insufficiently accurate	Establish (e.g., through modeling) how accurate predictions need to be to have economic value Improve accuracy of predictions
	Considered to have Inappropriate designs	Perform research to ascertain the optimum prediction designs (prediction period, lead time, weather parameters treated, resolution, etc; aee Sections 2d and 4d) for key agricultural areas Improve capability to predict (1) late spring-summer conditions prior to mid-Apr 11 and (ii) autumn conditions by August 1}
	Perceived to be of reatrlcted value	Develop procedures (e.g., economic models) to establish economic value Educate users about all sspects of predictions

mate predictions only) the accuracy of the information. Table 14 also introduces the data acquisition/assembly, information dissemination, scientific research, and related initiatives that are needed before the agribusiness use of climate information can be maximized. We conclude this study by offering an in-depth consideration of those needs.

(i) *Data acquisition*

Clearly, the provision of the best possible climate information to the private agricultural sector has, as its first prerequisite, the acquisition of high quality meteorological data. We have several specific recommendations regarding that important requirement.

The first concerns the "cooperative substation" network of the National Weather Service (NWS) that was discussed in Sections 4b(ii) and 4c(i). This network, which is manned by volunteer observers, records the daily precipitation totals and (to a lesser extent) daily maximum and minimum temperatures for a large number of locations (e.g., approximately 200 in Illinois for rainfall). As such, it makes the primary contribution to the nation's ever-expanding bank of historical climate data. In addition, this network has the potential to provide the accurate and timely year-to-date and now-only information that is desired for the monitoring of in-season conditions. It also seems possible for this potential to be realized (see below).

Since this network is clearly the basis for much of the climate information currently being supplied to agribusiness, and is likely to remain so, the preservation and (preferably) enhancement of its integrity deserve to be high priorities. For example, there should be no further reduction in the station density that has occurred in recent years [see National Research Council

(1982, p. 53)]. Strenuous efforts ought to be made to identify and retain the oldest stations with the most reliable records, a research task now being initiated by Griffith (1983). In addition, attempts should be made to (a) standardize the observation time [see Schaal and Dale (1977) and Nelson et. al. (1979) concerning the problems caused by varying observation times]; (b) increase the number of parameters monitored; and (c) improve the accuracy of the measurements. While the NWS has obvious responsibilities in this regard, the issues concerned are also of great relevance to the USNCP (see p. 1). The latter could profitably become a leading advocate for the maintenance and improvement of this important network, one that is probably of greater value to agriculture than any other economic sector.

The NWS has reduced the number of its "first-order" stations in recent years. Although this trend may be arrested, it is unlikely to be reversed. This development is unfortunate because, from the agricultural standpoint, the observations made at these scattered stations (e.g., there are presently five in Illinois) usefully complement those acquired by the cooperative substation network. Not only do first-order stations monitor a much wider range of agriculturally relevant parameters than cooperative substations [e.g., clover cover, weather, humidity, and wind speed and direction, in addition to temperature and precipitation; cf. Sections 4b(iv) and 4c(v)], but the measurements are made on an hourly or continuous basis. Furthermore, the latter circumstance facilitates interpretation of and extrapolation from the cooperative substation daily temperature and precipitation observations.

We therefore recommend that the decline in the NWS first-order station network be compensated for as much as possible. It appears that the states will have to take the initiative in this regard. If they accept this challenge, the states vill have the opportunity to construct networks that not only complement the aforementioned NWS one, but have agricultural considerations firmly embedded in their design. Such considerations would include the location and spacing of the stations, and the parameters to be monitored. A relatively even spatial distribution of stations that has at least one sited in each agriculturally important area, such as a crop reporting district, would seem appropriate. Sections 4b(iv) and 4c(v) suggested that, in order to serve agribusiness needs, solar radiation, soil temperature and moisture, screen height temperature and humidity, and wind speed and direction should be measured on a continuous or (in the case of soil moisture) frequent basis. Fig. 1 provides information on one state (Illinois) climate network that is being established in accordance with the above suggestions, and whose development is now receiving guidance from the results of this investigation. Further details on this network appear in Hendrie (1983). Nebraska (Hubbard et al., 1983) and Ohio are other agriculturally important north-central states that have established state weather networks to support that activity.

Two notes of caution in the above regard should, however, be issued at this point. The first is that the installation and operation of such a network is very resource demanding. For example, the "set-up" costs of the aforementioned Illinois network will total close to $500,000, while the annual operating expenses will be in the vicinity of $80,000. In addition, it is imperative that the staffing of such networks include one or two individuals with electronics expertise. Clearly, one of these networks cannot be established without a substantial and on-going commitment from state government, either through a state agency or a university.

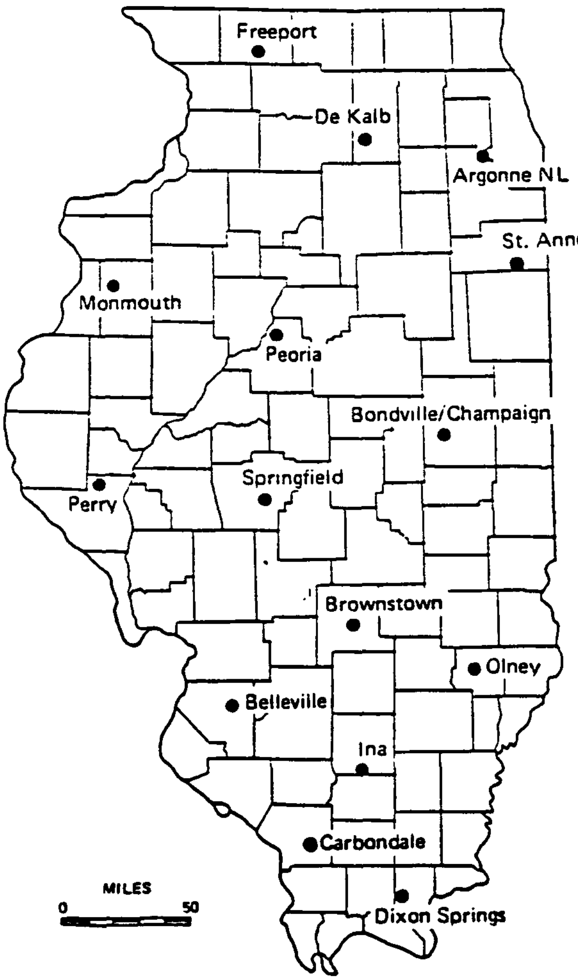

Fig. 1. Location of Illinois Climate Network stations. The stations continuously monitor the total flux of solar radiation (direct plus diffuse) on a horizontal surface, wind speed and direction at 10 m, screen height air temperature and relative humidity, precipitation, and soil temperature at 10, 20, and 40 cm. In addition, neutron-probe estimates of the soil moisture content of 20 cm layers between 0-2 m are obtained on a weekly, bimonthly, or monthly basis depending on the time of year.

Our second caution relates to the need for coordination among the state networks that might evolve in a given agricultural region. In order for their data to become the basis for climate information that is of the greatest possible utility to agribusiness, such networks will have to be reasonably consistent with respect to the sensors used, parameters monitored, and time periods over which integrations are made. This stems from the fact that the private agricultural sector's climate information needs tend to occur on a regional rather than state basis (cf., state government's requirements). It seems that the needed network coordination would be an ideal function for the USNCP's developing Regional Climate Centers (National Oceanic and Atmospheric Administration, 1983, p. 24; Hill, 1983), the first two of which have already been established (north-central and north-east regions). In fact, the North Central Regional Climate Center has already initiated project to assemble and manage the state network data from that 12-state region.

Conspicuously absent from the above discussion is the suggestion that any part of the acquisition of meteorological data be performed by private (i.e., nongoverment) agencies. A principal conclusion of the second Workshop Plenary Session, which dealt with the question of the relative roles of the public and private sectors in providing climate information for agribusiness (Appendix C), was that data collection should remain the responsibility of federal and state government organizations. The participants felt strongly that this was the best way to ensure that the observing procedures continue to be consistent, that the resulting data are accurate and credible, and that permanent archiving be performed by a "neutral" body. The need for meteorological data to have widespread credibility is a particular concern of agricultural chemical manufacturers, who must use that material in litigation over alleged product liability.

(ii) *Research needs*

The second step towards providing agribusiness with the best possible supply of climate information involves ascertaining what might be very simply and generally termed the "most appropriate formats" for that information. This will require considerable research. It is a potentially complex and open-ended task that has many dimensions. We here attempt to indicate some of the ways progress might be achieved in this regard.

- *First, it seems that the quality of this information supply would benefit from a concerted basic research effort in climatology that seeks to better understand the patterns and relationships contained within the historical data for important agricultural regions.*

This would greatly improve our knowledge of the climate (including its spatial and temporal variability) of the areas concerned, and accordingly constitute valuable background for decisions relating to the provision of climate information to agribusiness. The atmospheric science community has been slow to exploit the by now very large bank of historical data to this end. In particular, most of the work that has been undertaken has used these data in the time-averaged forms (e.g., monthly and seasonal means, both for individual years and longer periods) that are relatively easy to access and compact to process and analyze. Furthermore, the fine spatial resolution inherent in the cooperative substation data has seldom been fully realized; too many studies have used only the much sparser network of first-order stations. Because (a) growing season rainfall over much of the United States is convective and therefore highly variable in space and time and (b) crop development is particularly affected by runs of days of extreme temperatures, it is imperative that this research be performed on data that have rather fine temporal and spatial resolutions.

Fig. 2 provides an example of the type of product that can emerge from the above line of inquiry. This display divides the important agricultural region between the Rocky and Appalachian mountains into subareas within which weekly rainfall during the growing season tends to be spatially coherent. Separate patterns are given for the entire season and its constituent months. They result from an advanced statistical treatment (VARIMAX-rotated Principal Component Analysis) of 32 years of rainfall data for 402 cooperative substations that form an approximately rectangular grid. Full details on the computational procedures employed, along with a complete discussion of the results, appear in Lamb and Richman (1983a,b) and Richman and Lamb (1984). Here, however, we can only point out the potential for Fig. 2 to improve the use of climate information by agribusiness.

Section 4b(ii) stressed that the grain trade's operational crop yield prediction modelers are uncertain about the number and morphology of the regions for which individual models should be used, and also about the spatial representativeness of the observations they currently feed into the models. Because these observations have to be very recent, they are presently constrained to come from the sparse network of first-order stations. The latter is the only network for which daily updating is routinely possible. We believe that the patterns contained in Fig. 2 can substantially reduce the two above sources of uncertainty; their weekly time-scale coincides with the

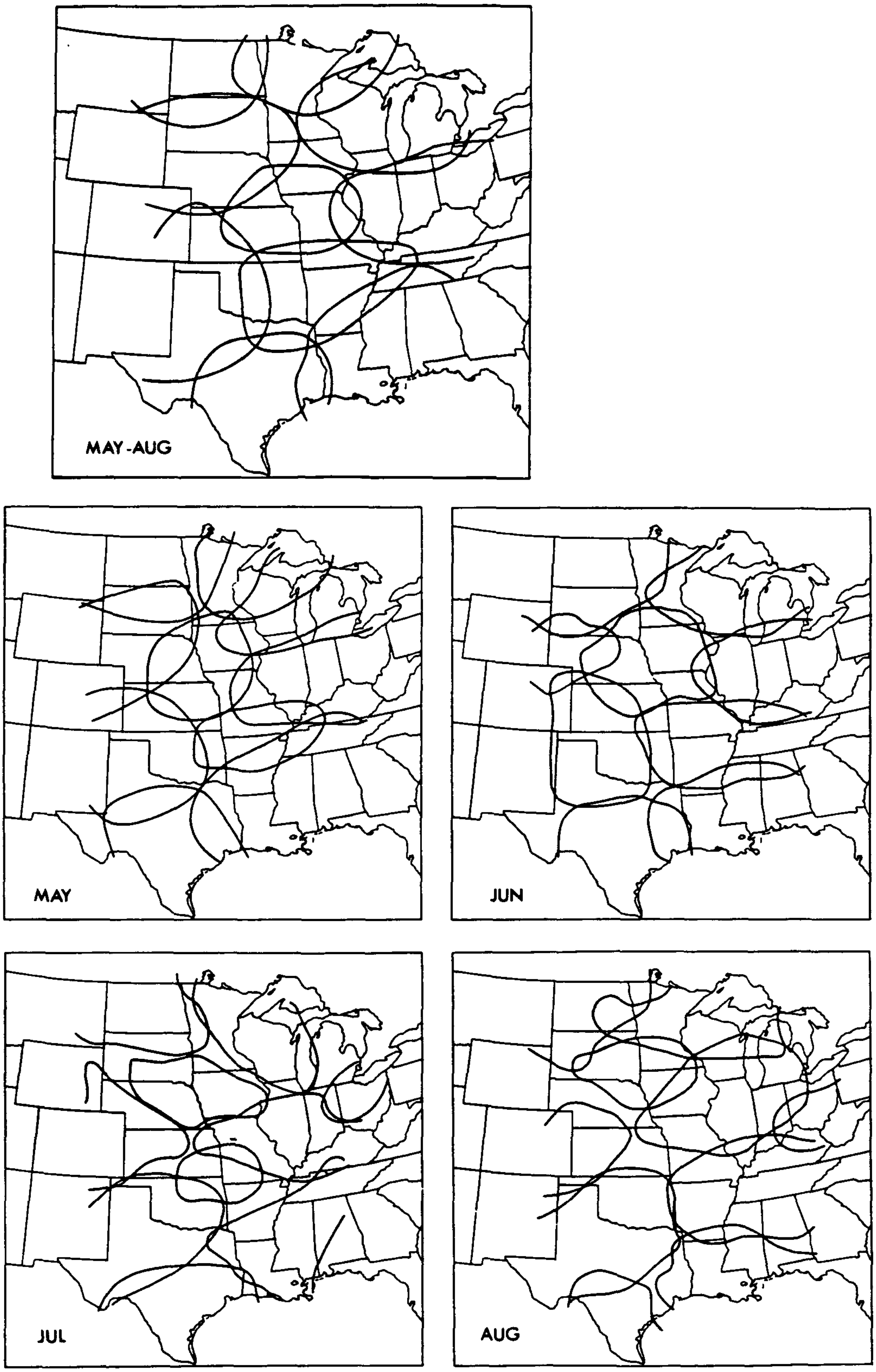

Fig. 2. Regionalization of the central United States for weekly summer rainfall on the basis of the patterns for the first 10 VARIMAX orthogonally rotated Principal Components (PCs). The regional boundaries are the +0.4 loading isopleths for each PC; they enclose areas for which at least 16% of the station variance is accounted for by that PC.

interval between many of the model runs. These patterns also suggest that intraseasonal variations should not be ignored. Counterpart analyses for temperature would be of further assistance in this crop modeling context.

To summarize, we have seen here an illustration of the potential for basic research using historical data to improve the agribusiness utilization of year-to-date and now-only information, and also climate predictions [see Section 4b(ii)]. Furthermore, similar research using data for longer time periods, examples of which appear in Lamb and Richman (1983b, 1984), could assist the location and planning of field trials and contract production by the chemical, seed, and canning companies [see Section 3b(i)].

Other analyses of the historical data base would benefit agribusiness. For instance, a comprehensive investigation of the variability of climate using daily observations would provide useful background for many activities, not the least of which is the ongoing development of plant growth regulators (PGRs) by chemical companies. This development process will in time require the assessment of these products' likely response to a wide range of possible environmental (largely climatic) conditions and extremes. This situation, in turn, will demand a more detailed documentation of past climatic variation than is presently available. It would also be useful to establish the extent to which entire medium-to-large states (e.g., Montana, Illinois, Texas) experience the same climate anomalies (e.g., "above normal" temperature, etc.) for individual months and seasons. Since the NWS's present monthly and seasonal climate predictions frequently place entire states or even regions in the same prediction category (e.g., "above normal" temperature, etc.) — the coarse spatial resolution that was disliked by the Workshop participants [see Section 4c(iii)] — such research could improve the utility of those predictions. Many other challenging basic research opportunities that could ultimately assist agribusiness exist for climatologists within the historical data base. A final example, taken from Changnon (1984), appears in Fig. 3. This provides an informative historical perspective on recent Illinois growing season rainfall fluctuations, and in particular shows that 1954-73 was highly favorable for agriculture.

- *A second way the climate information supply to agribusiness can be made more appropriate is through agrometeorological research that is designed to improve our understanding of the response of crops to climatic fluctuations.*

We need to have clearly identified — as functions of region, time of year, and crop type and variety — the weather conditions that most influence crop development and yield. Since it is highly probable that such conditions will involve the coincidence of particular values of more than one meteorological element (e.g., cool temperatures and excess precipitation, hot temperatures and low relative humidity), this research will have to provide for a wide range of possible outcomes. For example, Section 4c(iv) implied that the incorporation of solar radiation information into the purely temperature-based growing degree day accumulation statistic would enhance the latter's correlation with crop development. In short, there is an urgent need for the continued improvement of crop models and agroclimatic indices. This must occur before the agribusiness monitoring of in-season conditions, which is both important and growing, can be performed using the most appropriate year-to-date accumulations and now-only information. The latter are currently not well known.

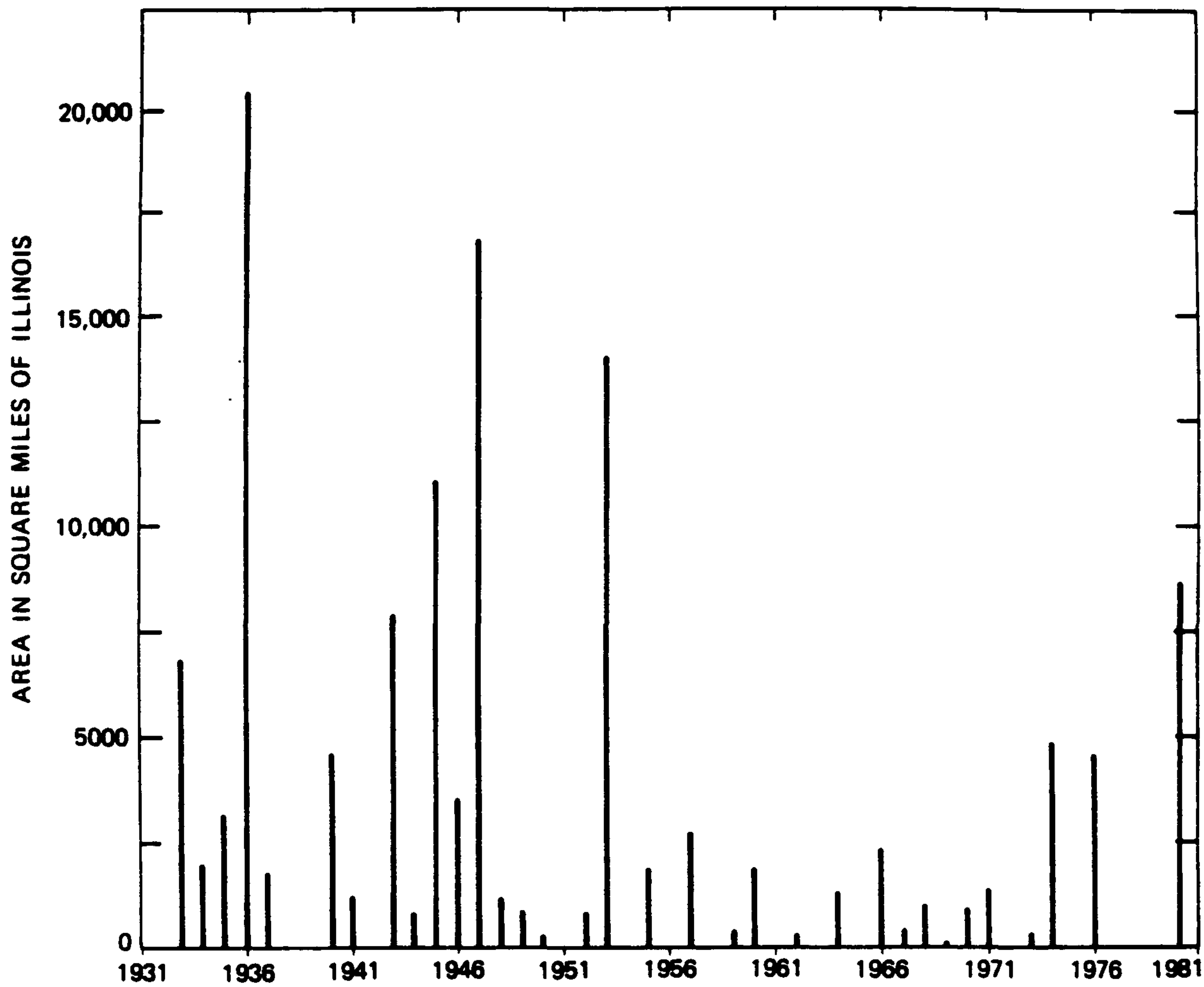

Fig. 3. Interannual variation of area within Illinois (total area = 55,748 square miles) that received less than 50 percent of normal July - August rainfall during 1931-81. The computations used data from a dense network of cooperative substations.

The accomplishment of the above task will not be easy. It will require a vide range of inputs. First, since the research will need the strongest possible physiological basis, it should exploit the wealth of information on crop-weather relations that exists within the records of trials that have been conducted previously at the agricultural experiment stations of Land Grant Universities. Further experimental work will also doubtless be necessary. Of equal importance, however, is the requirement that the results of this research have application to wide areas. They must not be too site specific, as is the case with at least some experimental plot work. Because of this need, the research will also have to utilize the historical climate data base, historical records of crop yields for crop reporting districts, and, where available, microclimate information for large areas such as is now being gathered by the Illinois Climate Network [see Section 5c(i)]. However, this necessary recourse to historical data should not force the research into an excessively statistical mode (cf., Huff and Neill, 1982). The approach that seems to be most appropriate would utilize both physiological and statistical methods. It is likely that the computer simulation of crop development (e.g., Reetz, 1976) can help substantially in that regard.

- *A third research effort that would substantially benefit the climate information supply to agribusiness is the development of and experimentation with appropriate economic models.*

This idea was introduced in Sections 4c(ii)-(iv) and 4d. As intimated there, such a line of inquiry would help in several important respects. First, it can provide conceptual frameworks for the utilization of climate information that in many instances do not currently exist. The latter deficiency **was** previously suggested to be one of the major contemporary impediments to a fuller use of climate information. In constructing such models, strenuous attempts should be made to incorporate the important non-climatic (e.g., economic, social, political) considerations that enter into the often complex decision making processes of this sector, as well as the relevant climatic factors. The models should be as rigorous and quantitative as possible. Their development probably should commence with rather narrowly-focused individual efforts that are limited to separate components of the sector (e.g., the production of row crops).

If the above structure can be achieved, the models will have the capability to quantitatively demonstrate the economic value of climate information for the activity concerned. This, in turn, should increase the agribusiness use of that material. Section 4c(ii) noted that the absence of such demonstrations has to date been an important impediment to a fuller utilization of climate information. Faced with that deficiency, and also the widespread perception that the management problems involving climate are especially complex, some agribusiness decision makers have tended to see little dividend in the sophisticated use of climate information. The development of appropriate economic models would permit much more rigorous future assessments of such dividends, while the latter may well prove to be larger than is presently thought. In addition, . experimentation with operational models would likely identify the most desirable formats for the needed climate information. The flexibility of the modeling approach would permit the estimation and intercomparison of the economic benefits to be obtained from a wide range of alternative "information designs". The products ultimately delivered to agribusiness (see next section) could be fashioned accordingly.

Table 15 provides a summary of a developing economic modeling research project that is being patterned along the lines advocated above, and which was partly motivated by the results of the present study. Its introduction here results from its illustrative value in the present context. The effort is restricted to considering the use of just one type of climate information (climate predictions) by a single agribusiness activity (Midwestern row crop production), a focus that was encouraged by the pilot study of Sonka jet. al. (1982). Central to this endeavor is the construction of an economic model capable of simulating the decision making processes of a farm operator in the setting of the physical and economic constraints on the "farm firm" and in an environment of uncertain outcomes. The economic benefits of using climate predictions will then be quantitatively estimated by comparing the results of running the model with "no prediction", "perfect prediction", and a range of "imperfect prediction" assumptions. This experimentation will also vary the prediction design, with the latter being specified by the likes of the prediction period, lead time, meteorological parameters treated, and resolution (see Sections 2d and 4d for definitions).

We expect that this research will begin to provide *ooncrete* information on such important issues as the optimum prediction design and the accuracy that must be attained before economic benefits accrue. Sections 3d, 4b(iii), and 4d indicated that many agribusiness decision makers *believe* that the climate predictions currently available are too unreliable to be useful and that they will need to become "highly accurate" before increased usage can occur. The possibility that these perceptions are incorrect has already been mentioned; they invite the type of quantitative investigation outlined above.

Table 15. Information on research project that is using an economic model. See Section 2d for explanations of climate prediction terminology.

TITLE: Design of Growing Season Climate Forecasts for Midwestern Agriculture

GOAL: To establish the characteristics climate predictions need to have to be useful for midwestern row crop production

COMPONENTS:

(1) Estimation of the interrelationships among climatic fluctuations, production practices, and crop yields. This seeks to isolate a farm operator's potential production practice flexibility.

(2) Development of an appropriate quantitative economic model that can be subsequently used to assess the value of alternative prediction designs and capabilities. This will include the relationships established in (1) above, and must be capable of simulating the decision making processes of a farm operator in the setting of the physical and economic constraints on the farm firm and in an environment of uncertain outcomes.

(3). Utilization of the model developed in (2) above to estimate the probable benefits of alternative prediction designs and capabilities. The design parameters to be considered include the prediction period, weather elements treated, lead time, and prediction resolution. The benefits of using climate predictions of various design will be estimated by comparing the results of running the model with "no prediction", "perfect prediction", and a range of "imperfect prediction" assumptions for prior years (e.g., 1979).

• *We next recommend that the three types of research advocated above be. conducted in environments that have strong traditions of scientific inauiry, such as universities and some government (federal and state) agencies.* Such institutions possess the large data bases, computer systems, experimental facilities, and curious personnel that are needed to accomplish the complex tasks involved. Although private meteorological companies may in due course prove able to furnish some routine climate information products to agribusiness, it is most unlikely that they have the resources to contribute significantly to the research that will ascertain the optimum design of those products .

• *Finally, we also have recommendations concerning the support of thvs research.* It seems that some of the required work lies within the terms of reference of existing National Science Foundation research programs, and therefore should be eligible for support from those sources. Presumably, too, some aspects of this work would benefit from the involvement and/or support of two other federal agencies, namely the United States Department of Agriculture (USDA) and the National Oceanic and Atmospheric Administration (NOAA). The latter is already playing the lead role in the research-based quest to improve climate predictions which, if accomplished, would clearly enhance their use by agribusiness. This objective is being pursued both within NOAA's relevant operational division [Climate Analysis Center; see Section 4c(iii)] and through the USNCP's Experimental Climate Forecast Center program (National Oceanic and Atmospheric Administration, 1980, 1983) that NOAA sponsors. Some extension of this type of effort into the areas outlined above, by both NOAA and the USDA, would be helpful. Furthermore, given the obvious potential utility of this research to agribusiness, it seems appropriate that some of the work be supported from private sources.

(iii) *Data assembly/processing and information delivery*

The next stage in the procedure that would improve the supply of climate information to agribusiness has three separate steps. These steps involve the assembly of the raw observational data, the processing of those data into the most desirable forms of information, and the delivery of that information to agribusiness users. We have specific recommendations concerning each of these activities.

• *In the case of the assembly of the raw observations, the most imortant requirement is that this function be performed as quickly as possible.* It **was** previously reported that the only NWS surface network for which the data are assembled in near real-time is the one containing the widely separated first-order stations that record on hourly or continuous bases. In contrast, the conventional national assembly and distribution of the daily temperature and precipitation data gathered at the much denser network of cooperative substations can take up to several months [see Sections 4b(ii) and 4c(i)]. Furthermore, although weekly summaries of substation data are available for some states during the growing season, relatively few locations are involved (e.g., about 20 in Illinois). Given the great potential of this network to be the basis for accurate and timely year-to-date and now-only information that has a fine spatial resolution, and the considerable need agribusiness has for such information, it is imperative that cooperative substation data from many stations be assembled at intervals of a few days to a week. At least initially, this task would be most easily accomplished on a state or regional (rather than national) basis. Furthermore, it would be desirable for data from state climate networks of the type advocated in Section 5c(i) to be assembled by the same system. This would increase the utility of the cooperative substation data (see earlier discussion).

That such an ambitious data assembly system is possible results from recent advances in electronic communications and computer systems. The actual data compilation would likely occur within the memory of a reasonably large central computer programmed to receive transmissions from the observing stations. Such transmissions could emanate either directly from the more sophisticated of the recording instruments or, in the case of the traditional cooperative substation measurements, from the volunteer observers themselves via touchtone telephone linkages. The availability of touchtone telephones substantially eases the digitization process and also facilitates quality control. The latter should be an integral feature of any future climate data assembly system.

The feasibility of establishing a data assembly system of the foregoing type is illustrated by recent developments in Illinois. Daily observations of maximum and minimum temperature and total precipitation from 35 cooperative substations in that state are now transmitted each morning to an Illinois State Water Survey computer via touchtone telephone. This initiative, which has been partly shaped by the results of the present project, cost $100,000 to implement [further details appear in Changnon _et_ _al_. (1984)]. The system's annual operating costs are expected to total $30,000. Data assembly, like data acquisition, thus requires a substantial investment.

It is unlikely that the NWS or the National Environmental Satellite,. Data, and Information Service (NESDIS) will organize and fund the nationwide establishment of near real-time data assembly systems that have station densities equal to that desired by agribusiness. For example, while the NWS has begun the installation (in the Central Region, CR) of a computerized system for the real-time acquisition of cooperative substation data that may eventually become nationwide, it is only including 15-20 stations per CR state (Friday, 1983; Vogel et al., 1984). This means that the bulk of the support for the "setting up" of more dense such systems will have to come from the states. The USNCP's Regional Climate Center program should be encouraged to fund these initiatives to the extent possible. At a minimum, however, that regional program ought to be responsible for the vital regional coordination of such efforts. Farm Bureau type organizations and trade associations may be other potential sources of funding for the establishment of these systems. The latter's operating costs, on the other hand, could probably be covered by charging users who acquire data from them (see below).

The routine operation of the systems would be most consistent and reliable if placed in the hands of government agencies or regional organizations with whom the former are affiliated, rather than private meteorological (or other) companies. Such companies are furthermore unlikely to contribute to the establishment of these systems. There would seem to be a much greater potential for private sector involvement in the second and third of the steps being considered in this section.

- *The second such step involves transforming the assembled raw data into the information forms most desired by agribusiness.*

Where year-to-date and now-only information are required, this process would occur routinely. In the case of information to be extracted from historical data, on the other hand, it would likely take place on a more individual basis. The determination of the nature of such information products should draw heavily on research of the type advocated in Section 5c(ii). It will also need to be guided by an intimate appreciation of each user's needs, which will vary substantially as a function of agribusiness activity. For example, while very small agribusiness concerns (e.g., pest management consultants) will likely require sophisticated information, larger organizations (e.g., grain traders) may have the capability and desire to do much of the analysis themselves using raw data. The effective performance of this information generation role will therefore be rather demanding.

Such a role is made possible by recent developments in the computer and communications fields. The organizations involved in this work will need to possess a computer system that is capable of quickly performing the required calculations, contains all relevant historical data, and is linked with both the source(s) of the raw observational data and the users of the generated information. Relevant data sources would include the state/regional assembly systems of the type advocated above, and probably also the National Climatic Data Center (NCDC) in Asheville, North Carolina.

It is likely that this climate information generation could be satisfactorily performed by private meteorological companies; they would purchase the raw data and sell the information products. There is already some limited but competent activity along these lines. The expansion of such efforts could produce, via the resulting economies of scale, the needed relatively cheap method of providing agribusiness with useful climate information. Section

4c(v) noted that the sector is sensitive to the cost of this material. This. information generation role could also be assumed by state agencies with the requisite expertise and the USNCP's developing regional climate centers. However, both types of institution would have to be permitted to charge for such services. Given agribusiness' aforementioned need for regional scale information, the development of regional climate information centers would seem especially appropriate.

• *The final step to be considered in this section is the actual delivery to aaribusiness users of climate information products that have the foregoing genesis.* As already intimated, this would ideally occur via computer linkages and be best performed by the organizations who generate those products. It may prove possible for trade associations and Farm Bureaus to at least partially support the establishment of the needed information dissemination networks. While the USNCP's Regional Climate Center program should assume a coordinating role in this context, as well as the others considered above, any further involvement by that program would probably be outside its area of responsibility.

The above type of distribution system would obviously require the user to maintain some kind of computer facility, one that should not necessarily be limited to a terminal for the receipt of the climate information. This is unlikely to be a problem for the larger agribusiness organizations. It should also be within the reach of the smaller concerns, given the increasing availability and decreasing cost of computer hardware, and the accessibility of guidance on the use of that equipment (e.g., Sonka, 1983). By receiving climate information in this way, users would have the flexibility of subjecting it to any further processing their experience might recommend.

(iv) *User education*

The final prerequisite for maximizing the utilization of climate information by the private agricultural sector is user education. This should seek to give potential users the best possible appreciation of the availablility, utility, cost, and value of such information, and thus render them able to make informed decisions about the extent of their utilization. Decisions of that type are not always possible at present. We have several specific recommendations on this subject.

First, there is a clear need for many agribusiness decision makers to become better acquainted with the range of climate information that is presently available. This is evidenced by the fact that approximately 20 percent of the questionnaire respondents perceived historical climate data to be unavailable (cf., Tables 2 and 12). Such an education effort should be sufficiently broad-based to encompass the sources and alternative formats (e.g., pamphlets, magnetic tape, etc.) of the information, the typical costs and time delays involved in its acquisition, and the explanatory material that would facilitate its utilization. The latter would likely be especially valuable for climate predictions. An initiative of this type should remove at least some of the impediments listed in Section 4c(v). It could logically emanate from state or regional climate centers, and include instructional publications in trade journals and the conducting of Workshops for potential users. The USNCP's Regional Climate Center program should, at a minimum, encourage and coordinate such efforts. In addition, there would seem to be a clear role for trade associations and Farm Bureau type organizations to play in the facilitating and funding of this educational initiative, given that it will be to the benefit of their members. When the initiative is directed at producers, the Cooperative Extension Service should be involved.

There is also a need for agribusiness decision makers to be routinely updated on the new climate information products that become available. This particularly applies to information shaped by or emanating from relevant research, such as that advocated in Section 5c(ii). It is imperative that this educational effort include demonstrations of the utility and value of new information, especially the most innovative and novel. One way to accomplish this would be through "closed demonstration projects," in which the use by a limited number of selected participants (for little or no cost) is very closely guided and monitored for an appropriate period of time. This could provide the basis for the final design of an information product, the documentation of its likely utility and value, and the instructions for its use. The latter material could be subsequently communicated to potential users via the trade journal articles and Workshops mentioned above. We believe that this procedure would hasten the profitable utilization of new climate information products by agribusiness. To be of the utmost success, it would require the professional expertise of state and regional climate centers, coordination by the USNCP's Regional Climate Center Program, the involvement of the Cooperative Extension Service, and financial and logistical support from agribusiness itself, perhaps via the likes of trade associations and Farm Bureau type organizations.

Ultimately, it will not be possible to provide agribusiness with the best possible climate information without the appreciable involvement and assistance of that sector.

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APPENDICES

APPENDIX A

Questionnaire survey administered by mail to agribusiness decision makers during the spring of 1982.

Section I

1. Does your firm (farm) currently use records of historical rainfall amounts or temperature levels?

RAINFALL: YES____________VQ ______

TEMPERATURE: YES____________NO ______
(If NO to both, please skip to question 10)

2. Are these data used as general background information, or are they required for specific decisions?

GENERAL BACKGROUND: YES____________NO ______

SPECIFIC DECISIONS: YES____________NO ______

3. If used in specific decisions, for what types of decisions are they used?

a.____

b.____

c.____

d. ____

4. Are these data used in any type of mathematical eauation or formula in helping your firm (farm) make decisions:

YES______________________NO ______

5. Is this data summarized only on an annual basis?

YES______________________NO ______
(If YES go to 7)

6a. For what seasons are the data summarized?

SPRING ______

SUMMER ______

FALL _______

WINTER ______

6b. What type of data do you use? DATLY ______

WEEKLY _____

MONTHLY _____

ANNUAL ______

7. For what geographic area are the data compiled?

SMALLER THAN A COUNTY ________ COUNTY ________ STATE _

CROP REPORTING DISTRICT ________ LARGER THAN A STATE ______

8. Do these data relate to the United States and/or foreign countries?

UNITED STATES: YES ________ NO ____

FOREIGN: YES ________ NO ____

9. How do you acquire these data?

DIRECTLY FROM NATIONAL WEATHER SERVICE _______

FROM OTHER GOVERNMENT AGENCIES ________

FROM PRIVATE CONSULTANTS ________

FROM OTHER SORUCES ________

10. Why do you presently not use such data? (Check those statements in a-c with which you agree.)

a. DATA HAVE NO VALUE TO US _______

b. DATA NOT AVAILABLE ______

c. TOO COSTLY TO CONVERT DATA TO A USABLE FORM _______

d. OTHER (please specify) ________

11. If you could receive data on historic Drecipitation and/or temperature levels at no cost to you, what weather events would you like to know about? (Please describe as to time and location of these events.)

Weather event Time period Area

a. ________

b. ________

c. ________

12. If more than one weather event is listed in 11, which would be most useful in making business decisions?

13. What business decisions does that event affect?

a.________________________________

b. ________________________________

c.________________________________

Section II

14. Does your firm (farm) currently use data on "year-to-date" precipitation amounts or temperature levels?

PRECIPITATION: YES________NO ____

TEMPERATURE: YES________NO ____
(If NO to both, please skip to question 22)

15. Are these data used as general background information, or are they required for specific decisions?

GENERAL BACKGROUND: YES________NO ____

SPECIFIC DECISIONS: YES________NO____

16. If used in specific decisions, for what types of decisions are they used?

a. ________________________________

b. ________________________________

c.________________________________

d. ________________________________

17. Are these data used in any type of mathematical equations or formula in helping your firm (farm) make decisions?

YES________________NO ____

18. During what seasons do you use this data?

WINTER______________SPRING ____

SUMMER______________FALL ____

19. For what geographic area are the data compiled?

SMALLER THAN A COUNTY____________COUNTY_______STATE ____

CROP REPORTING DISTRICT____________LARGER THAN A STATE ____

20. Do these data relate to the United States and/or foreign countries?

UNITED STATES: YES____________MO _____

FOREIGN: YES____________NO _____

21. How do you acquire these data?

DIRECTLY FROM NATIONAL WEATHER SERVICE ______

FROM OTHER GOVERNMENT AGENCIES ________________

FROM PRIVATE CONSULTANTS ______

FROM OTHER SORUCES ______

22. Why do you not use this type of data? (Check those statements in a-d with which you agree.)

a. NO NEED FOR IT ______

b. NOT AVAILABLE ______

c. TOO COSTLY ______

d. NOT AVAILABLE WHEN I NEED IT ______

e. OTHER (Please specify) ________________________________

23. If you could receive data on "year-to-date" precipitation and/or temperature levels at no cost to you, what weather events would vou like to know about? (Please describe as to time and location of these events.)

Weather event Time period Area

a. ____

b. ____

c. ____

24. If more than one weather event is listed in 23, which would be most useful in making business decisions?

25. What business decisions does that event affect?

a.____

b. ____

c. ____

26. When you are using such data, how current does it have to be to be useful? (CIRCLE ONE)

AS OF: YESTERDAY: ____

PREVIOUS WEEK: ____

PREVIOUS MONTH: ____

OTHER: ________________ (EXPLAIN)

27. How much would you pay (per year) for such information?

$________________

Section III

28a. Does your firm (farm) use short-term weather forecasts such as given by local radio or TV stations:

YES________________NO______

28b. If YES, are these the only forecasts your firm (farm) uses?

YES________________NO ____

29. Does your firm (farm) currently use longer-term forecasts of future precipitation or temperature levels?

PRECIPITATION: YES__________MO ____

TEMPERATURE: YES__________NO ____

(If NO to both, please skip to question 39.)

30. Are these forecasts used as general backgound information or are they required for specific decisions?

GENERAL BACKGROUND: YES__________NO ____

SPECIFIC DECISIONS: YES__________NO ____

31. If used in specific decisions, for what decisions are they used?

a. ________________________________

b. ________________________________

c. ________________________________

d. ________________________________

32. Are these data used in any type of mathematical equation in helping your firm (farm) make decisions?

YES ____________________ NO ____

33. For what length of period do these forecasts relate:

DAILY __________________ WEEKLY _____

MONTHLY _________________ ANUALLY _____

34 For what season are your forecasts?

WINTER __________________ SPRING ____

SUMMER __________________ FALL _____

35. For what geographic area are the forecasts required?

SMALLER THAN A COUNTY ________________ COUNTY ________ STATE ____

CROP REPORTING DISTRICT _______________ LARGER THAN A STATE _____

36. Do the forecasts relate to United States and/or foregin countries?

UNITED STATES: YES ___________ NO ____

FOREIGN: YES ___________ NO ____

37. How do you acquire these forecasts?

DIRECTLY FROM NATIONAL WEATHER SERVICE ____

FROM OTHER GOVERNMENT AGENCIES _____

PRIVATE FORECAST SERVICES ____

FROM OTHER SOURCES ____

38. How far in advance of the weather event do you receive these forecasts?

ONE DAY ______________________________ ONE WEEK ____

ONE MONTH ____________________________ TWO MONTHS ____

MORE THAN TWO MONTHS ____

Please skip to 40

39. Why do you presently not use long-term forecasts of precipitation or temperature in your firm?

NO NEED FOR INFORMATION ____

PRESENT FORECASTS ARE NOT SUFFICIENTLY ACCURATE _____

PRESENT FORECASTS ARE NOT AVAILABLE SOON ENOUGH _____

40. If you could receive long-term forecasts of future precipitation or temperature events, what events would you want to know about?

a.____

b.

c. ____

41. Of the events listed in 39 above, which would be most helpful to you in making business decisions?

42. What types of decisions does the event cited in 40 affect?

(use additional space as necessarv)

43. How far in advance of that event would you like to have the forecast?

44. What is the minimum lead time which the forecast could have been made and still have been useful to you?

45. How manv years it of ten would the forecast have to be approximately correct before it would affect your decision?

1___ 2___ 3___ 4___ 5___ 6___ 7___ 8___ 9___ 10___

46. How much would you pay per year for such a forecast?

$____________________

47. Please comment as to additional needs of your business for weather related information. Please be specific as to how vou could use such information.

APPENDIX B

Professional information (title, company, location) on each respondent to the nationwide mail questionnaire survey reproduced in Appendix A.

<u>Agricultural Chemical Manufacturers</u> (5)

Vice President (Research and Development), Agricultural Division, Ciba-Geigy Corporation, Greensboro, North Carolina.

Manager (Environmental Regulatory Activities, Water), Dow Chemical Company, Midland, Michigan.

Head (Plant Physiology Research), Lilly Research Laboratories (Division of Elanco Products), Greenfield, Indiana.

Director (Product Development), Monsanto Agricultural Products, St. Louis, Missouri.

Manager (Field Development and Technical Services), Shell Development Company, Houston, Texas.

<u>Agricultural Finance Companies</u> (12)

Vice President and Farm Loan Officer, Clinton County Bank and Trust Company, Frankfort, Indiana.

President, Citizens' State Bank of Norwood, Norwood, Minnesota

County Supervisor, Farmers' Home Administration, Jackson, North Carolina.

Vice President (Credit), Federal Land Bank of Wichita, Wichita, Kansas.

President, First Central State Bank, DeWitt, Iowa.

Senior Vice President, First Farmers' State Bank of Minier, Minier, Illinois.

Vice President, First National Bank of DeKalb, DeKalb, Illinois.

President, Fox Valley Production Credit Association, Morris, Illinois.

President, Production Credit Association-Lincoln, Lincoln, Nebraska.

President, Production Credit Association of Madison, Madison, Wisconsin.

Vice President, Rockingham National Bank, Harrisonburg, Virginia.

Vice President (Agribusiness Affairs), Wells Fargo Bank National Association, San Francisco, California.

<u>Food Processing/Canning Industry</u> (8)

Agricultural Research Manager (Eastern Production), Del Monte Corporation, Rochelle, Illinois.

General Manager, Dutch Valley Growers, South Holland, Illinois.

Agricultural Manager (Midwest), Heinz USA, Fremont, Ohio.

President, Joan of Arc Company, Peoria, Illinois.

District Manager (Contract Agriculture), Libby, McNeill, and Libby Inc., Morton, Illinois.

Agricultural Supervisor, Pillsbury Green Giant Company, Belvidere, Illinois. -
Agricultural Research Manager, Stokely-Van Camp, Indianapolis, Indiana.
Vice President (Agriculture), Viasic Foods Inc., Detroit, Michigan.

Grain Trade (19)

Manager, Anderson's Grain Company, Champaign, Illinois.

Assistant Vice President, A. G. Becker Inc., Chicago, Illinois.

Commodity Broker, Blunt, Ellis and Loewi, Decatur, Illinois.

District Manager, Bunge Corporation, Cairo, Illinois.

Research Analyst, Clayton Brokerage Company, St. Louis, Missouri.

Economic Analyst, Con Agra Inc., Omaha, Nebraska.

Vice President (Commodity Research), Continental Grain, New York, New York.

Research Data Analyst, Continental Grain, Chicago, Illinois.

Senior Agricultural Meteorologist and Crop Analyst, Control Data Corporation, Minneapolis, Minnesota.

Manager (Product Systems Research), Deere and Company, Moline, Illinois.

Manager, Farmers' Grain and Livestock Corporation, West Des Moines, Iowa.

Staff Economist, *Farm Journal,* West Lafayette, Indiana.

Grain Division Manager, Gelderman and Company Inc., Chicago, Illinois.

Chief Economist and Research Director, Heinold Commodities, Chicago, Illinois.

Chief Meteorologist and Assistant Vice President, E. F. Hutton and Company, Milwaukee, Wisconsin.

Account Executive, E. F. Hutton and Company, St. Charles, Missouri.

Senior Manager (Commodity Development), M and M/Mars, Hackettstown, New Jersey.

Vice President, Schnittker Associates, Washington, D. C.

Corporate Economist, A. E. Staley Manufacturing Company, Decatur, Illinois.

Integrated Pest Management Consultants (12)

Nematologist, Agri-Growth Research Inc., Hollandale, Minnesota.

Consultant, Ag. Service of Texas, Wharton, Texas.

Owner, Ascheman Associates, Des Moines, Iowa.

Crop Consultant, Spencer, Iowa.

Owner, Crop Pro-Man Inc., Glenwood, Iowa.

President, Crop Tech. Services Inc., Cedar Rapids, Iowa.

Owner/Agronomist, Eck-Cel Crop Production Consultation, Sioux City, Iowa.

Manager (Crop Monitoring Service), Laverty Sprayers Inc., Indianola, Iowa.

Owner, Nissen Crop Advising Service, Clear Lake, Iowa.

Owner/Entomologist, Pest Management Consultants Inc. , Lincoln, Nebraska.

Consultant, Prairie Crop Pro-Tech, Waterloo, Iowa.

Owner, Schaaf Consulting, Ames, Iowa.

Producers (2 7) (types specified were taken from questionnaire responses)

Farmer (corn, soybeans, cattle feeding), Altona, Illinois.

Fanner (cash grain; Past President of Corn Growers Association), Altona, Illinois.

Fruit Grower (apples, Peaches), Belleville, Illinois.

Farmer (Christmas trees), Champaign, Illinois.

Fruit and Vegetable Grower (general), Chester, Illinois.

County Extension Advisor, Geff, Illinois.

County Executive Director (USDA Agricultural Stabilization Board), Geff, Illinois.

Fruit Grower (apples, peaches), Grafton, Illinois.

Fruit Grower (apples), Griggsville, Illinois.

Farmer (cash grain), Harvard, Illinois.

Farmer (cash grain), Ogden, Illinois.

Farmer (cash grain), Ogden, Illinois.

Farmer (cash grain), Ohio, Illinois.

Farmer (corn, beans, swine), Oneida, Illinois.

Fruit Grower (apples), Poplar Grove, Illinois

Farmer (cash grain), Seymour, Illinois.

Farmer (cash grain), Sims, Illinois.

Fruit Grower (apples), Speer, Illinois.

Farmer (cash grain), Spring Valley, Illinois.

Farmer (cash grain), Walnut, Illinois.

Farmer (cash grain, livestock), Woodhull, Illinois.

Farmer and Farm Manager (corn, soybeans), Lewisville, Minnesota.

Rancher (livestock feeder), Fort Stockton, Texas.

Rancher (beef), Fort Stockton, Texas.

Farmer (cotton), Knott, Texas.

Farmer (cotton), Midkiff, Texas.

Farmer (cotton), Midland, Texas.

Professional Farm Managers (13)

Owner/Farm Manager, J. Blackburn Farm Management Company, Fresno, California.

Farm Managers, Doane Western Management Company, Phoenix, Arizona.

Vice President/Farm Manager, Farmcraft Service Inc., Logansport, Indiana.

District Farm Manager, Halderman Farm Management Service Inc., Lafayette, Indiana.

Vice President/Farm Manager, Hertz Farm Management Inc., Monticello, Illinois.

Board Chairman/Farm Manager, Hertz Farm Management Inc., Nevada, Iowa.

President/Farm Manager and Rural Appraiser, Hoysler Real Estate Service, Faribault, Minnesota.

Vice President/Farm Manager, Hutchinson National Bank and Trust, Hutchinson, Kansas.

Farm Manager, Jensen and Associates Farm Management Service, Dubuque, Iowa.

Sole Owner, Larson Farm Management, Princeton, Illinois.

Senior Vice President and Trust Officer/Farm Manager and Rural Appraiser, National Bank of Bloomington, Bloomington, Illinois.

Farm Manager, J. Sawyer Company, London, Ohio.

President/Farm Manager, Stalcup Agriculture Service, Storm Lake, Iowa.

Rural Insurance Industry (6)

Executive Secretary and Manager, Crop-Hail Insurance Actuarial Association, Chicago, Illinois.

Director (Actuarial Division), Federal Crop Insurance Corporation, United States Department of Agriculture, Kansas City, Missouri.

Assistant Manager, Insurance Services Office, New York, New York.

Assistant General Manager, Crop Insurance Research Bureau, National Association of Mutual Insurance Companies, Indianapolis, Indiana.

President, Reinsurance Association of America, Washington, D.C.

Director (Natural Hazards Program, Corporate Research Division), Travellers' Insurance Company, Hartford, Connecticut.

Seed Production Companies (5)

General Manager (U. S. Agronomics), Asgrow Seed Company, Kalamazoo, Michigan.

Manager (Agronomic Services), DeKalb Ag Research, DeKalb, Illinois.

President, Funk Seed International, Bloomington, Illinois.

Directors (Plant Breeding and Biotechnological Research Divisions), Hi-Bred International Inc., Johnston, Iowa.

Research Coordinator, North American Plant Breeders, Ames, Iowa.

APPENDIX C

Workshop to Assess the Present and Potential Use of Climate Information by the United States Private Agricultural Sector

Sturgeon Bay, Wisconsin

8-9 August 1982

Arranged by: Illinois State Water Survey, Champaign

Sponsored by: National Science Foundation
United States Department of Agriculture
Country Companies
Growmark
Crop-Hail Insurance Actuarial Association
State of Illinois

AGENDA

(1) Sunday 8 August (evening, 6-9 pm)

(a) Welcome, Introductions, Dinner

(b) *"Why are we here?"* — an attempt to place the Workshop in the context of international and U. S. Atmospheric Science policy developments that have resulted from the climatic fluctuations experienced during the last 10-15 years.
(Speaker: Peter J. Lamb)

(c) Review of the results of the earlier questionnaire survey and statement of the hypotheses they suggest. This material will provide the basis for much of Monday's effort.
(Speaker: Steven T. Sonka)

(2) Monday 9 August (morning, 8 am - 12 noon)

(a) Group Discussions: Participants' reactions to the results of the questionnaire survey, especially those dealing with the present use of climate information.

(b) *"How can we serve agribusiness?"* — a survey of the extent to which a government agency such as the Illinois State Water Survey (which deals with water and atmospheric resources) could assist the agribusiness community, and the facilities and support that would be needed ... from the present perspective of the Chief of the Illinois State Water Survey. This will set the stage for the rest of the Workshop ... which will seek to establish the industry's perspective on the matter.
(Speaker: Stanley A. Changnon, Jr.)

(c) Brief review of the present availability of climate information (excluding predictions). Written materials on this topic will be distributed.
(Speaker: Wayne M. Wendland)

COFFEE BREAK

(d) Group Discussions: Participants' views on the major impediments to a fuller present use of climate information by this sector.

(3) Monday 9 August (afternoon, 1-4 pm)

(a) Plenary Session: Review of morning discussions.
(Chairman: Steven T. Sonka)

(b) *"An introduction to climate prediction"* — a brief review of relevant terminology (e.g., climate - versus - weather prediction, lead time, prediction period, resolution, accuracy, skill, etc) and the current procedure, format, and skill levels of National Weather Service climate predictions.
(Speaker: Peter J. Lamb)

(c) Group Discussions: Participants' views on the major future climate prediction needs by this sector.

(d) Plenary Session: The question of the relative roles of the public and private sectors in providing climate information for agribusiness.
(Chairman: Steven T. Sonka)

(e) Closing

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