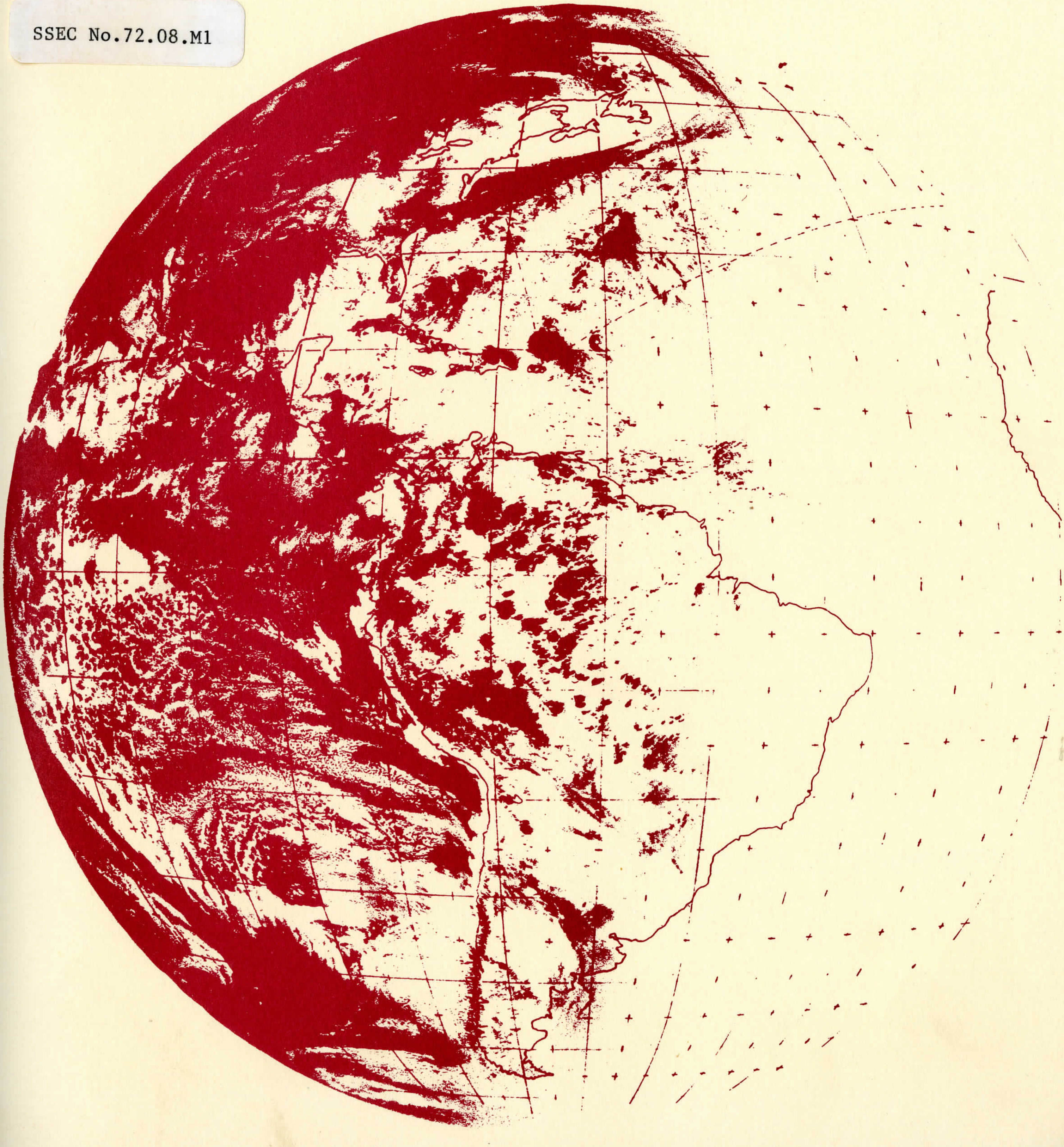
multidisciplinary studies of the social, economic, and political impact resulting from recent advances in satellite meteorology

an interim report
volume three

space science and engineering center
the university of wisconsin
madison, wisconsin



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MULTIDISCIPLINARY STUDIES OF THE SOCIAL, ECONOMIC AND POLITICAL IMPACT RESULTING FROM RECENT ADVANCES IN SATELLITE METEOROLOGY

Interim Report on

NGL 50-002-114

Volume III

The research in this document has been supported by the National Aeronautics and Space Administration.

August 1972

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PREFACE

This research is providing a detailed analysis of the social, legal, organizational and economic benefits of satellite meteorology. The multidisciplinary team at the Space Science and Engineering Center at the University of Wisconsin has undertaken to ascertain and isolate these benefits as an in-depth research effort. This effort was begun in 1969 and a two-volume interim report was issued in June 1971 consisting of some 890 pages.

The reports contained in the present two volumes include continued work on economic benefits, legal implications, management systems, and agricultural impacts. This research area which combines a working knowledge of satellite meteorology with expertise in various related software areas promises to, for the first time, produce data on the practical effects and impact of meteorological satellites.

We are grateful for the continued support of NASA and are looking forward to further research which we hope will benefit the entire nation.

Verner E. Suomi
Delbert D. Smith

MULTIDISCIPLINARY STUDIES OF THE SOCIAL, ECONOMIC AND POLITICAL IMPACT RESULTING FROM RECENT ADVANCES IN SATELLITE METEOROLOGY

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INTRODUCTION

Delbert D. Smith
Richard Martin

Technology traditionally outruns the social and legal thinking needed for orderly, efficient and humanitarian implementation of scientific developments. The consequence of this tendency is "cultural lag," the much-lamented disparity between science and the humanities. Hardware development too often precedes serious study of alternate applications and sociological consequences of new technological capabilities. At times, the result of this sequence of events is irreparable damage to the potential social usefulness of new scientific developments.

In the communications field, for example, research and development agencies often have little direct contact with the user public. Without a specific feedback mechanism, operators of the mass media systems have traditionally served as "linkers" between the user public and the available technology. Such a linkage has three notable weaknesses. First, it is not a formalized, established procedure, and as a result, the communication is often more speculative than systematic. Second, it is slow-moving. Third, the particular interests of the intermediary—the mass media operator—undoubtedly serve to filter and, in some cases, distort the real needs and desires of the user public. The field of weather information communication is a case in point. The National Aeronautics and Space Administration has developed advanced satellite capabilities which make great amounts of new, useful weather information available. Presently, this information is not communicated directly to the user public, but depends on the mass media for interpretation and dissemination.

The "user approach" employs social science research tools to more systematically anticipate and enhance the social uses to which modern technology can be applied. On the basis of systematic user research findings, guidelines can be formulated which minimize conflicts, delays and abuse in the implementation and operation of the technology. Most important, various alternative applications can be contemplated free from the pressures of already-established interests. On this basis, recommendations can be made for using new technology in ways that optimize the social benefit to the user public.

Returning to the example of weather information communication, it has been found that the mass media "linker" between the user public and satellite weather pictures is not ideally suited to determine user needs and priorities. Commercial interests, financial limitations, programming schedules, insufficient weather expertise, and lack of survey research capabilities compromise the quality and quantity of weather information available to the public. The "user approach" uses survey research, interviews with experts and user groups, and multidisciplinary academic studies to systematically and objectively evaluate the public need. On the basis of these findings, recommendations can be formulated for tailoring weather information to suit the needs, not of the mass media "linker," but of the user public itself.

The "user approach" in effect interposes a more sensitive feedback transmitter between the technology and the potential user, and makes the technology directly responsive to the social priorities of the public. The emphasis on the user approach exemplified by earth resources satellites, communications satellites, meteorological satellites, and the space shuttle reflects a renewed commitment on the part of many research and development agencies to directly serve the pressing needs of society. The ultimate goal of the user approach is to make systematic user research an integral part of all stages of research, development, implementation, and operation of new space science applications.

Systematic user research is best accomplished early in the research and development process. Research into applications of existing technology at best can influence the operation of the technology. As such it is still an *ex post facto* approach in which the nature of the service to the user is dictated by the shape of already-developed hardware. Ideally, user-research *anticipates* research and development, making it possible to build hardware which, from its inception, responds to the needs of the user public.

Volumes III and IV continue the work begun in Volumes I and II and further demonstrate the need for nowcasting, which is a greatly increased and improved dissemination of present weather information and its extrapolation up to six hours into the future.

Volume III contains an economic evaluation of recent advances in weather satellite meteorology, a legal study related to satellite use, a survey of comprehension and use of weather information, and an economic analysis of the production of peas and the impact of long-range weather information. Volume IV contains a study of weather satellite program management and organization systems, a work on tornado forecasting and an addendum to an earlier study on corn production.

ECONOMIC PROJECT PERSPECTIVES: AN OVERVIEW OF THE IMPACT RESULTING FROM RECENT ADVANCES IN SATELLITE METEOROLOGY

Kenneth R. Smith
Frederick H. Boness*

1. INTRODUCTION

Improving the accuracy and extending the range of weather forecasts can be expected to have an impact upon a large number of activities in many parts of the country. No study, working with limited funds and time, could actually analyze and evaluate the economic impact of such improved weather forecasting in every activity. But even if funds and time were not restricted, we would still think it a waste of resources to study every activity since it is possible to generalize the results of the analysis of certain activities to those activities which are similar. Of course, the generalizations will represent imprecise estimates, but this should not be too serious if care is exercised in extrapolating the findings of a particular case.

The best estimates of the total impact of improved weather forecasting can be generated by first dividing the economy into a small number of sectors, each of which encompasses a broad range of similar activities. Within each of these sectors we further subdivide hierarchically until we arrive at the basic unit—the individual activity. By selecting some activities from each sector as case studies and keeping in mind the similarities which

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they bear to nonselected activities, we can make rough estimates of the total impact upon each sector of the economy.

As illustrated by figure 1, in this study the economy has been divided into five major sectors: agriculture, commercial activities, resource utilization, manufacturing, and government. The order in which they are listed represents the general importance of weather to the sector; for example, weather has a much greater effect upon agricultural activities, which are primarily conducted outdoors, than on manufacturing activities which are primarily conducted indoors. The activities studied in this project are drawn from the first three sectors since the effect of weather in the latter two is extremely small. Furthermore, when the government and manufacturing sectors do engage in activities which are affected by weather, we can frequently include such activities in one of the other sectors; for example, resource management by the government—forest service activities, TVA, flood control, and so on—can be treated under the category of resource management rather than government.

We have above identified the scheme for extrapolation and generalization of the findings of a case study of a particular activity to similar activities. There is a second type of generalization which we must mention, namely the extension of the findings of a case study of a particular activity in one region of the country to that same activity (or related activities) in another part of the country. Since most of the case studies concentrate on Wisconsin, it has been necessary to consider which aspects are general

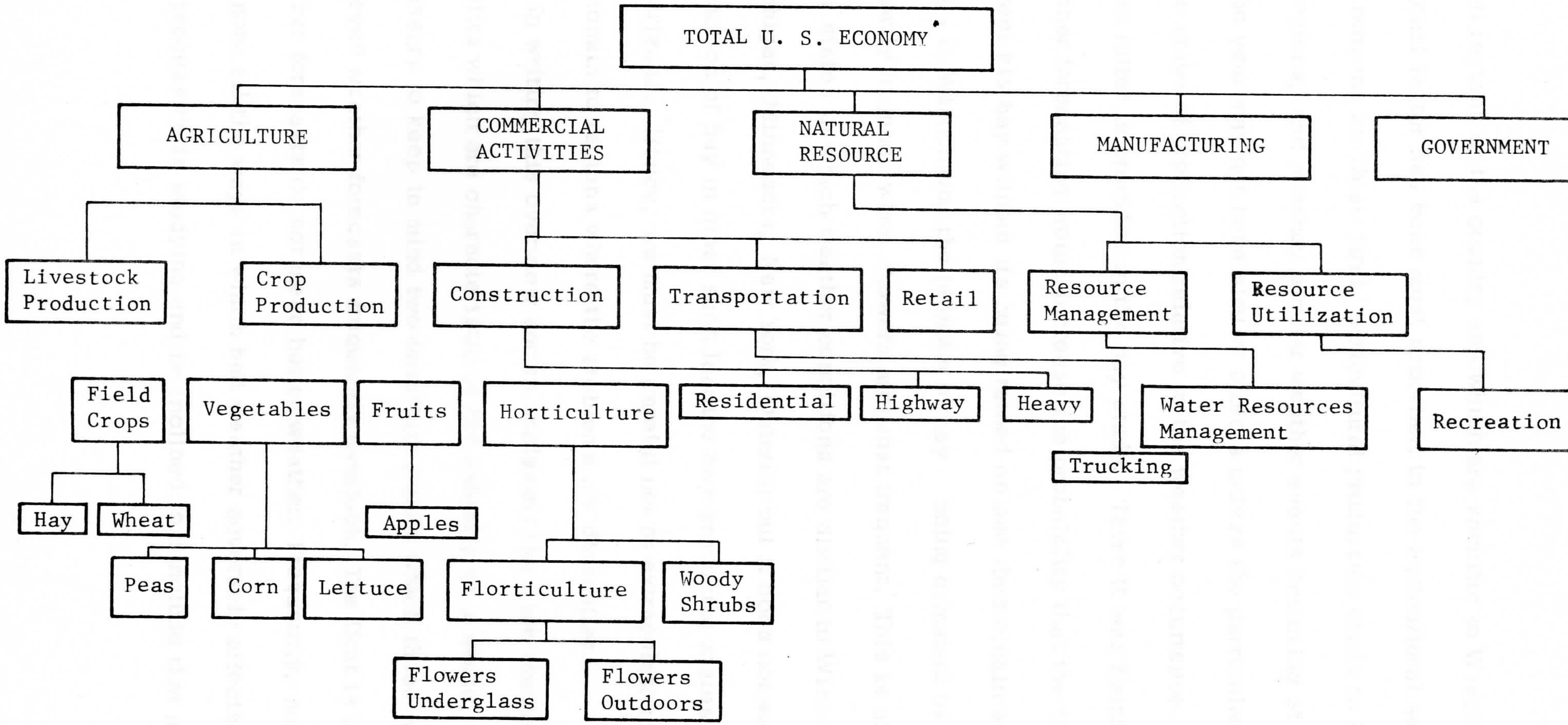

Figure 1. An Illustration of the Case Study Methodology

to all regions of the country and which are specific to Wisconsin. This regional factor has been most important in the agricultural sector. There are two reasons for this: first, agricultural production tends to be specialized by regions, and second, similar weather events occurring at different times of the year may not have similar effects unless the particular crop is at the same stage of production relative to the weather occurrence. An example of the latter is provided in the hay study. There it was found that improved weather forecasting would increase the probability that the farmer could harvest his hay without its being rained on and thus obtain a higher quality crop. In Wisconsin, the problem of hay being damaged by rain occurs primarily in June, when showers are most frequent. This is also true in other states in which weather conditions are similar to Wisconsin in June (Michigan, Minnesota, New York, Ontario) but it does not extend to the production of hay in other such leading hay-producing states as California and Arizona. Hence, we must be careful not to extrapolate results from Wisconsin to regions where the problems are dissimilar.

In writing this overview and in analyzing the case studies for those benefits which are characteristic of the industry as a whole, it has been necessary to keep in mind two important points which those writing about improved weather forecasts frequently overlook. The first is that improved weather forecasts do not mean better weather. Frequently, an investigator may note all the ways in which bad weather adversely affects the production process he is studying and be inclined to conclude that most, if not all, the losses and damages caused by the weather could be avoided with weather forecasts. But clearly this is not the case—as long as bad weather occurs, damages, disruption, and losses will occur; weather forecasting can only help to minimize these undesirable effects.

The second point is the need to distinguish between real social benefits and transfers, which are private benefits to one group or segment of society, but a private loss to another group. True social benefits accrue when the productive resources of society are utilized more efficiently, so that net production is increased. This means that benefits of the type which prevent losses of material (or product in the case of agriculture) are social benefits. Benefits which reduce the number of resources required to produce a given output are social benefits only if the freed resources can be employed elsewhere. Hence, if land is freed from production because weather forecasts reduce the amount required to produce a given output the result will be a social benefit only if the opportunity cost of that land is not zero; that is, only if it can be productively used in another activity. We shall not elaborate on this point further here, but shall have occasion to return to it in later discussions.

In this overview (and in the case studies) it has been necessary in order to arrive at estimates of the economic impact, to assume that the weather information will be utilized by the firm (unless the cost of use is greater than the benefit obtained from using it). Other parts of the multi-disciplinary study have been concerned with how and in what format the weather data must be transmitted to insure its utilization. This is certainly of vital importance if benefits are actually to be realized, but it is not relevant to estimation of what those benefits could be. Therefore, we have not concerned ourselves here with the communication aspects of the weather forecasting problem.

Finally, this overview, and in fact the entire project, should not be considered a benefit cost study. We have been solely concerned with identifying and to the extent possible, quantifying potential net benefits of better weather forecasts. There has been no attempt to determine the social costs associated with providing the weather data which was assumed to be available. In the same context, it should be pointed out that this overview includes all benefits identified by the case studies as long as the required weather forecast does not exceed two weeks. This means that benefits which require an accurate forecast of, say, only one, two, or three days, are included in this study as benefits from improved long-range weather forecasting. There has been no attempt to segregate those benefits which would only result from forecasts of, say, ten days to two weeks, but would not occur with shorter forecasts.

The remainder of this report is divided into three chapters corresponding to the three major sections of economic activity mentioned above, plus a concluding note on the extent to which the objectives of the project were accomplished. Each of the major chapters is further divided into four parts. In the first part we provide a general description of the sector. This description is basically statistical in nature, noting such things as the value of total activity conducted within the sector, and the geographical distribution of these activities. The second part is concerned with specifying the character of the case studies conducted for that sector. This involves an analysis of the limitations of the case studies. It also contains a discussion of the advantages of the particular approach of the case studies. The third section contains generalizations of the case study findings to the entire economic sector. In this section the objective has been to be as quantitative as possible. Unfortunately, in most instances it has not been possible to be as quantitative as we would have liked. Certain methods and techniques have been utilized to gain some perspective on general magnitudes of benefits, but we cannot in good faith present "grand total" estimates. The final section of each chapter discusses possible long-range impacts of improved long-term weather forecasting to the particular economic sector. This section is necessarily speculative. Change in our modern economy is a very complex thing and many factors enter into the process. In this section we suggest the directions of change which would be implied by improved weather forecasting, but other factors (new technology for one) may make the efforts of weather forecasting insignificant by comparison, and thus point in a completely different direction. It would have been desirable to be less speculative in this area, but economic models of the economy are not nearly disaggregated enough to cope with the marginal (relative to the entire economy) changes which improved weather forecasts will produce. Hence, the best it has been possible to do in this area is suggest the direction of change.

II. AGRICULTURE

General Economic Characteristics

Agriculture represents a vital part of our total economy. In 1964, it accounted for 5.5% of total gross national production. That same year, 62% of the labor force was employed in agriculture, and although this percentage has been declining for a long time due to the tremendous increases in productivity per man, it still remains an important source of employment for over three million people.

In a schematic way, agricultural production can be divided into two categories—livestock and livestock products and crop production. While this division cannot be taken too literally, it is useful for thinking about the impact of weather forecasting in the agricultural sector. It does not, however, imply that some farmers only grow crops while others only raise animals. In fact, almost all farmers grow crops, but those who are basically livestock producers grow mostly field crops, such as corn (except sweet corn and popcorn), oats, hay, sorghums, etc., which are used primarily as feed for their animals. Other field crops such as wheat and potatoes may be used either as feed for livestock or sold for human consumption. Livestock farmers may also grow vegetable and fruit crops but generally their production of these crops is limited to what they utilize themselves or sell in a local market. Crop production can be further divided into four categories—field crops, vegetables, fruits and nuts, and horticulture specialties. The primary focus is production for human consumption. Such farmers operate vegetable- and fruit-producing farms and also produce field crops for sale either to processors or to livestock producers. In addition, producers of horticulture specialties and seeds can be thought of as crop producers. In general, crop farmers have few, if any, animals to take care of.

Our purpose in making this somewhat arbitrary distinction is to provide a perspective on how improved weather forecasts can affect agricultural production. In most cases, improved weather forecasts affect the production of crops rather than animals. This means that those producers engaged primarily in crop production will be directly affected, while those who produce livestock will be indirectly affected.

In order to get some idea of the composition and distribution of agricultural crop production in the U. S., several tables of statistics and comments are presented below. Table 1 tells us a great deal about the potential savings from improved weather forecasting. Field crops make up 84.5% of the total value of all crops produced. This means that if even a small percentage improvement can be achieved in the production of field crops the total impact will be great. At the same time, however, such an improvement will have to be widely dispersed because of the relatively low value per acre of field crops. Finally, the low value per acre tells us that any improvement brought about by better weather forecasts and applied to field crop production will have to be relatively inexpensive to implement on a per acre basis. At the other end of the scale, for horticulture specialties, the opposite comments apply. Potential savings are much smaller because of

Table 1

Crop Production, 1964

	Total acreage (1,000)	Value ($ millions)	Value per acre
Cropland harvested	286,892	-	-
All crops except forest products	291,640	21,753	74.59
Field crops including irish and sweet potatoes	283,619	18,378	64.80
Vegetables	3,334	987	296.18
Fruits and nuts	4,412	1,683	381.32
Horticulture specialties	275	705	2,561.96

the smaller total value of the crop. However, the high value of the crop per acre means that a wide variety of actions are possible and even local benefits may produce significant savings. Potential savings in vegetable and fruit production fall in between these extremes.

Table 2 indicates the relative importance of selected field crops. Nineteen field crops account for 97.4% of the value of all field crops harvested in 1964. As we can see from Table 2, the most important field crop is corn harvested for all purposes (except sweet corn and popcorn) which accounts for more than one-fourth the value of all field crops produced. Other important field crops include cotton, soybeans, wheat and alfalfa.

Table 3a provides some data on the extent of geographical concentration of vegetable production. It shows that California and Florida combined

Table 2

Value of Selected Field Crops

	Value ($ millions)	Percent of total value	Percent of all farms	Average per farm
Total, all field crops	18,369	100.	n. a.	n. a.
Corn, for all purposes	4,636	25.2	49.0	2,996
Cotton	2,390	13.0	10.3	7,369
Soybeans, for all purposes	1,780	9.8	n. a.	n. a.
Wheat	1,672	9.1	23.4	2,261
Alfalfa, cut for hay	1,654	9.0	28.3	1,851
Tobacco	1,168	6.4	10.5	3,526
Irish potatoes	761	4.1	9.8	2,454
Sorghums, for all purposes	680	3.7	7.9	2,735
Oats, for grain	510	2.8	22.4	721
Clover, tim, cut for hay	486	2.6	17.5	878
Rice	369	2.0	.3	37,243
Barley, for grain	338	1.8	5.7	1,894
Sugar beets, for sugar	277	1.5	.7	12,482
Peanuts, for all purposes	230	1.3	n. a.	n. a
Sugar cane, for sugar	201	1.1	.1	71,486
Other hay	197	1.1	8.7	717
Wild hay	166	.9	5.4	978
Dry field and seed beans	136	.7	.9	5,020
Grass, slage from grasses alfalfa, clover or sand grains	85	.5	2.4	1,125

produced over half the total value of all vegetables, and the ten leading vegetable-producing states combined produce almost four-fifths of the value of vegetables harvested. Table 3b shows that ten vegetables account for 76.3% of the acreage of all vegetables harvested and indicates that the most important vegetable is sweet corn.

Finally, table 4a demonstrates that seven states accounted for more than 80% of the value of fruit production, while from table 4b we learn that

Table 3a

Vegetable Production—1964

State	Acres harvested for sales (1,000)	Value of vegetables harvested for sale ($ millions)
Total U. S.	3,334	987
California	626	348
Florida	290	146
Arizona	88	59
New York	164	44
Texas	295	42
New Jersey	115	37
Michigan	102	26
Wisconsin	266	25
Oregon	120	29
Ohio	59	23

Table 3b

Vegetable Production—1964

Vegetables	Acres
All vegetables	3,334
Corn	546
Green peas	395
Tomatoes	389
Snap beans	280
Watermelons	246
Lettuce and romaine	210
Asparagus	139
Cantaloupe and muskmelon	124
Cucumbers and pickles	110
Cabbage	106

Table 4a

Geographical Distribution of Fruit Production

State	Acres in orchard, groves and vineyards (000)	Value of tree fruit, grapes, nuts and coffee ($ millions)
California	35.8	45.8
Florida	21.8	25.7
Washington	3.3	5.7
Michigan	4.7	3.7
New York	3.4	3.4
Oregon	2.4	1.6
Texas	3.7	.6

Table 4b

Fruit Production

Fruit	Value ($)	Percent of total U. S. production of fruit
Total, all tree fruits, nuts, grapes and coffee	1,536,535	100.0
Oranges	471,527	30.7
Apples	222,103	14.4
Grapes	215,136	14.0
Peaches	137,569	8.9
Grapefruit	85,485	5.6
Plums and prunes	68,988	4.5
Pears	62,342	4.1
Lemons	54,516	3.5
Cherries	50,703	3.3
Almonds	36,094	2.3
Walnuts	36,437	2.4
Apricots	25,755	1.7
Pecans	13,820	0.9
All other	57,060	3.7

the total value of tree fruit, nuts, grapes and coffee was $1.5 billion (equivalent to 7.1% of the value of all crops produced), and that 12 crops comprised 95.4% of the value in this group.

The Case Studies

The design of the agricultural case study involved choosing a particular crop (or set of crops), and having an expert determine how improved weather forecasts could be used to improve production. The major advantage in focusing the case studies upon a particular crop is that a general uniformity among the case studies emerges. This uniformity in turn provides a basis for extrapolating the results of the studies to most agricultural crops. In addition, it provides some internal validation on each case study.

The basic uniformity which emerges in the agricultural case studies is provided by the life cycle of the crops. We can divide the production process into five periods: preplanting, planting, growth and cultivation, harvesting and finally, processing and shipping. Within each of these periods there may be one or many individual operations that a producer performs, and it is on these individual operations that our attempt to extrapolate conclusions to all agricultural production is based. A second feature contributing to the uniformity in the agricultural case studies is the fact that weather forecasts affect production in three ways. They can reduce the costs of production, they can increase the quantity produced either by increasing yield per acre or by reducing losses, or they can improve the quality of the product. It is thus possible to focus on these three alternative benefits of better weather forecasts within each of the five periods in the life cycle of the crop.

Our analysis, which attempts to generalize the conclusions of the case studies and evaluate the long-run economic impact, utilizes these case studies as basic data. Consequently, their shortcomings place restrictions on our generalizations and evaluations. It is therefore important that we explicitly consider the nature of these limitations.

First, and undoubtedly most important in an effort that attempts to generalize, is the fact that only a few of the case studies reached the quantitative stage. Where benefits are qualitatively identified but not quantified, it is naturally difficult to generalize in a quantitative sense. We are able to say whether or not such a benefit will occur but are not able to state its value. For other benefits quantitative estimates must be based on the limited data available, and the credibility of these generalizations is, therefore, not always as strong as would be desirable. It is, however, possible to obtain some quantitative insights despite the absence of sufficient data by observing the relative importance of those parts of the production process in which a benefit from better weather forecasts has been identified. For example, if a case study claims the cost of an irrigation could be saved, the value of the savings can be determined both in absolute and in percentage terms, by using cost-of-production statistics.

A second limitation of the agricultural case studies is their concentration upon production in Wisconsin. Wisconsin's climatic characteristics—and the problems they pose for agriculture—are fairly characteristic of the upper Midwest and probably also the Northern Middle Atlantic and New England States. However, they are not at all typical of the South and Southwest. This means that certain types of benefits which may be likely to occur in the South and Southwest but not in the North may have been overlooked. It also means that generalization of the results found in the Midwest to those areas must be done with caution. For example, it would be unjustified to extrapolate the quantitative conclusions of the hay study to hay production of the Southwest because rain at harvest time does not pose nearly the same problem it does in Wisconsin.

A third aspect of the case studies which introduces ambiguity into the conclusions is the failure to view the production process from a perspective broader than the individual crop. This has two effects upon the final results. On the one hand it means that benefits are overestimated (both qualitatively and quantitatively) because due consideration is not given to the individual producer's flexibility to respond to the weather information. An example is provided by those case studies where it is cited that a prediction of impending bad weather at harvest time would allow the harvest to be expedited. However, machines may be required to expedite the harvest. It may be that these additional resources are available, but for the most part the case studies give no indication one way or the other, and consequently we are left uncertain. On the other hand, certain types of benefits which could be realized by the farmer may not have been identified in the case studies because of this focus on an individual crop. For example, indoor work (such as repairing machinery) may be postponed in favor of outwork or leisure (something which should be, but is not considered a benefit for the farmer, whose hours are usually very long) if the farmer knows that bad weather will occur before the indoor work must be done.

Extensions of the Case Studies

In this section we shall analyze the benefits of better forecasts in the agricultural sector by examining first the nature of the benefits identified in the case studies for each of the five sub-periods in the life cycle of the crop and then extrapolating the result to those crops not explicitly studied.

Preplanting

This period in the production of almost all types of agricultural crops is relatively insensitive to weather and consequently few benefits from improved weather forecasting can be obtained. The case studies suggest that weather forecasts during the preplanting period can be used to determine when planting will begin. This, it is felt, will facilitate planning the arrival of supplies (seed, etc.) and labor. This benefit is probably of importance only to vegetable production and horticulture specialties because only these segments of agriculture employ migrant labor for planting operations. The benefit would take the form of reduced labor costs (and fewer delays) for the processing company. It is not possible to estimate the magnitude of this savings from the case studies.

Planting

Except for a few crops, the effect of weather upon planting is also not significant; consequently weather forecasts are not likely to yield many benefits. The case studies indicate few opportunities for forecasts to be utilized in the planting operation. One possibility that does exist is that forecasts can be utilized to prevent weather damage to the young plants. This may be done either by delaying the planting or by taking counter-measures (most often against frost). However, these techniques are probably limited to the very high value crops such as cranberries, certain other fruits and ornamentals. The benefit would be manifested at harvest time as greater yield per acre. That damage at planting time is not very significant is verified by the corn and pea studies (Smith and Torkelson) which indicate that planting losses by processing companies are so small that they do not even keep a record of the loss. This conclusion would probably extend to most of the other vegetable and field crops.

Another possible result is that better forecasts during the planting operation may assist processing companies to determine an appropriate planting schedule. Vegetable processing companies desire a steady flow of product at harvest time so that their plants can be fully utilized at all times. If too much of the product becomes ready for harvesting at the same time, some will be passed over because the processing plant cannot handle it. Alternatively, insufficient product will result in underutilization of capacity. The planting schedule is important because crops planted several days apart will reach maturity only a few days apart—the exact number of days depending in part on the weather conditions at planting time. Similarly, weather disruptions at planting time will leave gaps at harvest time. The gap could partially be eliminated by increasing plantings before the disruption due to weather. Improved weather forecasts will thus affect planting operations in the vegetable processing industries in a way that reduces abandoned acreage at harvest time (that is, increases total processed output). While we are not able to determine the magnitude of this benefit, the corn study tends to indicate that it would be quite small.

Growth and Cultivation

During the growing period there are a number of ways that weather forecasts can be utilized by the farmer. We shall consider these under the following subheadings: spraying, irrigation, frost protection and incidental.

a) Spraying

All crops are susceptible to various diseases and pests which can reduce yields, quality or both. Modern agriculture employs different techniques in an effort to combat this problem. One such technique is the development of genetic strains which are resistant to the disease or pest; this alternative is not influenced by improved weather forecasts. However, for other alternatives, such as chemical spraying, weather forecasts can be quite important. The case studies suggest several ways in which improved long-term weather forecasts can be of use to the farmer in dealing with this problem.

One way weather forecasts can be useful is to increase the effectiveness of the spraying process itself. In almost all types of spraying, wind speed and direction are important. If the farmer must spray on a windy day, the effectiveness of the spray may be greatly reduced. Furthermore, if the effectiveness is seriously reduced, he may even have to spray more often than he had planned. It is also the case that some sprays require particular types of weather to be most effective; for example, with some types of spray, a rain after a spray will increase its effectiveness, while with others a rain will ruin its effect. Appropriate weather forecasts would permit the farmer to choose a spraying time which would insure maximum effectiveness, thus minimizing his loss.

Another way weather forecasts may be useful is in permitting the farmer to eliminate a spraying and thus reduce his costs. Because the development of many diseases and the arrival of many pests is correlated very highly with certain types of weather conditions, the farmer may be willing to take a chance and avoid spraying when the forecast indicates weather conditions will be incompatible with disease development. The opposite case would be to increase the frequency of spraying if weather conditions are highly conducive to development of the disease. This would be particularly helped by improved weather forecasting because often, in order to be effective, the spray must be applied shortly <u>before</u> the occurrence of the weather conditions that are conducive to disease or pest development.

To summarize, we can note that the qualitative findings of the case studies indicate that improved weather forecasting would be useful in reducing the cost associated with disease and pest control and, more important, in reducing the crop loss caused by disease and pests.

Turning to a quantitative evaluation of this problem, we find ourselves uncertain of the specific value of improved weather forecasts. Savings are possible in those situations where weather conditions allow the spray to be effective. The lettuce study estimated a yearly saving of $3 per acre in Wisconsin, from avoiding those instances where the spray would otherwise be washed off. While not all sprays are susceptible to wash-off to the same degree, we can obtain a rough abstraction from the lettuce case to similar situations in other crops. The lettuce saving is 7.5% of a total spraying cost of $40 per acre. If this figure could be realistically extrapolated to other vegetable crops, we would, for example, obtain a saving of 75 cents per acre in sweet corn production and 30 cents per acre in pea production.* We should point out, however, that the 7.5% estimate is probably too large a figure to apply to <u>all</u> vegetable and fruit production because most of this production is carried on in the Southwest (California, Arizona) and in the South (Florida) where the problem of rain wash-off and wind are not as serious as in Wisconsin.

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*Production cost statistics for sweet corn and peas are taken from a report entitled "Wisconsin Farm Enterprise Budgets," University Extension Bulletin No. 7, the University of Wisconsin, June, 1969. See the cost of production statistics in Appendix A.

There is another factor which will tend to mitigate this cost reduction. Spraying costs usually amount to between 1% and 10% (in most cases, including lettuce, about 5%) of total production costs. Hence, the savings of 7.5% of spraying costs translates into .5% of total production costs. Of course, this could still represent a substantial saving in the aggregate. However, for it to do so, the farmer must have the incentive to change his way of operating in the presence of the weather forecast. Elsewhere in the case studies it is noted that the farmer may not be willing to skip a spray even if the weather forecast indicates it is safe to do so, because of the risk of loss if the forecast is inaccurate. This fact, combined with the relative unimportance of the saving, makes it unlikely that this potential reduction in production cost actually will be realized.

Finally, we turn to the question of reducing product loss. On the basis of the studies it is not possible to say anything quantitative about the potential impact of improved weather forecasts. However, we can get some idea of the potential savings by noting current losses. A report by the USDA, entitled "Losses in Agriculture," gives us some indication of annual losses from disease, nematodes and insects for the period 1951–60. The tables presented in appendix B are compiled from several different tables in this report. It is important to point out that the figures presented below are best estimates and not actual counts. Furthermore, the dollar values presented in these tables are likely to be overestimates. This is so because they were computed by multiplying average price by the annual loss; however, if the loss is reduced and the supply increased, the average price would most likely be less. Nevertheless, these figures provide rough estimates of the general magnitude of losses caused by insects and disease and also some idea of the relative losses among the various types of crops.

Some studies dealing with the benefits of improved weather forecasting have gone so far as to assume that all losses of this type could be prevented with adequate weather predictions. Of course this is an unreasonable assumption. There are many reasons why it is true. Spraying, even at the optimum time, is usually not 100% effective, and even if it were, new strains of disease would probably develop. In addition, for some field crops the net loss to the farmer may be minimized by allowing part of the crop to be lost rather than by incurring the expense of additional spraying. There are also other factors which would result is less than the total loss being prevented, for example, poor communication or a lack of spraying materials when they are needed.

We can, however, estimate that the savings would be somewhere between 10% and 50% of current losses. If this is applied to the total value of losses we obtain a dollar savings of between $36, 235, 000 and $181, 172, 000 for crops destroyed by disease and nematodes, and an additional $17, 895, 000 to $89, 476, 000 for crops destroyed by insects. This reduction in the magnitude of the loss resulting from more effective spraying could in most cases be achieved with an accurate forecast of from two to five days.

(b) Irrigation

The importance of irrigation to the production process depends in large part on where the crop is being grown and on the type of crop. Tables 5 and 6 present some information on the number of acres of irrigated crops by region of the country and the type of crop. There are several things which should be noted from these tables. First, by far the greatest amount of irrigation is done in the western states. Second, in general, irrigation is more important in the production of vegetables and fruits than it is in field crops (86% of vegetables grown in the west and 42% of those grown in the south are irrigated). Third, the only field crops which have more than 30% of their harvest coming from irrigated lands are Irish potatoes (52.0%) and sugar beets for sugar (79.8%). Most other field crops have only a small percentage of their total production under irrigation.

The case studies suggest three types of irrigation-related benefits that might result from improved weather forecasting. The first benefit would be saving the cost of a planned irrigation when the occurrence of rain is predicted before the stress point is reached. A second benefit is the improvement in the quality of the crop in those cases where the occurrence of rain shortly after irrigation would have caused leaching. A final benefit is derived from the use of supplemental irrigation to compensate for drought periods either within a single production year or for a series of bad years.

The quantitative evidence we have on irrigation tends to show that the magnitude of these benefits would be very small. The lettuce study concluded

Table 5

Farms with Irrigated Land, 1964

	Farms with Irrigation		Irrigated Land		Irrigated Cropland Harvested	
	No. of farms (1,000)	Percent of all farms	acres (1,000)	Percent of all land in farms	acres (1,000)	Percent of all irrigated land
U.S.	297	9.4	37,056	3.3	30,759	83.0
17 western states and Louisiana and Hawaii	239	25.6	33,933	4.7	28,014	82.6
31 states	58	2.6	3,123	.8	2,735	87.6

Table 6

Selected Crops, Total Production and Percent Irrigated, 1964

Crop	Acres Harvested	Acres Harvested from Irrigated lands	Percent of crop harvested from irrigated land
	FIELD CROPS		
Corn for all purposes	63,514,906	2,428,000	3.8
Sorghums for all purposes	14,965,707	3,377,778	22.7
All wheat	47,958,362	1,963,525	4.1
Oats, harvested	18,935,713	300,039	1.6
Barley, harvested	9,805,327	1,503,666	15.3
Soybeans	30,351,248	427,206	1.4
Hay crops	65,294,703	8,229,598	12.6
Cotton	13,916,648	3,769,194	27.0
Tobacco	1,025,240	172,321	16.8
Sugar beets, for sugar	1,376,026	1,099,481	79.8
Irish potatoes	1,173,918	608,880	52.0
Sweet potatoes	112,128	18,156	16.1
	VEGETABLES		
Sweet corn	545,563	157,164	28.7
Green peas	394,549	39,341	10.0
Tomatoes	388,541	251,784	64.6
Snap beans	280,316	116,903	41.6
Watermelons	245,761	46,118	18.8
Lettuce and romaine	210,255	202,159	95.8
Asparagus	139,439	81,961	58.7
Cabbage	105,724	58,651	55.6
Cucumber and pickles	110,491	38,356	34.7
Cantaloupe, honeydews, and muskmelon	124,207	93,821	75.5
	FRUITS AND BERRIES		
Strawberries	66,171	34,905	52.8
Cranberries	20,493	20,493	100.0
Land in orchards	4,251,130	2,203,342	51.8
Nursery products and flowers, etc.	257,307	112,765	40.7

that the benefits from irrigation were insignificant. We can see why when we realize that a cost breakdown for lettuce grown in the Imperial Valley shows irrigation costs to be $16 out of a total preharvest cost of $208, and a total production cost (harvest and preharvest) of $837.20. This $16 is for eight irrigations, hence the benefit from saving the cost of one irrigation is $2. Furthermore, while the frequency with which such a savings might occur is not documented in the study, it is probably reasonable to assume that this would not occur more than once or twice a year.

This same problem is confronted when we consider the magnitude of the benefit obtained from the prevention of leaching. Although leaching is theoretically possible and may actually occur at times, the frequency with which the phenomenon occurs is probably quite small. When the fact is considered that the contributing cause must be a combination of rainfall and irrigation, the frequency with which weather forecasts could be used to prevent the phenomenon becomes even lower. The conclusions drawn from the lettuce study most likely apply to other crops that are irrigated. This speculation is supported by an analysis of costs of production data for other crops which indicates that for these crops irrigation also represents a small percentage of total costs and that the cost of a single irrigation is even less significant (see appendix A).

The third aspect of irrigation which we must consider is supplemental irrigation. This type of irrigation can take two different forms. It can be supplemental in the sense that the crop requires irrigation only during bad years, or in the sense that it is only used once or twice per year. The case study on sweet corn (Smith and Torkelson) analyzes supplemental irrigation and concludes that in most cases supplemental irrigation cannot be profitable to the corn producer even if he has available and utilizes correct weather forecasts. This conclusion is arrived at by comparing the relatively large investment costs of an irrigation system with the relatively small returns that will be generated.

However, we should not conclude from this study that weather forecasts will not be useful for supplemental irrigation operations. The corn report itself notes that supplemental irrigation is not used for sweet corn because it is more profitable for other crops. Specifically, supplemental irrigation is important to those crops for which yield can be markedly increased and for which yield per acre is high. In these cases the benefits from improved weather forecasting are likely to be significant. In supplemental irrigation there is a need to begin irrigation before the stress point is reached. Depending on the crop and the method of irrigation this period may be as much as two or three days. Thus weather forecasts can play an important role in determining when to begin irrigation operations.

Quantitatively, we do not have the data from the case studies to estimate the magnitude of this benefit. The nature of the benefit will be increased output and possibly improvements in quality. To the individual producer these improvements will be important. However, the benefits are not likely to be large in absolute terms since supplemental irrigation is relatively unimportant in the general scheme of agricultural production.

(c) Frost Protection

Several case studies note the possibility of increasing output by reducing the loss caused by early frost. With adequate warning this can be done with fans or helicopters, by irrigating (to release the heat of fusion as the water freezes) or, in the case of ornamentals, by moving the crop inside. As a possible step in the production process, this action applies only to fruit and nut crops, vegetables and ornamentals. The value per acre of field crops would be much too low to make this operation worthwhile.

On a quantitative basis we cannot estimate this impact. The case studies do not provide information on the frequency of such losses nor the approximate loss per occurrence. On the other hand, we might note that producers currently attempt to watch for and predict this occurrence, so that the additional loss which would be prevented by a long-range forecast may be small. Probably what would be most useful for producers would be a short-range (12- to 24-hour) forecast of extremely high resolution (exact temperature at a given location). This would enable the producer to decide effectively if some action is needed and, if taken, whether it will be profitable. A longer-range forecast would not be useful unless it could achieve the same degree of resolution. If that were possible, then the benefit of a longer-range forecast would be primarily one of convenience to the producer rather than additional increases in output.

(d) Incidental Considerations

There are also a number of incidental ways that weather forecasts can be used by farmers during the growing period. For example, the case studies indicate that for crops which utilize bees for pollination, weather forecasts could be utilized to determine when the blossoms will open. This would allow the producer to contract for the bees for the appropriate time. It should be noted that if contracts for bees must be made more than two weeks in advance, then a two-week forecast will be of no value. Assuming that the benefit does occur, the result will be increased yields for those producers who otherwise would not have contracted for bees for the proper time.

A similar type of benefit may accrue for those crops which need to be thinned in order to produce high quality products. The case studies indicate that, to be successful, thinning operations must be undertaken at a particular time and that weather forecasts could be utilized to determine when this will be.

A third operation conducted during the growing season which can utilize weather forecasts is cultivation to eliminate weeds. Here again weather forecasts can be utilized to determine the most appropriate time for this operation. In contrast to the length of the forecast required to produce a benefit in contracting for bees, the forecast required to improve thinning and weeding operations may be only a day or two and will rarely exceed a week.

Unfortunately, we are not able to say very much about the quantitative magnitude of such benefits. In general, it is very difficult to measure actual losses which occur from these factors. Furthermore, even if it were possible to make crude estimates we would not know how important a role weather forecasts can play in reducing the loss. It is probably reasonable to assume that overall the benefit would not be large—that is, supply would not increase appreciately.

Harvesting

Harvesting is probably the most important operation of the entire production cycle, primarily because it is the most expensive operation, requiring the greatest amount of labor and machine time. In addition, at harvest time the total crop is in the field and every effort must be made to see that losses do not occur. The importance of weather and weather forecasting to the harvesting operation varies greatly from crop to crop.

Vegetables for both fresh and processing markets must meet strict quality standards on the degree of maturity (that is, moisture content). As indicated in the case studies, the length of time the crop is in the acceptable range depends upon the weather. Extremely hot and dry weather will cause the crop to progress through this acceptable quality range very rapidly. Rain during the harvesting period will probably lengthen the time the crop is acceptable but it may also prevent the farmer from getting into the field when the crop is acceptable for harvesting. In such cases weather forecasts could be very useful because, if producers have sufficient warning of these weather disruptions, they can speed up the harvest. This results in less abandonment of fields and consequently greater output.

Both the corn and pea studies (Smith and Torkelson) suggest that the average annual increase may be as much as 5% of total production in Wisconsin. This figure is probably representative of the possible effect weather forecasting could have on harvesting operations for several other varieties of vegetables produced in the midwest, such as beans and tomatoes. We cannot say whether or not the benefit would be as great for vegetables produced in western and southern regions of the country since no case study has examined the extent of this problem in those regions.

For processing vegetables, there is another constraint on speeding up the harvest; that is, the processing plant must be able to handle the increased load. If this is not possible the field will still be abandoned unless the crop can be sold to another processor or shipped to another processing plant some distance away. It is clear that long-term weather forecasts would improve the chances that one of these options could be utilized.

For most field crops the exact time of harvest is not quite as crucial as for vegetables. In fact, some crops such as corn for grain and oats can be harvested at any time over a period of two or more months. There are, however, field crops such as hay, for which the range is more restricted (two weeks) and for which there may even exist an optimum day on which to harvest. In these cases the crop must be dried after cutting and accurate short- to medium-range weather forecasts can play a very crucial role. The farmer is able, with the aid of forecasts, to select the cutting date which will enable him to dry his crop successfully. The alfalfa study indicates that a savings of approximately $40 million may be possible for alfalfa produced in Wisconsin. The basic conclusions of this study can be extended to include the states of Minnesota, Michigan, and New York, and hence we can estimate additional savings in alfalfa production of approximately $60 million. This conclusion is not applicable to alfalfa production in the west because the problem which is solved by weather forecasts in Wisconsin does not exist there to nearly the same extent. While we could also generalize the alfalfa study to other types of hay produced in the midwestern states, this is a less certain abstraction since weather's effect upon other types of hay is not quite the same as its effect upon alfalfa.

As we have already noted, some field crops do not have specific constraints on the time of harvest. Nevertheless, weather forecasts may still be useful in helping a farmer plan when the harvesting should be done. Most crops, and almost all field crops, are harvested by mechanized harvesting machinery. The amount of waste produced by this machinery depends upon several factors, including weather conditions. A study by the USDA notes that, "harvesting machines are designed for specific crops under specific conditions. When the weather changes, methods and equipment must be modified." Table 7 below, taken from the above-cited report, presents estimates of annual losses during harvesting. Although weather forecasts would be helpful in reducing the losses, the actual percentage which would be saved is probably quite small. This is because the losses reported above also include such losses which cannot be attributed to weather conditions as

Table 7

Crops: Estimated Average Annual Losses During Harvest, 1951–60

Commodity	Loss from Potential Production	
	Percent reduction	Value ($1,000)
Barley	5	19,787
Castorbeans	7	117
Corn	8	351,523
Cotton, lint and seed	5	125,383
Flax (seed)	5	5,802
Oats	5	47,242
Peanuts	15	28,776
Potatoes	7	108,375
Rice	5	13,428
Rye	5	1,547
Safflower	5	256
Sesame	10	110
Sorghum, grain	10	37,858
Soybeans	8	81,620
Sugar cane	5	2,939
Tungnuts	10	610
Wheat	5	118,319

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the use of improper machinery for the particular crop or terrain and natural losses which would occur under the most ideal conditions.

Shipping

Several of the case studies indicate that foreknowledge of the weather in those regions through which the shipment must pass on the way to market will enable the producer to plan appropriate shipping procedures. All the reports on processing vegetables note that cans packed in a cool region and shipped through a hot humid region may "sweat." This loosens or discolors the label and may make the can unmarketable. Weather forecasts would enable the processing company to order refrigerated trucks to prevent this from occurring. This phenomenon is no doubt not specific to the vegetable-processing industry; it probably applies to the shipment of most canned products. Consequently, we would expect weather forecasts to be of great benefit to canned food shippers in general. Unfortunately, we cannot estimate the benefit in quantitative terms because it has not been possible to locate data on the current level of losses caused by this weather phenomenon.

Similar types of shipping benefits are also indicated in the case studies. For example, for the shipment of flowers and ornamentals, the amount of insulation required depends on the temperature along the shipping route. If a shipper were certain that the temperature would not be extreme, he could save the cost of some of the insulation. In general, temperature-controlled trucks could be used only when required rather than as a precaution against uncertainty. This would reduce shipment costs, since these trucks are substantially more expensive. To achieve this benefit, the full long-term forecast would be required because reservations for train cars and trucks are usually on a one- to two-week basis.

Conclusion

At the beginning of our discussion of agriculture we indicated that three types of benefits were possible: quantity increases, quality improvements and reduced costs of production. We also divided crop production into general categories: field crops, vegetables, fruits, and horticultures. Our analysis clearly indicates that by far the most important benefit would be increased supply, resulting from reduced waste and more effective operations.

In the field crops it appears that the major factors contributing to supply increases are better protection from disease and insects, and to a lesser extent (except in the case of hay) reduced harvesting and shipping losses. Based on the discussion of this section, we would probably have to estimate that the supply of field crops other than hay would increase .5% to 5%, with most increases near the lower end of the range. Quality increases would also be present in field crops other than hay, but for the most part they would be insignificant. The reduction in production costs would quite likely also be insignificant.

For hay, the benefit would be primarily a quality improvement. We cannot say exactly how this would be reflected in the market, although, if nothing else changed, it would result in an increase in the supply of milk, beef, and other products for the production of which hay is used as feed.

Supply increases would also be the major benefit in the production of fruits and vegetables, although for certain crops the reduction in production costs might also be significant. In the production of fruits and vegetables weather forecasts can be utilized in a greater variety of ways than for field crops because the higher value per acre of fruits and vegetables permits responses to bad weather which would not be worthwhile in field crop production. Thus, we should conclude that supply increases should be on the whole greater for these crops than for field crops. It would, however, be misleading to suggest a quantitative range because, as our discussion of the preceding section indicated, we simply do not have the data.

Long-Run Impacts

Income Distribution Effects

Where resources are utilized more efficiently because of improved weather forecasts, we can be sure that there is a social benefit. However, in order to determine which individuals or groups of individuals will share in the benefit we must undertake a more careful analysis of the market for the particular product involved. All of the case studies and much of this overview have focused upon the individual producer and described the benefits from his perspective. Implicitly, this has given the impression that it is the producer who will receive the benefits, but that need not be the case.

An unstated, and often unconscious, assumption that an individual producer makes when he claims that he will benefit from improved weather forecasts is that other producers will not utilize the forecasts. Clearly, if any single producer could increase output without affecting the price of the product, his gross receipts would be greater, and with his gross expenditures the same, his total profits will rise. This is the benefit that the case studies have identified. But if all producers utilize the weather forecasts and all realize an increase in output, there will be an appreciable effect upon total supply and, as a result, the price that each producer receives will decline.

Such a decline in the price of the product will lead to either of two outcomes depending upon its magnitude. If the decline is very large, the producer's gross return may fall even though the quantity he sells increases. This will imply a decline in net return. If, on the other hand, the price decline is not too great, the producer's return may increase. Economists use a measure known as price flexibility to represent the impact of a supply increase upon farm income. Price flexibility is defined as the percentage change in the price of a commodity brought about by an isolated 1% increase in the quantity offered for sale. It is possible to consider the flexibility of price at either the retail or the farm level; depending upon how the spread between the two prices is determined, these flexibilities may or may not be equal. Briefly, it can be shown that if the spread is a constant percentage of the retail price, then the price flexibility at retail and at the farm will be equal. If the spreads are absolute amounts of dollars and cents, prices will be more flexibile at the farm than at retail. This is important, because if the price flexibility F is less than minus one (minus because price increases are associated with quantity decreases), then a 1% increase in quantity will result in a price decrease of more than 1%. This in turn will cause a fall in the net revenue received by the farmer; he will be worse off than he was before the better weather information allowed him to reorganize his operation and increase the quantity that he produces.

In the discussion of supply increases, it has been assumed that the crop is ungraded or, alternatively, if graded that the increase in supply has been such as to leave the share of the total crop for each grade unaffected. In fact, we expect quality improvements resulting from better weather forecasts to change these shares, specifically to increase the share of better grades and reduce the share of poorer grades. The effect of a change in the quality mix may be separated from the effect of a general increase in supply by examining the effect that changes in the mix has on total revenue, given a fixed total supply. In this case we must deal with a separate price flexibility for each grade. It is, of course, necessary to determine whether the price function for each grade can be defined in terms of the supply of that grade only or whether it is also necessary to take account of cross-effects, that is, interactions from other grades. For the case of an upgrading of quality, the condition (in terms of the price flexibilities) for an improvement to result in a lowering of the net revenue received by the producer is slightly more complicated. Nevertheless, such a loss still remains a possibility.

Some examples of price flexibilities for various products are given in the following table. As table 8 indicates, it is likely that for some crops the producer's return will actually decline if, as a result of improved weather forecasting, the supply increases. A natural reaction to this conclusion may be to say, "Well, if he is worse off with the forecast than without it, he need not use it." But this will not be true, because it will always be to the individual producer's advantage to operate as efficiently as possible. If he should decide not to use the weather forecast, the price will still decline as long as his neighbors utilize it. As a result, he will find himself in an even worse situation since the price is less and his output has not increased. Providing the private cost of using the information is not greater than the additional revenue received from the increase in production at the new price, he will use the forecast.

Regardless of what happens to the farmer's profits, there is a social benefit, in the strict economic sense that resources are being used as efficiently as possible. And this benefit, if it is not reflected in a better return to the producer, will be reflected elsewhere in a lower price of food for consumers.

The above discussion indicates that one long-run effect of increased supply may be a shift in the distribution of income between producers and consumers. Another type of potential income shift is between producers and retailers. We cite an example from the case study on floriculture. There it was concluded that the "overall effect of more accurate short- and long-range

Table 8

Price Flexibilities for Various Agricultural Products

Product	At Retail[1]	At Farm[1]	At Farm[2]	At Farm[3]
Potatoes	-2.57	-5.28	-2.14	
Sweet potatoes	-.76	-1.15		
Tomatoes	-.85	-1.03	-.215	
Grapefruit	-.82	-2.06		
Lettuce			-.387	
Peas				
Fresh			-.35	
Canned			-.10	
Apples	-.81	-1.43		
Fresh				-1.3
Canned				-1.7
Other				-2.1

1. F. V. Waugh, "Demand and Price Analysis: Some Examples from Agriculture," USDA Technical Bulletin 1316 (1964), pp. 19-20.

2. D. M. Shuffert, "The Demand and Price Structure for Selected Vegetables," USDA Technical Bulletin 1105 (1954), p. 22.

3. Lynn M. Bartto, "Effects of Apple Supply Management Programs in N. Y. State," New York, Cornell University, Agriculture Economics Research, No. 62.

weather predictions would be a more steady flow of flowers throughout the year with a stabilization of prices and a better chance for adequate profits." To the extent that losses are prevented because of weather forecasts, it is certainly true that the flow of flowers will be more steady and prices more stable. However, in some instances, as we noted earlier, it is not possible to prevent the loss even with the knowledge that the weather will be unfavorable. In such a case, market interactions will not stabilize consumer prices but will distribute the profits one way when weather information is available and another way when information is not available. Presently, a retailer (or wholesaler) places his order with a supplier. If unfavorable weather forces the supplier to default on the order the retailer is simply left without flowers. At the same time, since the supply has been reduced, the price to consumers will rise. This means that retailers whose orders were filled are making large profits while those whose orders were not filled are making none. The larger profits occur only to those retailers with flowers and not to their suppliers because the flowers were bought at a lower price when it was thought there would be an adequate supply. On the other hand, if weather forecasts enable the defaulting suppliers to notify their customers in advance that their orders cannot be filled, these retailers could seek out those suppliers whose flowers were not affected by unfavorable weather. The result would be a higher wholesale price of flowers. Those wholesalers whose supply of flowers was not affected by the weather would receive this higher price, and all retailers could obtain part of the limited supply of flowers. The price to consumers would be the same as in the case without weather information because the supply is the same, but now there are no retailers receiving large profits; all retailers are receiving a moderate profit. This type of market interaction will most likely occur for those crops where unfavorable weather forces suppliers to default on orders, namely, highly perishable crops such as lettuce and flowers which must be ordered a week or more in advance.

If the effect of weather forecasts on society was to leave no one worse off and some individuals (or possibly everyone) better off, then it seems unlikely that there would be much disagreement about the desirability of the improvement. But, in a situation such as may occur in agriculture where some groups are worse off and others better off, the question of desirability is not as easily answered. One must consider social, political, and ethical values as well as economic criteria of efficiency.

Market Structure Effects

There are other long-run effects of improved weather forecasting besides changes in the distribution of income. It seems quite likely that improved weather forecasting will contribute to the forces which lead to a reduction in the number of small farms and the growth of the large corporately managed farms. There are several reasons for this. First, if prices do decline, the smaller inefficient farms—that is, the marginal producers—may be forced out of business. Second, the larger resources of a corporate farm increase their ability to invest in the specialized communication and interpretative facilities that are required to obtain weather reports more frequently. Third, the greater resources of the corporate farm also increase their ability to respond to and utilize the weather information; this in turn increases their competitive advantage over smaller farms.

Resource Allocation Effects

The preceding analysis has dealt with the supply response generated as a result of better weather forecasts, by those producers who were already producing the product. In fact, the total quantity of the product supplied may also change either because new producers enter the industry—that is, start producing the particular crop—or because some of those who were producing the crop leave the industry—that is, stop producing it. The amount of land allocated to the production of each crop may change because the weather forecasts change the relative profitability of producing various alternatives.

At any point in time there are producers earning different rates of profit either because their businesses are operated at different levels of efficiency or because the quality of the factors used in production, such as land, differs. Furthermore, the rate of profit earned by a producer is not deterministic but rather varies randomly from one period to the next as a result of variations in actual output, price, etc. For some given amount of uncertainty we can draw a schedule relating the number of producers (or alternatively the acres in production) to the marginal expected (or average) rate of return. On figure 2 this schedule is represented by $MERR_0$. As we increase the number of farms we are adding farms with a lower level of efficiency or lower quality of inputs. Thus, the expected rate of return on each additional farm is smaller. There is some minimum expected rate of return r_0 necessary if the producer is to continue in operation and it is this rate in conjunction

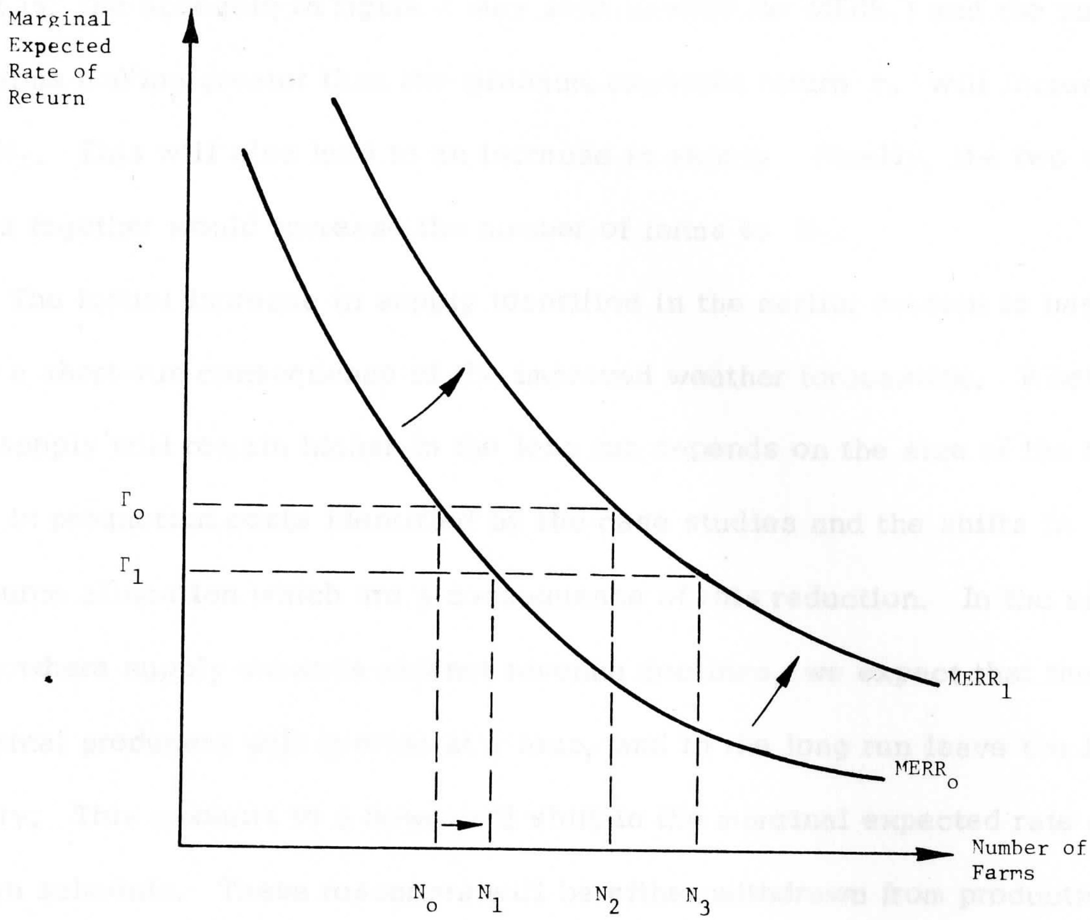

Figure 2

with the schedule that determines the actual number of farms N_0 and as a result the amount of output. It is quite likely that this minimum expected rate of return depends upon the amount of uncertainty, and that the lower the amount of uncertainty the lower the expected rate of return required to induce farms into production. If the variance of output (and price) is reduced by better weather information, even if the average rate of return schedule is unaffected, we might expect that the minimum rate of return will fall to r_1 and the number of farms and thus supply will increase. The availability of better weather information may also increase the average return on all farms.

That is, the schedule in figure 2 may shift upward (to $MERR_1$) and the number of farms making greater than the minimum expected return r_0 will increase to N_2. This will also lead to an increase in supply. Finally, the two effects together would increase the number of farms to N_3.

The initial increase in supply identified in the earlier section is basically a short-run consequence of the improved weather forecasting. Whether the supply will remain higher in the long run depends on the size of the reduction in production costs identified by the case studies and the shifts in resource allocation which are a consequence of this reduction. In the simple case where supply expands and net revenue declines, we expect that the marginal producers will operate at a loss, and in the long run leave the industry. This amounts to a downward shift in the marginal expected rate of return schedule. These resources will be either withdrawn from production entirely or shifted into the production of other crops. However, if the increased supply is accompanied by reduced costs of production, the marginal producers may still be able to make sufficient profits; in fact, if costs decline significantly relative to the decline in revenues, new producers may actually enter this market, thus increasing supply even further. In any case there is quite likely to be a shift in the allocation of resources among various crops from that which would have existed in the absence of the weather forecasts.

For example, resources will be reallocated if it becomes relatively more profitable to produce in a particular geographical area. Such a situation may occur in the production of lettuce in eastern states. In the eastern part of the country, predicting the quantity of lettuce production is difficult because of the weather. If better weather knowledge enables better predictions, producers will be able to enter the seven-day market to a greater extent than presently, and as a result there may be less reliance on western suppliers (whose lettuce is more expensive because of transportation costs). We would thus expect lettuce production in eastern states to increase and the demand for western lettuce to decline (other things being equal).

A reallocation of resources similar to this might also occur among different crops produced within the same region. It is usually true that a producer has the opportunity to produce a variety of alternative crops on his land. His particular choice will depend on what his land is best suited for, given the methods of production available for each type of crop and also his expectation of the price of that crop. Now, if long-term weather forecasts cause differential changes in the costs of production or if the changes in supply affect the relative prices of the different crops, it may become profitable for the farmer to produce a crop other than the one he had been producing. We should note that if many producers make this type of adjustment, supplies will be further affected.

Conclusions

The conclusions we can draw from our analysis of market interactions and resource allocations are not nearly as specific and definite as desired. However, we can make some general statements about the benefits resulting from improved weather forecasts. The fact that resources can be utilized more efficiently means that there will be a net social benefit. While the quantitative studies indicate that this benefit will be significant, they have not considered its distribution among various groups in the economy. When we estimate the benefit to the individual producer, assuming that all other things are unchanged, we conclude that the benefit will accrue to that individual producer. However, if all producers are utilizing the weather information then competition may transfer the benefit to the consumer. In fact, under certain conditions the result may be a situation in which the producer is absolutely worse off with the weather forecasts than without them; however, while he loses others will gain. In such a situation we face the difficult problem of comparing the gains of some with the losses of others.

III. COMMERCIAL ACTIVITIES

General Economic Characteristics

Although we have combined both construction and transportation activities under the heading of Commercial Activities, for purposes of describing the sector it is useful to separate the two activities. This arises from the fact that most available data describing the sector is presented by the more specific categories of construction and transportation rather than in the more general category of commercial activities.

New construction put in place had a total value of $91 billion in 1970, consisting of approximately two-thirds private and one-third public construction. This figure represents about 10% of the Gross National Product for that year. Furthermore, in projecting the importance of construction into the future, estimates indicate that construction put in place should continue to constitute about 10% of GNP (see table 9). However, the relative importance of certain types of construction can be expected to increase while others will decline. For example, the projections in table 9 suggest that construction of private and public apartment buildings, which has been the most rapidly growing area of construction with an annual rate of increase of 14.3% current dollars in the period 1967–75, will decline to a rate of 1.4% in the period 1975–80. At the same time construction of educational buildings will follow a change in growth rates in the opposite direction going from -0.4% in the early period to 8.0% in the later period.

Table 9 also provides information on the relative importance of various types of construction in the overall construction picture. It indicates that the single most important area of construction is "new housing units" and that this element combined with other types of residential construction (additions and alterations and nonhousekeeping units) accounted for $25 billion in 1967 or about one-third of all new construction. The next largest categories of construction are commercial buildings and highways and streets, each accounting for slightly over 10% of total construction.

Because residential construction makes up such a large share of total construction, it is in this area that weather forecasts have their greatest potential impact. However, all but a few types of construction classifications have a total worth of at least $1 billion (and of those that are less,

Table 9

Construction Put in Place and GNP Estimates, 1975 and 1980

	Billions of dollars					Annual rate of change: Percent			
	Actual	Current dollars		Constant(1967) $		Current dollars		Constant dollars	
	1967	1975	1980	1975	1980	1967-75	1975-80	1967-65	1975-80
Gross National Product: Total	789.7	1,366.6	1,920.1	1,105.7	1,384.3	7.1	7.0	4.3	4.6
Total new construction as a percent of GNP	10%	10%	10%	10%	10%	-	-	-	-
Total new construction: private and public	76.2	138.5	199.3	107.4	131.5	7.8	7.6	4.4	4.1
Residential buildings: private and public	25.0	52.6	72.3	41.4	49.1	9.7	6.6	6.5	3.5
Total new housing units: private and public[1]	19.3	41.6	55.8	32.8	38.0	10.1	6.0	6.9	3.0
One- and two-family homes: private and public	14.6	27.9	41.1	22.0	28.0	8 8.4	8.1	5.3	4.9
Apartments: private and public	4.7	13.7	14.7	10.8	10.0	14.3	1.4	10.8	-1.6
Additions and alterations: private[1]	4.4	8.6	13.2	6.8	9.0	8.7	8.9	5.6	5.8
Nonhousekeeping: private	1.3	2.4	3.3	2.1	2.1	8.0	6.6	4.2	3.1
Nonresidential buildings: private and public	28.6	41.0	57.0	31.8	37.7	4.6	6.8	1.3	3.5
Industrial: private and public	6.5	9.6	13.1	7.9	9.5	5.0	6.4	2.5	3.8
Commercial: private	7.0	10.8	14.9	8.3	9.8	5.6	6.6	2.2	3.4
Religious: private	1.1	1.8	2.3	1.4	1.5	6.4	5.0	3.1	1.4
Educational: private and public	7.0	6.8	10.0	5.0	6.0	-0.4	8.0	-4.1	3.7
Hospital and institutional: private and public	2.0	3.6	5.0	2.6	3.0	7.6	6.8	3.3	2.9
Other public buildings:	2.2	4.0	5.5	3.1	3.7	7.8	6.6	4.4	3.6
Misc. bldg. construction (incl. farm): private	2.8	4.4	6.2	3.5	4.2	5.8	7.0	2.8	3.7
Utilities: private	7.0	11.5	15.8	9.8	12.2	6.4	6.6	4.3	4.5
Highways/streets: public	8.5	19.8	34.6	13.9	19.5	11.1	11.8	6.3	7.0
Sewer/water: public	2.3	6.1	9.5	4.6	6.1	13.0	9.3	9.1	5.8
Other nonbuilding const., incl. military facilities, conservation/development, and misc. public const: public[1]	4.7	7.5	10.1	5.9	6.9	6.0	6.1	2.9	3.2

[1] For most categories there is general agreement between the Census Bureau put-in-place data carried monthly in Construction Review and the F. W. Dodge data shown above. However small differences exist for new housing units, additions and alterations, and other nonbuilding construction.

Source: GNP ESTIMATES—National Economic Projections to 1978-79, Report 68-N-1 (Washington, D. C. 20009, National Planning Association), pp. 117 and 118. CONSTRUCTION ESTIMATES—Construction Market Outlook, 1980 (New York, N. Y. 10036, F. W. Dodge Division, McGraw-Hill Information Systems Company). F. W. Dodge categories regrouped by BDSA to make them comparable with those in Construction Review.

the smallest is $741 million). This means that very small percentage improvements can yield significant quantitative benefits if they apply generally to a construction category (that is, without regard to regional or other possible differences).

The transportation element of the commercial activities sector is less homogeneous in character than the construction activities sector. Transportation includes not only common carrier trucking, which was the focus of a case study, but also trucking conducted by nontrucking firms which own their own fleet of trucks. It also includes other forms of transportation such as air flight, water transport and railroads. The transportation sector can also be divided into freight and passenger movement.

Tables 10 and 11 below, taken from the 1963 Census of Transportation, provide information on the relative importance of the various modes of transportation in the shipment of freight. The approximate balance between the various modes of shipping freight (with the exception of air transport) suggests that all types of transportation are equally important for their potential benefits from improved weather forecasting.

Table 12 provides information on the distribution of shipments on a distance basis. This table suggests that short-range shipments (199 miles or less) by far predominate over medium- and long-distance shipments—not really a surprising conclusion.

Turning to the trucking aspect of transportation, for which we have a case study, tables 13 and 14 illustrate some important characteristics of

Table 10

Shipper Group Summary—Means of Transport (Tons of Shipments)

Shipper group	Tons (thousands)	Percent distribution by means of transport: All Means	Rail	Motor carrier	Private truck	Air	Water	Other	Unknown
United States, total	[a]1,334,838	100.0	32.8	25.9	16.2	-	24.5	0.5	0.1
1 Meat and dairy products	39,787	100.0	27.1	29.8	42.6	-	.1	.3	.1
2 Canned and frozen foods and other food products, except meat and dairy products	125,726	100.0	59.9	21.6	17.4	-	.7	.1	.3
3 Candy, beverages, and tobacco products	44,249	100.0	22.3	29.8	45.7	-	1.9	.2	.1
4 Textile mill and leather products	12,609	100.0	13.5	65.3	19.0	0.1	.1	1.8	.2
5 Apparel and related products	3,906	100.0	9.3	62.0	11.2	.8	-	16.3	.4
6 Paper and allied products	65,551	100.0	49.9	33.1	13.9	-	1.9	1.0	.2
7 Basic chemicals, plastics materials, synthetic rubber and fibers	79,916	100.0	54.2	23.4	9.5	-	12.3	.4	.2
8 Drugs, paints, and other chemical products	60,318	100.0	42.0	34.8	19.9	.1	2.2	.6	.4
9 Petroleum and coal products	398,066	100.0	8.0	10.2	7.9	-	73.5	.4	-
10 Rubber and plastics products	8,884	100.0	25.4	63.4	8.7	.2	.3	1.8	.2
11 Lumber and wood products, except furniture	70,380	100.0	53.7	14.4	29.7	-	2.1	.1	-
12 Furniture, fixtures, and miscellaneous manufactured products	9,494	100.0	22.4	39.8	35.5	.1	.4	1.5	.3
13 Stone, clay, and glass products	175,597	100.0	30.1	35.8	28.1	-	5.9	-	.1
14 Primary iron and steel products	120,521	100.0	52.8	36.4	4.1	-	6.3	.3	.1
15 Primary nonferrous metal products	18,862	100.0	51.5	33.9	11.0	-	2.9	.3	.4
16 Fabricated metal products, except metal cans and miscellaneous fabricated metal products	16,298	100.0	22.5	42.8	31.7	.1	.5	1.9	.5
17 Metal cans and miscellaneous fabricated metal products	12,787	100.0	27.1	55.4	15.0	.2	.9	1.2	.2
18 Industrial machinery, except electrical	5,876	100.0	21.0	65.0	8.2	.5	1.1	3.3	.9
19 Machinery, except electrical and industrial	14,130	100.0	37.0	50.6	9.7	.3	.2	1.9	.3
20 Communication products and parts	2,391	100.0	22.2	56.2	9.0	2.8	.4	9.1	.3
21 Electrical products and supplies	10,106	100.0	34.0	49.5	13.4	.2	.4	2.2	.3
22 Motor vehicles and equipment	34,717	100.0	51.2	42.2	5.7	.1	.2	.4	.2
23 Transportation equipment, except motor vehicles	3,242	100.0	35.5	38.9	21.7	.7	.8	2.0	.4
24 Instruments, photographic equipment, watches and clocks	1,423	100.0	13.3	69.8	8.4	1.2	.2	7.0	.1

[a]Because of rounding, detail may not add to total.

Table 11

Shipper Group Summary—Means of Transport (Ton-Miles of Shipments)

Shipper Group	Ton-miles (Millions)	Percent distribution by means of transport: All means	Rail	Motor carrier	Private truck	Air	Water	Other	Unknown
United States, total	[a]619,908	100.0	36.4	14.2	4.6	0.1	44.0	0.6	0.1
1 Meat and dairy products	15,910	100.0	46.5	36.2	16.2	-	.1	.9	.1
2 Canned and frozen foods and other food products, except meat and dairy products	49,258	100.0	74.9	16.8	6.6	-	1.3	.2	.2
3 Candy, beverages, and tobacco products	13,615	100.0	53.5	27.5	15.6	-	2.8	.5	.1
4 Textile mill and leather products	6,470	100.0	25.3	58.8	11.5	.1	.1	4.1	.1
5 Apparel and related products	2,183	100.0	10.0	62.1	6.7	1.5	.1	19.3	.3
6 Paper and allied products	26,849	100.0	70.9	20.7	4.6	-	2.4	1.3	.1
7 Basic chemicals, plastics materials, synthetic rubber and fibers	36,397	100.0	61.8	13.8	3.7	-	20.3	.2	.2
8 Drugs, paints, and other chemical products	23,145	100.0	61.5	24.3	7.3	.2	5.4	.9	.4
9 Petroleum and coal products	274,436	100.0	4.3	1.7	1.1	-	92.8	.1	-
10 Rubber and plastics products	4,602	100.0	37.0	52.4	5.9	.3	.8	3.3	.3
11 Lumber and wood products, except furniture	41,500	100.0	83.8	6.7	6.9	-	2.5	.1	-
12 Furniture, fixtures, and miscellaneous manufactured products	4,467	100.0	41.4	35.9	18.1	.2	1.8	2.4	.2
13 Stone, clay, and glass products	27,879	100.0	45.5	31.2	14.9	-	8.1	.2	.1
14 Primary iron and steel products	34,033	100.0	61.7	24.3	2.3	-	11.2	.4	.1
15 Primary nonferrous metal products	11,033	100.0	73.2	21.0	3.8	.1	1.3	.5	.1
16 Fabricated metal products, except metal cans and miscellaneous fabricated metal products	6,133	100.0	40.6	36.6	17.7	.2	.4	4.2	.3
17 Metal cans and miscellaneous fabricated metal products	4,655	100.0	41.6	46.9	7.0	.4	2.3	1.7	.1
18 Industrial machinery, except electrical	2,803	100.0	25.4	62.2	4.0	.9	.3	6.3	.9
19 Machinery, except electrical and industrial	8,678	100.0	51.5	40.0	4.5	.6	.6	2.6	.2
20 Communication products and parts	1,537	100.0	28.1	49.5	3.9	4.3	.5	13.5	.2
21 Electrical products and supplies	5,989	100.0	48.4	39.5	7.4	.5	.9	3.1	.2
22 Motor vehicles and equipment	15,877	100.0	69.8	26.2	2.9	.1	.3	.5	.2
23 Transportation equipment, except motor vehicles	1,445	100.0	33.0	44.0	16.0	2.1	.8	3.8	.3
24 Instruments, photographic equipment, watches, and clocks	1,015	100.0	28.2	7.8	3.4	2.1	.2	8.2	.1

[a]Because of rounding, detail may not add to total.

Table 12

Shipper Group Summary—Distance of Shipments (Tons of Shipments)

Shipper group	(thousands)	All distances	Under 100 miles	100–199 miles	200–299 miles	300–399 miles	400–499 miles	500–999 miles	1000–1499 miles	1500 miles or over
United States, total	[a]1,334,838	100.0	30.0	15.6	11.1	7.2	4.4	13.9	12.7	5.1
1 Meat and dairy products	39,787	100.0	34.6	14.3	9.0	7.1	4.6	17.7	10.4	2.3
2 Canned and frozen foods and other food products, except meat and dairy products	125,726	100.0	22.4	20.5	14.2	11.0	5.8	18.9	3.4	3.8
3 Candy, beverages, and tobacco products	44,249	100.0	39.1	19.3	12.4	7.5	4.0	11.4	2.7	3.6
4 Textile mill and leather products	12,609	100.0	17.1	12.6	7.8	11.5	10.6	31.4	2.3	6.7
5 Apparel and related products	3,906	100.0	17.0	12.9	8.8	11.5	8.5	26.9	6.1	8.3
6 Paper and allied products	65,551	100.0	22.3	15.7	13.5	8.7	8.1	25.1	4.2	2.4
7 Basic chemicals, plastics materials, synthetic rubber and fibers	79,916	100.0	20.7	14.6	18.0	10.0	7.1	16.9	8.1	4.6
8 Drugs, paints, and other chemical products	60,318	100.0	31.5	16.8	10.7	7.9	4.1	21.2	5.8	2.0
9 Petroleum and coal products	398,066	100.0	26.8	10.2	5.7	4.5	1.6	11.1	33.2	6.9
10 Rubber and plastics products	8,884	100.0	18.7	13.3	11.6	9.7	8.4	25.5	6.1	6.7
11 Lumber and wood products, except furniture	70,380	100.0	34.0	13.6	7.8	5.2	3.3	13.9	5.3	16.9
12 Furniture, fixtures, and miscellaneous manufactured products	9,494	100.0	22.3	15.5	12.2	9.4	7.4	22.2	4.7	6.3
13 Stone, clay, and glass products	175,597	100.0	51.3	22.1	13.2	5.9	3.0	3.8	.4	.3
14 Primary iron and steel products	120,521	100.0	31.3	20.8	18.0	9.8	5.6	10.5	2.0	2.0
15 Primary nonferrous metal products	18,862	100.0	19.3	15.5	9.9	7.4	7.4	19.9	10.3	10.3
16 Fabricated metal products, except metal cans and miscellaneous fabricated metal products	16,298	100.0	30.1	18.1	12.8	10.1	5.0	15.5	2.9	5.5
17 Metal cans and miscellaneous fabricated metal products	12,787	100.0	31.3	14.7	15.9	7.2	6.7	17.3	2.8	4.1
18 Industrial machinery, except electrical	5,876	100.0	20.5	14.9	13.4	10.8	6.1	21.6	6.6	6.1
19 Machinery, except electrical and industrial	14,130	100.0	12.7	11.4	10.7	10.5	7.9	28.1	8.3	10.4
20 Communication products and parts	2,391	100.0	12.2	14.9	9.9	5.1	5.9	33.6	7.1	11.3
21 Electrical products and supplies	10,106	100.0	12.8	14.1	12.3	9.8	8.9	25.9	5.2	11.0
22 Motor vehicles and equipment	34,717	100.0	20.8	15.2	14.1	7.8	12.9	18.7	3.0	7.5
23 Transportation equipment, except motor vehicles	3,242	100.0	25.1	13.4	12.6	9.2	8.5	20.1	5.8	5.3
24 Instruments, photographic equipment, watches, and clocks	1,423	100.0	12.9	10.0	13.4	7.3	8.3	26.3	6.6	15.2

[a]Because of rounding, detail may not add to total.

Table 13

Area of Operation and Size of Truck Fleet: 1963
(Percent distribution of motor trucks)

Size of truck fleet	Total	Local	Intermediate	Long distance	Not reported
	Distribution by area of operation				
All trucks	100.0	72.6	7.7	1.7	18.0
Trucks in fleets of:					
1 truck	100.0	71.6	5.2	0.9	22.3
2 or 3 trucks	100.0	78.6	10.3	1.8	9.3
4 or 5 trucks	100.0	76.1	13.1	2.1	8.7
6 to 9 trucks	100.0	75.6	14.9	2.7	6.8
10 to 19 trucks	100.0	73.1	16.6	3.9	6.4
20 to 29 trucks	100.0	71.8	15.8	4.4	8.0
30 to 49 trucks	100.0	71.2	16.7	4.6	7.5
50 to 99 trucks	100.0	70.1	17.5	5.6	6.8
100 to 149 trucks	100.0	71.8	12.5	7.6	8.1
150 trucks or more	100.0	72.4	9.1	11.7	6.8
	Distribution by size of truck fleet				
All trucks	100.0	100.0	100.0	100.0	100.0
Trucks in fleets of:					
1 truck	70.3	69.3	47.6	37.8	87.0
2 or 3 trucks	8.7	9.5	11.8	9.2	4.5
4 or 5 trucks	4.2	4.4	7.2	5.4	2.0
6 to 9 trucks	4.4	4.6	8.5	7.1	1.7
10 to 19 trucks	4.3	4.3	9.3	10.0	1.5
20 to 29 trucks	1.9	1.8	3.8	4.9	0.8
30 to 49 trucks	2.0	1.9	4.3	5.4	0.8
50 to 99 trucks	1.9	1.9	4.5	6.5	0.8
100 to 149 trucks	0.8	0.8	1.2	3.5	0.3
150 trucks or more	1.5	1.5	1.8	10.2	0.6

Table 14

Size of Truck Fleet and Major Use of Truck: 1963
(Percent distribution of motor trucks)

Major Use	Total	Trucks in fleets of: 1 truck	2 or 3 trucks	4 or 5 trucks	6 to 9 trucks	10–19 trucks	20–29 trucks	30–49 trucks	50–99 trucks	100–149 trucks	150 or more trucks
					Distribution by size of truck fleet						
Total	100.0	70.3	8.7	4.2	4.4	4.3	1.9	2.0	1.9	0.8	1.5
Agriculture	100.0	87.3	8.1	2.0	1.4	0.7	0.2	0.1	0.1	0.1	-
Personal	100.0	97.6	1.9	0.3	0.1	0.1	-	-	-	-	-
For hire	100.0	31.0	9.8	6.2	9.3	12.3	6.1	7.8	7.7	2.9	6.9
Contract construction	100.0	50.3	13.4	8.0	8.1	8.0	4.1	3.3	3.0	0.8	1.0
Manufacturing	100.0	36.6	11.7	8.0	10.4	11.8	5.6	5.6	5.4	2.1	2.8
Wholesale and retail business	100.0	45.6	14.8	9.2	9.3	8.0	3.0	3.2	3.4	1.5	2.0
Services	100.0	62.8	12.7	5.8	6.1	5.7	1.8	2.4	1.4	0.5	0.8
Other businesses	100.0	38.5	10.2	7.0	7.2	9.3	4.7	5.4	6.3	2.2	9.2
Other uses	100.0	47.7	6.4	1.9	6.3	5.3	3.3	4.2	7.9	4.7	12.3
					Distribution by major use						
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Agriculture	28.0	34.7	25.8	13.2	8.8	4.5	2.3	1.4	1.9	3.0	0.7
Personal	24.5	34.0	5.3	1.4	0.4	0.6	0.3	0.1	0.4	0.6	-
For hire	5.9	2.6	6.7	8.7	12.7	17.0	19.3	23.4	23.1	22.6	27.7
Contract construction	10.0	7.2	15.4	19.1	18.5	18.6	22.0	16.6	15.5	11.2	6.8
Manufacturing	4.6	2.4	6.1	8.7	10.9	12.6	13.6	12.9	12.5	12.7	8.6
Wholesale and retail business	13.7	8.9	23.2	29.9	29.1	25.5	22.3	22.1	23.6	27.8	18.4
Services	8.2	7.3	11.8	11.3	11.3	10.8	7.8	9.9	6.0	5.0	4.7
Other businesses	4.5	2.4	5.2	7.4	7.3	9.5	11.2	12.1	14.2	12.8	27.3
Other uses	0.6	0.5	0.5	0.3	1.0	0.9	1.2	1.5	2.8	4.3	5.8

Source: United States Truck Inventory and Use Survey.

this industry. Table 13 indicates that most truck fleets are small: 70.3% consist of only one truck, and 91.9% consist of 19 or fewer trucks. Table 14 indicates that common-carrier trucking fleets are generally larger: slightly over one-fourth of all fleets contain 150 or more trucks. This means that in general terms the industry can be characterized as made up of numerous small firms, a point which will be important in our later analysis.

The data above provide only a general outline of the activities of the commercial sector and no effort is made to characterize the industries in this sector along regional lines. Of course, it would be possible to depict the industry in much greater detail but for our purposes this is really not necessary. In general, regional differences are not as important as they were in agriculture; transportation and construction activities of the type we are examining are conducted throughout all regions of the country, in contrast to certain agricultural activities such as citrus fruit production which is almost exclusively located in the south and west. The basic regional differences are the consequence of much more severe winters in the north than in the south. Thus, construction activities decline more in the north than in the south during the winter months, but even this difference does not apply to the transportation part of the commercial activities sector. In the agricultural section it was useful to provide a detailed statistical picture of the sector as this aided our later discussion. However, as we shall see, a general outline will be sufficient for a discussion of the commercial activities sector.

The Case Studies

The shortcomings of the commercial activities case studies derive from two sources. One, the less important of the two, is the very structure of the commercial activities sector of the economy and the design of the project. The various economic activities subsumed under this heading are much less similar than was the case for those activities included in the agricultural sector. As a result, the generalization process is somewhat more difficult. This problem is further complicated by the fact that only three case studies have been conducted for this sector. In the agricultural sector the larger number of case studies provided reinforcement for the major conclusions on the sector. The important effects from improved weather forecasting became apparent through their repeated appearance in several studies while at the same time attention was called to those effects which may have also been important, but which were specific to a smaller subgroup of agricultural activities. In the commercial sector with a smaller number of case studies and greater diversity of activity, this reinforcement function is missing. It should be noted, however, that in spite of this disadvantage, there were reasons for designing and selecting the case studies in the way that was done. The emphasis on agriculture reflects the a priori assumption (since confirmed by the case studies) that the greatest impact would be in the agricultural sector and that for this reason more resources ought to be devoted to examining carefully the nature and magnitude of that impact.

The second and more important limitation of the commercial activities case studies derives from their findings. The economic activities of the commercial sector, as we have defined it, are most often labor intensive, at least relative to manufacturing. As such, labor costs may account for more than 50% of total production costs. This means that significant benefits will be most likely to accrue from improvements in labor productivity. This is a fact which is realized and understood by management. As a result, when investigators interviewed those people involved in commercial activities sector their responses stressed how improved weather forecasts would enable them to reduce labor costs.

This has had an unfortunate consequence for the benefits identified in these studies. They have in some instances identified as a benefit a situation where the firm is able to reduce its labor costs at the expense of their employees. While this type of benefit can be considered a private benefit for the firm, it cannot be considered a benefit for society; rather it represents a transfer of income between employer and employee. Furthermore, it seems likely that such an outcome would be short-lived. When workers realize that their net income has declined and the company's profit has risen they will probably attempt to seek some redress through higher wages, a guaranteed minimum income or some other mechanism.

A social benefit occurs when improved weather forecasting enables society's limited resources to be utilized more efficiently. This usually happens in either of two ways: losses caused by weather damage may be avoided, or labor, unable to work in certain weather conditions can, if sufficient notice is given, be employed elsewhere. With respect to the second type of social benefit, if it is not possible to employ those people elsewhere, then no social benefit results. Only if we consider their temporary unemployment as increasing their leisure can we argue that social welfare is increased, and this would seem to be a very tenuous argument.

Finally, generalization of the commercial activities case studies is made difficult because of their negative conclusions; they argue that the benefits from improved weather forecasting would be relatively insignificant. While this conclusion may apply generally to commercial activities, we cannot simply assert that it does. In generalizing the results of the case studies to the other activities in this sector we must first seek to establish the reasons that the case studies arrived at this negative conclusion and then determine if those reasons have general applicability to the commercial sector or if they are unique to some subset of that sector into which the case studies happen to fall. If the latter is the case, we will not be able to conclude very much about the effect of weather forecasts on the commercial sector. It could be that other commercial activities would yield significant benefits or it could be that other activities will also have insignificant benefits but for reasons other than those identified in the case studies. We would have no basis for determining which alternative applies except through additional case studies. On the other hand, if the case studies are typical of the commercial sector as a whole we can legitimately conclude (with an exception we shall note in the section on long-run impact) that the benefits from improved weather forecasting will be insignificant in this sector.

Extensions of the Case Studies

As expected, the commercial activities case studies identified specific functions which are common to all commercial activities. Furthermore, they defined the relationship between these functions and weather variables and indicated the possible role of weather forecasts. For example, both the highway construction study and the residential home-building study noted the importance of temperature in pouring concrete. They suggested that heating the mix or planning for a different pouring date are possible responses to a forecast of cold weather. Pouring concrete is a necessary part of almost all construction activities although its relative importance varies greatly with the particular type of construction; for example, it is much more important in highway building than in home building. Similarly, the construction studies identified how weather forecasts might be utilized to improve excavating operations and the scheduling of labor and materials. Since these operations are also common to other types of construction, we should be able to generalize to the industry as a whole. Similar comments can be made with respect to the common carrier trucking study. Functions such as docking, pick-up and delivery, line haul, and driver scheduling were identified. These functions were also characteristic of and common to rail, air, and water transportation.

However, the fact that the case studies reached the conclusion that the benefits from weather forecasting were insignificant makes the generalization process difficult. A reading of the case studies indicates that losses due to weather were significant in the construction sector. The home-building study concludes that approximately 1% of expenditures are related to adverse weather. While the highway construction study does not provide a quantitative estimate of actual losses due to bad weather, careful examination of it suggests that the loss may be slightly greater than the losses identified in the home building industry. If we discount those benefits which are not truly social benefits but rather transfers between labor and management, then the actual benefits may be around 1% to 3% of total expenditures. Finally, another study (cited in the home building case study), conducted by the Environmental Science Services Administration, estimates losses due to adverse weather for all construction at approximately 3%. The trucking transportation study found losses due to adverse weather to be considerably smaller. The estimate for the Gateway Transportation Company was $106,000 or .2% of total operating expenses.

In both the construction and transportation studies the researchers found that even though weather losses may have been significant the potential savings which would result from accurate long-range weather forecasts were extremely small and probably insignficant. The reason for this conclusion was the existence of institutional constraints which limit the firm's ability to respond to the weather forecast. Consequently, a better approach for extrapolating the results of the case studies in the commercial sector is to determine if the structural constraints identified in the case studies are characteristic of all commercial activities or if they apply only to the subdivision of the sector on which the case studies concentrated. If the latter is the case, we will not be able to estimate the benefits quantitatively because we lack appropriate studies from which to generalize. On the other hand, if the former situation holds true then we can be reasonably certain that the conclusions of the commercial activities case studies apply to that area of the economy in general.

A major constraint on effective use of weather forecasts was found to be the large number of small firms. In the construction industry the fact that the typical firm is small tells us several things about its ability to utilize long-range weather forecasts. First, it probably means that the crew cannot be shifted to another project at a different stage of completion where the weather is less important because there will be no other project. Most small firms work on only one or two projects at a time. Second, it means that crews cannot be shifted to another geographical area where weather conditions are different, because the firm will be local in nature. And, third, it may mean that the firm engages only in very crude methods of planning and consequently would not know how or where to use weather information more than one or two days ahead.

Even when a firm is not so small, the first two constraints may still apply because of the manner in which large firms operate. That is, large firms which operate over large geographic areas and on many different projects at the same time often subcontract much of the actual work to small firms which do have those constraints. The large firm then employs most of its workers in administrative and supervisory roles, and hence, even though it probably has the planning capability to utilize weather forecasts, its subcontracting practices limit its ability to react.

Table 15 provides some data on firm size in the construction industry. Note that out of 322,781 firms, only 188 employ 500 or more people, and 174,356 or approximately 56% employ between one and three people. Furthermore, this pattern seems to be approximately the same in all the various subdivisions of the construction industry. This would indicate that the highway and residential home-building studies are typical of the industry as a whole, and hence conclusions based on structural characteristics of the activity apply to the industry as a whole.

In the transportation industry the inflexibility of the responding to weather forecasts is caused indirectly by the large proportion of small firms. Although a large proportion of small firms may mean lack of planning ability, the real significance of small firms is that there will be substantial competition. In the transportation industry as a whole there is usually relatively little price competition, often because of governmental regulations. As a result, firms compete with each other on a service basis. Hence transportation firms feel they cannot reduce service as a result of predicted bad weather, because they risk losing customers to those competitors who maintain quality service. Hence, firms will feel the risk associated with utilizing the weather forecasts are greater than the costs incurred by adverse weather.

This problem most likely applies to all forms of freight transportation

Table 15

Number of Employees and Number of Reporting Units by Employment—Size Class and Contract Construction, March 1966

Number of employees	3,054,375
Total Reporting Units	322,781
Number of Reporting Units, by Employment—	
Size Class	
1 to 3	174,356
4 to 7	67,141
8 to 19	50,429
20 to 49	20,779
50 to 99	6,536
100 to 249	2,835
250 to 499	517
500 or more	188

(with the possible exception of air transportation) since there is inter-industry as well as intra-industry competition. It may be the case that significant benefits are possible in passenger transportation, especially air transportation. This would be the case even though competition is again exercised in terms of service, since they must all use the same airport. We cannot on the basis of the trucking study say anything concrete or quantitative about this possibility.

A second constraint upon a firm's ability to respond to weather forecasts is its high degree of labor intensity. This acts as a constraint in several ways:. first, the fact that labor represents a significant fraction of total production costs (over 50% in the construction industry) means that increases in efficiency must usually involve increasing labor productivity. Second, the high wages of labor in this sector, as opposed to those of agriculture workers, often means it is less costly from the firm's point of view to incur weather losses than it is to speed up work by employing additional workers or by paying premium wage rates for overtime work. A third factor is that in the commercial sector strong unions exist which have imposed certain additional constraints on the firm's ability to respond to weather forecasts. The most important of these is the limit on layover time for drivers in the transportation industry. In the construction industry the constraint imposed by union regulations is a restriction on the type of job a particular worker may perform; for example, excavating crews cannot be employed as carpenters on those days when excavation operations are not feasible. This limits the ability of a company to use weather forecasts. This constraint is characteristic of the industry and is also applicable to the commercial sector as a whole.

Our general conclusion then about the commercial activities sector of the economy must be that at the present time and for the foreseeable future, improved weather forecasts would have only a very small effect and, in relative terms, a probably insignificant benefit.

Long-Run Impacts

One might be tempted to conclude that if the benefits from accurate long-range weather forecasts are insignificant, then there will be no long-run impact. Indeed, this is a possibility. On the other hand, the reason that the benefits would be insignificant is not that weather has no effect, but rather that institutional constraints limit the ability of firms to respond. In the long run these institutional constraints could be modified or eliminated so that firms could respond to weather forecasts. For example, we can imagine an increase in the average size of firms if significant benefits accrue to larger firms as a result of weather forecasts. It may even be the case that labor contracts could be negotiated which would enable firms to utilize weather forecasts without undercutting labor's income. That is, it may be possible to effect actual social benefits rather than simply transfers between labor and management.

But, of course, the trend toward actual social benefits would emerge only if the advantage from utilizing weather forecasts were large enough.

On the basis of the case studies it seems unlikely that weather forecasts by themselves will be important enough to set these trends in motion. However, if the impetus provided by weather forecasts combines with other factors (for example, technological change) which also favor larger firms, more thorough planning, etc., then the net result may be a shift in this direction.

We should note, however, that it is possible that other forces may work in a direction counter to that implied by improved weather forecasting. For example, prefabrication and other types of factory-build construction tend to minimize the importance of weather and hence reduce the effect which weather forecasting could possibly have. Similarly, in the transportation industry, improved methods of handling shipments on the dock (for example, building enclosed docks) could also reduce the importance of weather forecasts. If these factors should dominate, then no new trends may occur in the commercial activities industries and weather forecasts would continue to go unutilized.

IV. NATURAL RESOURCES

General Economic Characteristics

What we have chosen to call the natural resources sector of the economy includes a variety of activities. We can, however, divide these activities into two parts for purposes of determining the effects of improved long-term weather forecasting. The first part consists of those activities involving the management of the nation's natural resources. These include water resource management, for which a case study was done, forest and timber management, and possibly coal mining and oil and natural gas production. The second part includes those activities that involve the utilization of the nation's natural resources. These involve the entire range of outdoor activities from camping and canoeing to skiing; the other, an attempt to evaluate the extent to which families are flexible in planning their vacations and other activities, and, on the basis of this information, to estimate the potential benefits to individuals and their families.

No attempt will be made to place these activities within the context of the nation's total production as was done for the agricultural and commercial sectors. There are a number of reasons for not doing so. First, statistics on these activities are harder to find than on the other activities we have considered. Furthermore, those statistics that are available generally do not report production in terms of dollar values. It is difficult and somewhat arbitrary to make the conversion that is necessary in order to compare and evaluate this sector in the same way as was done for the other sectors. Second, those statistics that do report monetary values for a particular industry include much more than the area with which this study is concerned. For example, in the lumber industry statistics regarding the value of lumber produced would have little meaning for determining the value of forest management. Finally, any statistics that did, in fact, focus upon a particular management activity would quite likely give a misleading impression of the natural resources sector. This sector no doubt accounts for a small proportion of the GNP but this fact should not be allowed to belie its importance. The impact of management activities is multiplied through an effect in other sectors of the economy. For example, if water resources are mismanaged because of decisions made on the basis of insufficient weather information, the consequences may be a shortage of irrigation water or an inability to generate required power. In both these cases the loss registered in the natural resources sector is merely the loss of sales of irrigation water or power which otherwise could have been made. But the actual loss to the economy is much greater. Crop yields may be reduced and manufacturing plants may be forced to operate at less than optimum capacity.

The resource utilization part of this sector draws its importance from the fact that it is the area in which improved weather forecasts will directly benefit a large percentage of the population. For the activities discussed in earlier chapters the benefits usually accrued directly to a specific group such as farmers, contractors, dam operators, etc., and although these benefits were, in many cases, passed on to a larger segment of society, most people would not be aware of the link between the improved forecast and the more efficient use of resources that created the benefit. However, in the case of planning recreational activity a large part of the population would personally experience the benefits brought about by improved weather forecasts. Table 16 provides an idea of the numbers of individuals likely to be affected in this way.

Table 16

Participation in Selected Outdoor Activities—
Persons 12 Years Old and Older: 1965

Outdoor Activity	Participants Number (millions)	Participants Rank	Average number of days per participant	Number of days of participation, total (millions)
Picnicking	80.5	1	5.6	451
Driving for pleasure	77.7	2	12.1	940
Sightseeing	69.2	3	6.6	457
Swimming	67.8	4	14.3	970
Walking for pleasure	67.8	5	15.2	1031
Playing outdoor games and sports	53.7	6	17.3	929
Fishing	42.4	7	7.6	322
Attending outdoor sports events	42.4	8	5.8	246
Boating	33.9	9	6.5	220
Bicycling	22.6	10	20.6	466
Nature walks	19.8	11	5.9	117
Sledding	18.4	12	nm	nm
Hunting	17.0	13	nm	nm
Attending outdoor concerts and plays	15.5	14	3.0	47
Camping	14.1	15	6.9	97
Ice skating	12.7	16	nm	nm
Horseback riding	11.3	17	6.8	77
Hiking	9.9	18	5.1	50
Water skiing	8.5	19	6.6	56
Bird watching	7.1	20	15.9	13
Snow skiing	5.7	21	nm	nm
Canoeing	4.2	22	4.5	19
Sailing	4.2	23	6.2	26
Wildlife and bird photography	2.8	24	5.9	17
Mountain climbing	1.4	25	3.1	4

nm: not measured in the 1965 survey.

Source: Department of the Interior, Bureau of Outdoor Recreation; The 1965 of Outdoor Recreation Activities, Oct. 1967.

The Case Studies and Extensions

Turning first to an analysis of the case studies on outdoor recreation, we confront a problem of extrapolation not encountered in the other areas of this study. In this sector the conclusions of the case experts are considerably more quantitative than they were in the other sectors. We would, therefore, expect that the findings of these case studies could be extrapolated in greater detail and that a general conclusion regarding the total benefit could be quantitatively estimated. Indeed, this can be done. For example, the study by Nelson indicates that approximately one-fourth of those who participated in outdoor recreational activities had that activity spoiled by bad weather. An analysis of the factors that respondents felt affected their planning of activities, and their flexibility to respond to weather forecasts, indicates that this unfortunate occurrence would be eliminated by one-week forecasts. A similar proportion of activities spoiled by bad weather would probably be found in outdoor activities not covered by Nelson's study, such as family gatherings, garden shows, outdoor concerts, or even outdoor work around the home. A slightly different example of extrapolation is illustrated by the study of the ski industry: that study suggests ways in which improved weather forecasts will benefit not only those who participate in outdoor activities but also those who operate outdoor recreational facilities. The findings for ski lodge operations probably apply to dock and yacht yard operators, operators of hunting and fishing lodges and those who operate similar types of outdoor recreation facilities. The weather information may also be of value to a variety of merchants in resort towns.

The difficulty in evaluating these benefits and arriving at an aggregate benefit for the sector is that in many instances the benefit is non-monetary. If actual use of a recreation facility is increased, the benefit could be measured by the increase in revenue at such facilities. Also, if new participants are enticed into an outdoor activity, their benefit could be measured by the expenditure associated with entering into that activity for the first time. The problem with this approach is that it would require a detailed cost analysis of each activity, a task beyond the scope of this study. Even if this task were undertaken, the conclusion would be inadequate. In order to understand more fully the nature of the problem, consider the following: there are two ways in which a weather-disrupted event can be avoided. Either the participants may cancel their plans or change them to a different date, or they may move to a different location where the weather is better. If the event must be cancelled, the benefit is one of having been spared the discomfort of bad weather; if the participants move to an alternative site, the benefit is not only the avoidance of discomfort but also consists of the satisfaction derived from being able to enjoy the originally-planned activity. In either case it is difficult adequately to evaluate the benefit in monetary terms. Furthermore, for the owner of a boat who must decide in advance whether to plan a trip, there is only a non-monetary loss if his choice should turn out to be the wrong one because of bad weather. As a result of these considerations, we must be satisfied with an evaluation of the benefits in terms of the percentages and numbers of people who will likely be affected.

Both the studies indicate that a substantial benefit is quite likely to occur in outdoor recreational activities.

When we turn to the resource management sector we find the possibilities for extrapolation more limited. The water resources case study simply does not provide a sufficient basis for generalizing. Water resource management does not tell us much about forest management, timber management, mining operations, etc. The conclusion that emerges is that a large number of case studies would be needed to capture the potential benefit of longer-term weather forecasts to the resource management activities. In fact, perhaps a study would be needed for each major activity in this area.

Long-Run Impact

While the long-term impacts of better weather forecasts are not discussed in any detail in the case studies it would seem that they are potentially quite significant. One quite obvious consequence of better weather information is a peaking effect. This possibility is briefly alluded to in the case studies. Recreational facilities either would not be utilized at all or would be crowded. This would lead to a variety of new developments designed to counteract it. These include an increased interest in the four-day work week, which would increase the number of potential peak days. Other developments might result in recreational facilities being more flexible for reacting to peaks or more diversified in their activities so as to attract a clientele under various weather conditions.

V. CONCLUSIONS

In this report we have provided an overview of the economic impact from recent advances in satellite meteorology identified in the multidisciplinary studies project and, in addition, we have attempted to extrapolate these benefits to those parts of the economy not specifically examined in the case studies. In concluding it is, I think, useful to stop and take note of the extent to which the objectives of the project were accomplished.

The objective which was most fully accomplished was that of obtaining a picture of various user needs. The case studies indicate the weather information required by a user in order to obtain a specified benefit. It should be possible from the case studies to decide upon the technical aspects of the satellites which would best fulfill the needs of various users as, in fact, Volume I claims it is. While this aspect of the study is limited by the highly concentrated geographical distribution of activities examined, this does not appear to be a significant limitation.

The educational or "linking" function objective of the study was carried out, but certainly not on a large scale. At most a few hundred people were informed in a serious way about potential weather forecasting capabilities. Furthermore, I think that the case studies demonstrate that some of the case study experts were not the relevant linkers. The case study investigators should have been less research-oriented and more familiar with the day-to-day operations as well as the cost of these operations. This would have led to the identification of benefits which were realistically likely to occur rather than benefits which were only theoretically possible. Nevertheless, it is probable that the combination of having obtained a picture of user needs along with some initial "linking" experience could lead to a more rational format for delivering weather information to various groups.

In the case studies and in this overview, benefits have been lumped together without regard to the length of the forecast required to obtain the benefit. If one were interested in identifying the benefit due specifically to 10- to 14-day forecasts, all those benefits which could be achieved using forecasts of less than this (alternatively, all benefits which could be achieved with less than one-week forecasts) should be subtracted from the benefits identified in the case studies and in this overview. If this were done, I believe the analysis would show that the most important benefits could be achieved by improving the accuracy of the one- to three-day forecast, or if it is already accurate, improving the dissemination of that information. The next most important forecast would be the one- to three-month forecast, depending on the industry or crop, and the two-week forecast would probably be a close third.

A general conclusion that emerges from the analysis is that in terms of quantitative evaluation, more could be done. Unlike past attempts to evaluate the benefits of the weather satellite program, the present effort was built on a strong microanalytic foundation. The case study approach was designed to identify the impact of weather information on the individual producer or user group. From these selected studies an attempt was made to generalize to the remaining economic activities. This generalization process was made with respect to characteristics that were similar in many activities. But at the time the case study selections were made it was not known specifically what these common characteristics would be. Thus, the distribution and approach of the case studies did not conform to what was later identified as appropriate for achieving the quantitative objectives of the project. We found ourselves in the proverbial position of having the information at the end of the project that was required optimally to design the research effort at its commencement.

With few exceptions (such as hay production), most activities upon which weather forecasts can have an effect are very complex, and the effect of the forecast (in contrast to the effects of the actual weather) is marginal. For the most part, the studies attempted to document possible actions and responses to forecasts. An alternative approach (the one followed in the transportation case study) would have been to collect data on current losses which are attributable to adverse weather conditions. Once the data were collected they could then be analyzed to determine which factors are most important in causing the loss, which of these factors might be potentially sensitive to two-week forecasts, and, finally, what percentage of these might be saved. This estimate would involve consideration of many of the factors on which the present case studies concentrate. The difference between this approach and the one taken in most of the studies is that many of the reports lack any figures whatsoever and, as a result, we have no idea of the possible magnitudes involved. The alternative approach would provide a maximum benefit and enable one to explore the importance of marginal improvements in the estimates on the final conclusion.

The major advantage of this project is that because it is based upon a microanalytic methodology the policy decision-maker is provided with the information needed to bring about the potential benefits that have been identified. As a result the entire process has a degree of credibility often lacking in more macro-oriented studies. Clearly, more research of this type is justified by the present experience.

APPENDIX A

COSTS OF PRODUCTION FOR VARIOUS AGRICULTURAL PRODUCTS

Note: The first nine tables are from Wisconsin Farm Enterprise Budgets University Extension Bulletin No. 7, The University of Wisconsin, June, 1969.

Table A-1. Costs and Returns per Acre of Corn, Grain[1]

	Soil and Climatic Capability[2]			YOUR
	Low	Medium	High	FARM
I. Receipts				
1. Yield per acre	70 bu.	90 bu.	120 bu.	
2. Harvest time price #2	$ 1.00	1.00	1.00	
3. Gross returns per acre	$70.00	90.00	120.00	
II. Variable Costs				
4. Fertilizer ($N-P_2O_5-K_2O$)[3]	70+30+30	90+40+40	130+50+50	
5. Fertilizer and lime cost[4]	$10.46	12.98	16.70	
6. Seed	3.00	4.00	5.00	
7. Insecticide and herbicide	3.50	5.00	7.00	
8. Machine operation	11.00	11.50	12.50	
9. Interest on above (6 mo. at 8%)	1.12	1.34	1.65	
10. Total variable costs	29.08	34.82	42.85	
III. Returns above variable costs	40.92	55.18	77.15	
IV. Fixed Costs				
11. Machinery and equipment	11.00	12.00	13.00	
12. Land—annual charge at 8%[5]	14.00	20.00	40.00	
13. Labor—5 hrs/acre at $2	10.00	10.00	10.00	
14. Total fixed costs	35.00	42.00	63.00	
V. Total all costs	64.08	76.82	105.85	
VI. Returns to management	5.92	13.18	14.15	
VII. Returns to labor and management	15.92	23.18	24.15	
VIII. Returns to land, labor and management	29.92	43.18	64.15	

[1] Based on Wisconsin and other midwest data. The examples may or may not be typical of your farm. Labor and machine costs include harvest, drying charges, and putting into storage.

[2] Climatic and other factors may affect yields of certain crops in relation to land value. See Page 1 and Special Circular 65, "What Yields from Wisconsin Soils," May 1966, for yield potentials of Wisconsin soils.

[3] Maintenance fertilization. Ten lbs. of N in row as starter fertilizer, remainder applied as anhydrous ammonia.

[4] Includes charges of $1.50 per year for corrective fertilization of 30 lbs. P_2O_5 and 120 lbs of K_2O once every five years plus $.50 per year for lime.

[5] Land charges allow 6% for interest and 2% for taxes and repairs. See also Footnote 2.

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Table A-2. Costs and Returns per Acre of 35% Dry Matter Corn Silage[1]

	Soil and Climatic Capability[2]			YOUR
	Low	Medium	High	FARM
I. Receipts:				
1. Yield per acre	12 tons	15 tons	20 tons	
2. Harvest time price	$ 7.50	7.50	7.50	
3. Gross returns per acre	$90.00	112.50	150.00	
II. Variable costs				
4. Fertilizer (N-P_2O_5-K_2O)[3]	70+30+30	90+40+40	130+50+50	
5. Fertilizer and lime cost[4]	$10.46	12.98	16.70	
6. Seed	3.00	4.00	5.00	
7. Insecticide and herbicide	3.50	5.00	7.00	
8. Machine operation	19.50	22.50	25.00	
9. Interest on above (6 mo. at 8%)	1.46	1.78	2.15	
10. Total variable costs	37.92	46.26	55.85	
III. Returns above variable costs	52.08	66.24	94.15	
IV. Fixed costs				
11. Machinery and equipment	8.50	10.50	12.00	
12. Land—annual charge at 8%[5]	14.00	20.00	40.00	
13. Labor at $2 per hour	12.00	16.00	18.00	
14. Total fixed costs	34.50	46.50	70.00	
V. Total all costs	72.42	92.76	125.85	
VI. Returns to management	17.58	19.74	24.15	
VII. Returns to labor and management	29.58	35.74	42.15	
VIII. Returns to Land, labor and management	43.58	55.74	82.15	

[1] Based on Wisconsin and other midwest data. The examples may or may not be typical of your farm. Labor and machine costs include harvest and putting into storage.

[2] Climatic and other factors may affect yields of certain crops in relation to land value. See Page 1 and Special Circular 65, "What Yields from Wisconsin Soils," May 1966, for yield potentials of Wisconsin soils.

[3] Maintenance fertilization. Ten pounds of N in row as started fertilizer, remainder applied as anhydrous ammonia. Silage removes more P_2O_5 and K_2O than grain. This level of application assumes added manure would be applied to replace additional P_2O_5 and K_2O removal.

[4] Includes charges of $1.50 per year for corrective fertilization of 30 lbs. P_2O_5 and and 120 lbs. K_2O once every five years, plus $.50 per year for lime.

[5] Land charges allow 6% for interest and 2% for taxes and repairs. See also footnote 2.

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Table A-3. Costs and Returns per Acre of Oats[1]

	Soil and Climatic Capability[2] Low	Medium	High	YOUR FARM
I. Receipts:				
1. Grain				
a. Yield per acre	55 bu.	75 bu.	90 bu.	
b. Harvest time price	$ .60	.60	.60	
c. Returns per acre	$33.00	45.00	54.00	
2. Straw				
a. Yield per acre	1.25 tons	1.25 tons	1.5 tons	
b. Harvest time price	$16.00	16.00	16.00	
c. Returns per acre	20.00	20.00	24.00	
3. Credit value for alfalfa seeding				
4. Gross returns per acre	53.00	65.00	78.00	
II. Variable costs				
5. Fertilizer ($N-P_2O_5-K_2O$)[3]	5+20+20	10+25+25	20+30+30	
6. Fertilizer and lime cost[4]	$ 5.09	6.20	7.76	
7. Seed	3.00	3.00	3.00	
8. Insecticide and herbicide	.50	.50	.50	
9. Machine operation	11.00	11.20	11.50	
10. Interest on above (6 mo. at 8%)	.78	.84	.91	
11. Total variable costs	20.37	21.74	23.67	
III. Returns above variable costs	32.63	43.26	54.33	
IV. Fixed costs				
12. Machinery and equipment	6.00	6.30	6.50	
13. Land—annual charge at 8%[5]	14.00	20.00	40.00	
14. Labor—4.5 hrs/acre at $2	9.00	9.00	9.00	
15. Total fixed costs	29.00	35.30	55.50	
V. Total all costs	49.37	57.04	79.17	
VI. Returns to management	3.63	7.96	-1.17	
VII. Returns to labor and management	12.63	16.96	7.83	
VIII. Returns to land, labor and management	26.63	36.96	47.83	

[1] Based on Wisconsin and other midwest data. The examples may or may not be typical of your farm. No legume seeding costs or credits are included. Labor and machine costs include harvest and putting into storage. Oats and alfalfa budgets need to be considered together as they fit into the rotation.

[2] Climatic and other factors may affect yields of certain crops in relation to land value. See Page 1 and Special Circular 65, "What Yields from Wisconsin Soils," May 1966, for yield potentials of Wisconsin soils.

[3] Maintenance fertilization.

[4] Includes charges of $1.50 per year for corrective fertilization of 30 lbs. P_2O_5 and 120 lbs. K_2O once every five years, plus $.50 per year for lime.

[5] Land charges allow 6% for interest and 2% for taxes and repairs. See also footnote 2.

Table A-4. Costs and Returns per Acre of 12% Moisture Alfalfa Hay[1]

	Soil and Climatic Capability[2]			YOUR
	Low	Medium	High	FARM
I. Receipts:				
1. Yield per acre	3 tons	4 tons	5 tons	
2. Harvest time price	$19.00	19.00	19.00	
3. Credit for N Fixation[3]	1.50	2.00	3.00	
4. Gross returns per acre	58.50	78.00	98.00	
II. Variable costs				
5. Fertilizer (N-P_2O_5-K_2O)[4]	0+10+60	0+20+120	0+30+180	
6. Fertilizer and lime cost[5]	5.42	8.84	12.26	
7. Seed[6]	1.85	2.47	3.70	
8. Insecticide and herbicide	1.75	3.50	3.50	
9. Machine operation	10.00	15.00	18.00	
10. Interest on above (6 mo.. at 8%)	.76	1.19	1.50	
11. Total variable costs	19.78	31.00	38.96	
III. Returns above variable costs	38.72	47.00	59.04	
IV. Fixed costs				
12. Machinery and equipment	12.00	14.00	17.00	
13. Land—annual charge at 8%[7]	14.00	20.00	40.00	
14. Labor at $2 per hour	10.00	16.00	18.00	
15. Total fixed costs	36.00	50.00	75.00	
V. Total all costs	35.78	81.00	113.96	
VI. Returns to management	2.72	-3.00	-15.96	
VII. Returns to labor and management	12.72	13.00	2.04	
VIII. Returns to land, labor and management	26.72	33.00	42.04	

[1] Based on Wisconsin and other midwest data. The examples may or may not be typical of your farm. No costs for establishment are charged other than seed and added machine costs beyond those for oats with no seeding. Labor and machine costs include baling and putting into storage, two cuttings on low yield, three on medium and high.

[2] Climatic and other factors may affect yields of certain crops in relation to land value. See Page 1 and Special Circular 65, "What Yields from Wisconsin Soils," May 1966, for yield potentials of Wisconsin soils.

[3] Credit for 100 lbs. nitrogen fixed at $.06 per lb. or $6.00, spread over years stand is left down—four years on low capability, three years on medium capability and two years on high capability.

[4] Maintenance fertilization.

[5] Includes charges of $1.50 per year for corrective fertilization of 30 lbs. P_2O_5 and 120 lbs. K_2O once every five years, plus $.50 per year for lime.

[6] Spread over four years on low capability, three years on medium capability, two years on high capability soil.

[7] Land charges allow 6% for interest and 2% for taxes and repairs. See also footnote 2.

Table A-5. Costs and Returns per Acre of Low Moisture (50%) Alfalfa Silage[1]

	Soil and Climatic Capability[2] Low	Medium	High	YOUR FARM
I. Receipts:				
1. Yield per acre	6 tons	8 tons	10 tons	
2. Harvest time price	$11.00	11.00	11.00	
3. Credit for N fixation[3]	1.50	2.00	3.00	
4. Gross returns per acre	67.50	90.00	113.00	
II. Variable costs				
5. Fertilizer (N-P_2O_5-K_2O)[4]	0+10+60	0+20+120	0+30+180	
6. Fertilizer and lime cost[5]	$ 5.42	8.84	12.26	
7. Seed[6]	1.85	2.47	3.70	
8. Insecticide and herbicide	1.75	3.50	3.50	
9. Machine operation	10.00	15.00	18.00	
10. Interest on above (6 mo. at 8%)	.76	1.19	1.50	
11. Total variable costs	19.78	31.00	38.96	
III. Returns above variable costs	47.72	59.00	74.04	
IV. Fixed costs				
12. Machinery and equipment	13.00	15.00	18.00	
13. Land—annual charge at 8%[7]	14.00	20.00	40.00	
14. Labor at $2/hr.	8.00	14.00	16.00	
15. Total fixed costs	35.00	49.00	74.00	
V. Total all costs	54.78	80.00	112.96	
VI. Returns to management	12.72	10.00	.04	
VII. Returns to labor and management	20.72	24.00	16.04	
VIII. Returns to land, labor and management	34.72	44.00	56.04	

[1] Based on Wisconsin and other midwest data. The examples may or may not be typical of your farm. No costs for establishment are charged other than seed and added machine costs beyond those for oats with no seeding. Labor and machine costs include chopping and putting into storage, two cuttings on low yield, three on medium and high.

[2] Climatic and other factors may affect yields of certain crops in relation to land value. See Page 1 and Special Circular 65, "What Yields from Wisconsin Soils," May 1966, for yield potentials of Wisconsin soils.

[3] Credit for 100 lbs. nitrogen fixed at $.06 per lb. or $6.00 spread over year's stand is left down—four years on low capability, three years on medium capability and two years on high capability.

[4] Maintenance fertilization.

[5] Includes charges of $1.50 per year for corrective fertilization of 30 lbs. P_2O_5 and 120 lbs. of K_2O once every five years, plus $.50 per year for lime.

[6] Spread over four years on low capability, three years on medium capability and two years on high capability soil.

[7] Land charges allow 6% for interest and 2% for taxes and repairs. See also footnote 2.

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Table A-6. Costs and Returns per Acre of Barley[1]

	Soil and Climatic Capability[2] Low	Medium	High	YOUR FARM
I. Receipts:				
1. Grain				
a. Yield per acre	30 bu.	45 bu.	65 bu.	
b. Harvest time price	$ .95	.95	.95	
c. Returns per acre	28.50	42.75	61.75	
2. Straw				
a. Yield per acre	1 ton	1 ton	1 ton	
b. Harvest time price	$16.00	16.00	16.00	
c. Returns per acre	16.00	16.00	16.00	
3. Gross returns per acre	44.50	58.75	77.75	
II. Variable costs				
4. Fertilizer ($N-P_2O_5-K_2O$)[3]	5+20+20	10+30+30	35+35+35	
5. Fertilizer and lime cost[4]	5.09	6.86	9.77	
6. Seed	5.00	5.00	5.00	
7. Insecticide and herbicide	.50	.50	.50	
8. Machine operation	9.50	9.70	10.00	
9. Interest on above (6 mo. at 8%)	.80	.88	1.01	
10. Total variable costs	20.89	22.94	26.28	
III. Returns above variable costs	23.61	35.81	51.47	
IV. Fixed costs				
11. Machinery and equipment	5.50	5.80	6.00	
12. Land—annual charge at 8%[5]	14.00	20.00	40.00	
13. Labor—4.5 hrs/acre at $2	9.00	9.00	9.00	
14. Total fixed costs	28.50	34.80	55.00	
V. Total all costs	49.39	57.74	81.28	
VI. Returns to management	-4.89	1.01	-3.53	
VII. Returns to labor and management	4.11	10.01	5.47	
VIII. Returns to land, labor and management	18.11	30.01	45.47	

[1]Based on Wisconsin and other midwest data. The examples may or may not be typical of your farm. Labor and machine costs include harvest and putting into storage.

[2]Climatic and other factors may affect yields of certain crops in relation to land value. See Page 1 and Special Circular 65, "What Yields from Wisconsin Soils," May 1966, for yield potentials of Wisconsin soils.

[3]Maintenance fertilization.

[4]Includes charges of $1.50 per year for corrective fertilization of 30 lbs. P_2O_5 and 120 lbs. K_2O once every five years, plus $.50 per year for lime.

[5]Land charges allow 6% for interest and 2% for taxes and repairs. See also footnote 2.

Table A-7. Costs and Returns per Acre of Soybeans[1]

	Soil and Climatic Capability[2]			Your
	Low	Medium	High	Farm
I. Receipts:				
1. Yield per acre	20 bu.	30 bu.	40 bu.	
2. Harvest time price	$ 2.15	2.15	2.15	
3. Gross returns per acre	43.00	64.50	86.00	
II. Variable costs				
4. Fertilizer ($N-P_2O_5-K_2O$)[3]	0	5+20+20	10+30+30	
5. Fertilizer and lime cost[4]	0	5.09	6.86	
6. Seed	4.00	4.00	4.00	
7. Insecticide and herbicide	5.00	5.00	5.00	
8. Machine operation	9.50	10.50	11.50	
9. Interest on above (6 mo. at 8%)	.74	.98	1.09	
10. Total variable costs	19.24	25.57	28.45	
III. Returns above variable costs	23.76	38.93	57.55	
IV. Fixed costs				
11. Machinery and equipment	5.00	5.00	5.00	
12. Land—annual charge at 8%[5]	14.00	20.00	40.00	
13. Labor—5 hrs/acre at $2	10.00	10.00	10.00	
14. Total fixed costs	27.00	35.00	55.00	
V. Total all costs	45.20	60.57	83.45	
VI. Returns to management	-3.24	3.93	2.55	
VII. Returns to labor and management	6.76	13.93	12.55	
VIII. Returns to land, labor and management	20.76	33.93	52.55	

[1] Based on Wisconsin and other midwest data. The examples may or may not be typical of your farm. Labor and machine costs include harvest and putting into storage.

[2] Climatic and other factors may affect yields of certain crops in relation to land value. See Page 1 and Special Circular 65, "What Yields from Wisconsin Soils," May 1966, for yield potentials of Wisconsin soils.

[3] Maintenance fertilization.

[4] Includes charges of $1.50 per year for corrective fertilization of 30 lbs. P_2O_5 and 120 lbs. K_2O once every five years, plus $.50 per year for lime.

[5] Land charges allow 6% for interest and 2% for taxes and repairs. See also footnote 2.

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Table A-8. Costs and Returns per Acre of Sweet Corn[1]

	Soil and Climatic Capability[2]		Your
	Medium	High	Farm
I. Receipts:			
1. Yield per acre	3.8 tons	5.5 tons	
2. Harvest time price	$22.50	22.50	
3. Gross returns per acre	85.50	123.75	
II. Variable costs			
4. Fertilizer (N-P_2O_5-K_2O)[3]	70+40+40	110+50+50	
5. Fertilizer and lime cost[4]	$11.78	15.50	
6. Seed	5.00	5.50	
7. Insecticide and herbicide	9.50	10.25	
8. Machine operation	20.70	25.70	
9. Interest on above (6 mo. at 8%)	1.88	2.28	
10. Total variable costs	48.86	59.23	
III. Returns above variable costs	36.64	64.52	
IV. Fixed costs			
11. Machinery and equipment	5.00	5.00	
12. Land—annual charge at 8%[5]	20.00	40.00	
13. Labor—3 hrs./acre at $2	6.00	6.00	
14. Total fixed costs	31.00	51.00	
V. Total all costs	79.86	110.23	
VI. Returns to management	5.64	13.52	
VII. Returns to labor and management	11.64	19.52	
VIII. Returns to land, labor and management	31.64	59.52	

[1]Based on Wisconsin and other midwest data. The examples may or may not be typical of your farm. Sweet corn is not commonly contracted on low capability soils. Provisions of contracts vary in terms of gross price, price differentials for yield level and quality, and share of costs provided by the processor. These budgets reflect gross sales and total costs. Labor and machine costs include harvest.

[2]Climatic and other factors may affect yields of certain crops in relation to land value. See Page 1 and Special Circular 65, "What Yields from Wisconsin Soils," May 1966, for yield potentials of Wisconsin soils.

[3]Maintenance fertilization. Ten lbs. of N in row, remainder as anhydrous ammonia.

[4]Includes charges of $1.50 per year for corrective fertilization of 30 lbs. P_2O_5 and 120 lbs. K_2O once every five years, plus $.50 per year for lime.

[5]Land charges allow 6% for interest and 2% for taxes and repairs. See also footnote 2.

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Table A-9. Costs and Returns per Acre of Peas[1]

	Soil and Climatic Capability[2]		YOUR
	Medium	High	FARM
I. Receipts:			
1. Yield per acre	1.0 tons	1.5 tons	
2. Harvest time price	$100.00	100.00	
3. Gross returns per acre	100.00	150.00	
II. Variable Costs			
4. Fertilizer (N-P_2O_5-K_2O)[3]	10+40+40	15+60+60	
5. Fertilizer and lime cost[4]	8.18	11.27	
6. Seed	25.00	25.00	
7. Insecticide and herbicide	4.00	4.00	
8. Machine operation	24.60	25.70	
9. Interest on above (6 mo. at 8%)	2.47	2.64	
10. Total variable costs	64.25	68.61	
III. Returns above variable costs	35.75	81.39	
IV. Fixed costs			
11. Machinery and equipment	5.00	5.00	
12. Land—annual charge at 8%[5]	20.00	40.00	
13. Labor—3 hrs./acre at $2	6.00	6.00	
14. Total fixed costs	31.00	51.00	
V. Total all costs	95.25	119.61	
VI. Returns to management	4.75	30.39	
VII. Returns to labor and management	10.75	36.39	
VIII. Returns to land, labor and management	30.75	76.39	

[1] Based on Wisconsin and other midwest data. The examples may or may not be typical of your farm. Peas are not commonly contracted on low capability soils. Provisions of contracts vary in terms of gross price, price differentials for yield level and quality, and share of costs provided by the processor. These budgets reflect gross sales and total costs, including labor and machine costs for harvest.

[2] Climatic and other factors may affect yields of certain crops in relation to land value. See Page 1 and Special Circular 65, "What Yields from Wisconsin Soils," May 1966, for yield potentials of Wisconsin soils.

[3] Maintenance fertilization.

[4] Includes charges of $1.50 per year for corrective fertilization of 30 lbs. P_2O_5 and 120 lbs. K_2O once every five years, plus $.50 per year for lime.

[5] Land charges allow 6% for interest and 2% for taxes and repairs. See also footnote 2.

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Sample Costs for Growing Lettuce in the Imperial Valley

	Custom rate	Type Materials	Cost	Hand labor ($)	Sample cost per acre
Land Preparation					
Plow or subsoil	$8.00				$ 8.00
Disc 2x	2.00				4.00
Border and break border					1.00
Flood		water	$ 1.50	$2.00	3.50
Fertilize	1.00	440# 11-48-0=	19.00		20.00
Disc 2x	2.00				4.00
Landplane 2x	2.75				5.50
List=	3.00				3.00
TOTAL Land Preparation					$ 49.00
Growing Period					
Rotovate and shape beds	9.00	herbicide	$5.00		14.00
Plant	3.00	seed 1# at $9.00	9.00		12.00
Thin					25.00
Cultivate 3x	3.00				9.00
Fertilize— Sidedress 3x	3.00	300# N at 6¢	18.00		27.00
Hoe					15.00
Irrigate 8x		water	8.00	$8.00	16.00
Pest control 6x	1.50—2.00	insecticides	30.00		41.00
TOTAL Growing Period					$159.00
TOTAL Pre-Harvest Costs					$208.00
Harvest					
Custom harvest: 400 cartons at $1.10					$440.00
TOTAL CASH COSTS					$648.00
Overhead					
Rent					80.00
Misc. 15% as general overhead					109.20
Total overhead costs					189.20
TOTAL COSTS					$837.20

Source: Western Grower and Shipper, April, 1967.

Cost and Return Information for Cranberries

	Range of Prices	Mean Prices
I. FIXED COSTS		
A. Land, equipment, and development costs	$	$
1. Land cost		50.00
2. Survey and layout		25.00
3. Clearing of trees and brush	75.00—150.00	115.00
4. Scalping and leveling	150.00—250.00	200.00
5. Ditching: a. bed ditches	50.00—125.00	90.00
b. main ditches	50.00—100.00	75.00
6. Roads and dikes	45.00—100.00	75.00
7. Pumps and water control structures	500.00—600.00	550.00
8. Sprinkler irrigation system	500.00—600.00	550.00
9. Warehouse: $6,000 ÷ 40 acres		150.00
10. Equipment: tractors, $10,000; pickers, $5,000; sprayers, $3,000; trucks, $5,000; sorting and drying equipment, $4,500; clipper, $500; misc. tools and equipment, $2,000. Total: $30,000 ÷ 40 acres		750.00
TOTAL OF ITEM A		$2,630.00
B. Planting costs		
1. Planting stock	250.00—500.00	375.00
2. Cost of planting	75.00—100.00	90.00
3. Sanding	75.00—100.00	90.00
TOTAL OF ITEM B		$ 555.00
C. Establishment cost, four-year period from time of planting to time of production.		
1. Fertilizer		20.00
2. Weed control		100.00
3. Manager's salary: $\frac{\$3,600}{40 \text{ acres}}$ x 4 years		360.00
4. Other labor, insurance, gas, etc.		750.00
Total		$1,230.00
ITEM C: $1,230.00 ÷ 4 years		307.00
TOTAL—ITEMS A, B, and C		$3,492.00

D. Annual operating costs	Range of Prices	Mean Prices
1. Maintenance of Items I-A, 5-10		$ 210.00
2. Sanding: 1.2 to 1" sand every 3 years (1/3 x $100.00)		33.00
3. Fertilizer cost	5.00—15.00	10.00
4. Weed control	30.00—50.00	40.00
5. Frost control	40.00—50.00	45.00
6. Insect control	5.00—10.00	7.50
7. Disease control	6.00— 7.00	6.50
8. Pruning and training vines[1]	25.00	25.00
9. Taxes		25.00
10. Misc.—insurance, association dues, etc., 15% of I-D, 1-8		50.00
TOTAL OF ITEM D		$452.00
Annual investment cost per acre (total of ITEMS A, B, and C—$3,492 amortized for 25 years at 6%)		272.18
Annual operating cost (ITEM D)		452.00
Total Annual Fixed Costs		$724.18
II. VARIABLE COSTS		
A. Harvesting costs—per barrel	1.00— 1.50	1.25
B. Packaging and hauling to processor—per barrel	2.00	2.00
TOTAL OF ITEMS II, A AND II, B		$ 3.25

The cost-return information for cranberries is based on grower experiences in Sawyer and Vilas Counties. Information was obtained by Bob Hoene and Nils Dahlstrand. Somewhat revised following Cranberry Workshop at Hayward, July 19 and 20, 1966.

[1] Some growers sell the pruned vines to other growers to use as planting stock. This item becomes income.

TYPICAL AVERAGE POTATO PRODUCTION COSTS
MEDIUM TO LARGE-SIZED POTATO FARMS, CENTRAL WISCONSIN

VARIETY—Russet Burbank
Irrigated
Sandy soil

YIELD—300 to 350 cwt. per acre

FIXED COSTS		
Land	$200 at 8%	$ 16.00
Machinery	200 at 8%	16.00
Building	100 at 8%	8.00
Taxes		20.00
Repairs		25.00
Insurance		15.00
Irrigation equipment and water source	$150 at 8%	12.00
Depreciation (10 years)		35.00
	TOTAL	$147.00
VARIABLE COSTS		
Seed		$ 40.00
Fertilizer		60.00
Soil preparation		2.50
Seed cutting		8.00
Planting		2.00
Weed control		7.00
Insecticide		14.00
Fungicide		16.00
Irrigation operation		25.00
Vine killing		6.50
Labor		60.00
Electricity		2.00
Telephone		1.00
Clerical		3.00
Other		10.00
	TOTAL	$257.00
Storage costs (fixed)		$ 20.00
Marketing (bags, grading, etc.)		85.00
Crop insurance		20.00
	TOTAL	$125.00
	TOTAL ALL COSTS	$529.00

Assuming 70% grade-out United States No. 1's and no return from off-grade potatoes, break-even point at farm level:

For 300 cwt. per acre crop $2.52 per cwt.
For 350 cwt. per acre crop $2.16 per cwt.

Acreage Apple Production Expenses—Wisconsin

	Per bushel
Production	
Labor	.25
Chemicals	.12
Repair	.08
Fertilizer	.05
	$ .50
General Expense	
Taxes, insurance, legal	.15
Gas and oil	.04
Electricity, water	.03
Mgrs. expense	.01
Office supply, advertising	.05
Interest	.05
Depreciation	.20
Misc.	.03
	$ .60
Harvest and Grading	
Picking, hauling, supervision	.30
Packing	.20
Packing materials	.35
Transportation to market	.10
Storage	.05
	$1.00
Avera total production costs for an average year	$2.10

Notes: The above figures are only average and may be adjusted up or down depending on the size of the crop and, in many cases, the skill of the operator. Yields will vary from orchard to orchard. A reasonable average for standard trees would be 300-400 bushels (totals per acre); an excellent yield would be anything over 500 bushels per acre. With the newer size-controlled (dwarf) trees planted at higher density, yields will be higher. 500—700 bushels per acre under Wisconsin conditions would be reasonable. Production figures in Wisconsin fluctuate up and down annually due to biennial bearing of a number of varieties. Available figures show Wisconsin produces around 1.5 million bushels of apples. This we know is unrealistic. If a more accurate means of sampling were devised, I believe yields would be more nearly 3 million annually.

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*Compiled by George Klinbeil, Prof. of Horticulture, Univ. of Wisconsin.

APPENDIX B

TABLES FROM A USDA REPORT

ENTITLED

"Losses in Agriculture, 1951–60"

Table B-1

Estimated Average Annual Losses in Value Caused by Plant Diseases to Various Groups of Crops During Production, 1951–60.

Crop Group	Average Annual Loss ($1,000)
Field crops	1,890,836
Alfalfa and other hay plants	614,766
Forage seed crops	23,584
Pasture and range plants	193,935
Fruit and nut crops	223,505
Vegetable crops	290,380
Ornamental plants and shade trees	14,099
TOTAL	3,251,114

Table B-2

Field Crops: Estimated Average Annual Losses Due to Diseases, 1951-60

Commodity	Loss from potential production[1] Reduction[2]	Value
	Percent	($1,000)
Barley	14	55,403
Beans, dry	17	[3]24,934
Castorbeans	11	184
Corn	12	527,285
Cotton	12	300,920
Flax (seed)	10	11,603
Hops	13	3,318
Mint[4]	10	1,474
Oats	21	198,417
Peanuts	28	53,716
Peas, dry	14	2,404
Rice	7	18,799
Rye	3	928
Safflower	12	615
Sesame	11	[5]121
Sorghum:		
Grain	9	34,072
Silage and forage[6]	9	8,550
Sweet	15	987
Soybeans	14	142,835
Sugarbeets	16	27,254
Sugarcane	23	13,521
Tobacco	11	132,203
Wheat	14	331,293
Total		1,890,836

[1]So far as possible, the basic data used to calculate the loss represent the averages for the period 1951-60 as estimated by the Statistical Reporting Service. Where data were not available, best approximations were used.

[2]Estimate is based on full production with the causes eliminated. These percentages were applied to the data of actual farm production to obtain estimates of loss of farm production in terms of quantity and value. Loss in quality is included in the loss in value. Value loss is computed upon the assumption that market outlets would be available for reduced production with no change from average farm prices.

[3]Includes blackeyes and garbanzos in California in addition to ordinary edible beans and beans grown for seed.

[4]Peppermint and spearmint.

[5]Basic data are from the 1959 Census of Agriculture.

[6]See discussion under sorghum, grain and sweet.

Table B-3

Vegetables: Estimated Average Annual Losses Due to Diseases, 1951–60

	Loss from potential production[1]	
	Reduction[2]	Value
	Percent	($1, 000)
Artichokes	5	162
Asparagus	9	4,073
Beans:		
Green lima	10	1,922
Green snap	20	17,651
Beets, table	3	145
Broccoli	2	369
Cabbage	8	3,973
Cantaloupe	16	9,126
Carrots	8	3,845
Cauliflower	8	1,476
Celery	17	10,866
Corn, sweet	8	1,034
Cowpeas	8	6,786
Cucumbers:		
Fresh market	18	4,110
Greenhouse	8	42
Pickling	11	2,261
Eggplant	12	327
Escarole (endive)	6	214
Kale	8	70
Lettuce, field-grown	12	17,274
Melons, honeydew and honeyball	14	1,119
Mushrooms	16	6,813
Onions	20	13,901
Peas, green	23	11,976
Peppers, green sweet	14	3,752
Potatoes	19	89,527
Shallots	21	245
Spinach	20	3,753
Sweetpotatoes	18	8,932
Tomatoes:		
Fresh market	21	31,800
Greenhouse	20	[3]4,038
Plant bed	8	[3] 522
Processing	22	23,868
Watermelons	10	4,417
		290,389

[1] See table 2, footnote 1

[2] See table 2, footnote 2.

Table B-4

Fruit and Nut Crops: Estimated Average Annual Losses Due to Diseases, 1951–60

Commodity	Loss from potential production[1]	
	Reduction[2]	Value
	Percent	($1000)
Almonds	9	2,521
Apples	8	17,791
Apricots	7	1,782
Blackberries[3]	34	[4]1,472
Blueberries	14	1,842
Cherries	24	12,355
Cranberries	9	1,298
Filberts (hazelnuts)	4	122
Grapefruit	2	1,020
Grapes	27	48,415
Lemons	25	11,137
Oranges	12	38,560
Peaches	14	19,805
Pears	17	10,176
Pecans	21	9,963
Plums	10	1,612
Prunes, fresh	10	4,895
Raspberries	38	5,191
Strawberries	26	[5]26,869
Tung	2	109
Walnuts	18	6,570
Total		223,505

[1] See table B-2, footnote 1.

[2] See table B-2, footnote 2.

[3] Includes both trailing (dewberries) and erect blackberries.

[4] Basic data are from the 1959 Census of Agriculture.

[5] Basic data represent the value of the quantity marketed.

Table B-5

Estimated Average Annual Losses to Various Crops Caused by Nematodes, 1951–60

Crop Group and Commodity	Loss from potential production[1]	
	Reduction[2]	Value
Field and forage crops:	Percent	($1000)
Alfalfa	3	48,581
Corn	3	131,821
Cotton	2	50,153
Lespedeza	3	457
Peanuts	3	5,755
Soybeans	2	20,405
Sugarbeets	4	6,814
Tobacco	3	36,055
Total		300,041
Fruit crops:		
Lemons	4	1,782
Oranges	4	12,853
Peaches	4	5,658
Raspberries	4	4,134
Total		24,427
Vegetable crops:		
Beans:		
Green lima	5	961
Green snap	5	4,413
Cantaloupes	5	2,852
Potatoes	4	18,848
Tomatoes:		
Fresh market	8	12,114
Processing	8	8,679
Total		47,867
TOTAL all crop groups		372,335

[1] See table B-2, footnote 1.

[2] See table B-2, footnote 2.

Table B-6

Field Crops: Estimated Average Annual Losses Due to Insects, 1951–60

Commodity	Loss from potential production[1]	
	Reduction[2]	Value
	Percent	($1000)
Barley	5	19,787
Beans, dry	20	29,335
Corn	12	527,285
Cotton	19	476,457
Hops	15	3,829
Mint[3]	15	2,211
Oats	4	37,794
Peanuts	3	5,755
Peas, dry	6	1,030
Rice	4	10,742
Sorghum (grain)	9	34,072
Soybeans	3	30,607
Sugarbeets	12	20,441
Sugarcane	15	8,818
Tobacco	11	132,179
Wheat	6	141,983
Total		1,482,325

[1] See table B-2, footnote 1.

[2] See table B-2, footnote 2.

[3] Peppermint and spearmint.

Table B-7

Vegetable Crops: Estimated Average Annual Losses Due to Insects, 1951–60

Commodity	Loss from potential production[1]	
	Reduction[2]	Value
	Percent	($1000)
Asparagus	15	6,789
Beans:		
Green lima	13	2,499
Green snap	12	10,591
Broccoli	17	3,139
Brussels sprouts	17	1,040
Cabbage	17	8,443
Cantaloupes	8	4,563
Carrots	2	961
Cauliflower	17	3,137
Celery	14	8,949
Cucumber, fresh market	21	2,740
Escarole	7	250
Kale	17	148
Lettuce	7	10,077
Melon, honeydew	8	640
Onions	18	12,510
Peas, green	4	2,083
Peppers, green sweet	7	1,876
Potatoes	14	65,968
Spinach	4	750
Sweet corn	19	16,575
Sweet potatoes	8	3,970
Tomatoes:		
Fresh market	7	10,600
Processing	7	7,594
Total		185,892

[1] See table B-2, footnote 1.

[2] See table B-2, footnote 2.

Table B-8

Fruit and Nut Crops: Estimated Average Annual Losses Due to Insects, 1951-60

Commodity	Loss from potential production[1]	
	Reduction[2]	Value
	Percent	($1000)
Apples	13	28,910
Blackberries	31	1,342
Cherries	3	1,544
Grapes, fresh	4	7,172
Grapefruit	5	2,549
Lemons	6	2,673
Oranges	6	19,280
Peaches	4	5,658
Pears	6	3,592
Pecans	12	5,693
Plums	6	967
Prunes, fresh	6	2,937
Raspberries	23	[3]3,142
Strawberries	25	[4]25,836
Miscellaneous fruits and vegetables		[5]10,000
Total		121,295

[1]See table B-2, footnote 1.

[2]See table B-2, footnote 2.

[3]Based on data from the 1959 Census of Agriculture.

[4]Basic data represent value of quantity marketed.

[5]Damage by Japanese beetles.

GOVERNMENT LIABILITY FOR METEOROLOGICAL SATELLITE DATA

by Delbert D. Smith

INTRODUCTION

As with any technological development, the advent of meteorological satellites has resulted in legal issues being raised as to the utilization and distribution of the data. Since the development of meteorological satellites rests with the National Aeronautics and Space Administration (NASA), the legal ramifications of existing and future systems are of concern.[1] The issues raised here will, of course, also be of concern to the National Oceanographic and Atmospheric Administration (NOAA). The attempt here is to determine areas of future growth for the law and to anticipate legal problems so that technology can be advanced at an optimum rate.

I. ISSUES

Since satellite observation and data acquisition substantially increase the accuracy of weather forecasting, the question is raised whether this accuracy may create a reliance in the receivers of the data and a corresponding duty of the United States government—a breach of which would create

[1]The author acknowledges the research assistance of James Gerlach in the preparation of this paper.

liability of the government under the Federal Tort Claims Act.[2] A breach may be a negligent act by the government employees in either assimilating and relaying satellite data or in negligently failing to rectify a dysfunction of satellite equipment or related equipment.[3]

The question of potential liability of the government for inaccurate nowcasting—since the emergence of satellite observation—is a three part issue:

A. Whether nowcasting of weather is a "discretionary function" regardless of the instruments used and therefore still protected by the doctrine of sovereign immunity as an exception to the Federal Tort Claims Act.

B. Even if weather nowcasting were not to be a "discretionary function," whether negligently inaccurate forecasting is immune from allegation as the cause of an individual's or a business' damage because this kind of forecasting is a "misrepresentation" and thus still protected by the doctrine of sovereign immunity as an exception to the Federal Tort Claims Act.

C. If the "discretionary function" and "misrepresentation" exceptions are held inapplicable, what condition and acts of the government and its employees must exist to create liability for negligent nowcasting and thus be recoverable under the Federal Tort Claims Act.

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[2] 28 U.S.C.A. secs. 2674 et seq. (1965).

[3] Although weather forecasting and weather information dissemination to the public is performed by nongovernmental broadcasting—and admittedly there is room for error at this level of dissemination—mitigating negligence by the broadcasting networks is disregarded in this paper for the sake of argument. Nevertheless, there is a suggestion that the National Weather Service will take an increasingly active role in transmitting information directly to the public or designated members of the public which fall within commerce, agriculture and navigation.

II. BACKGROUND

The National Aeronautics and Space Administration through its Office of Space Science and Applications, and specifically through the director of meteorology, is active in research leading to meteorological satellite development. This development has significant user applications and will eventually have a direct effect on people's lives.[4] Further, an organization such as the Space Science and Engineering Center of the University of Wisconsin receives transmissions from ATS and ESSA satellites, the data from which—in pictorial or other form—may eventually be disseminated to users. In both situations it is desirable to know the liabilities that may be involved in this dissemination.

Concerning operational systems, the United States Congress, by ch. 9, title 15 U. S. C. A., created the Weather Bureau (now the National Weather Service) within the Department of Commerce. The duties imposed on the Bureau and its employees are "the forecasting of weather, the issue of storm warnings, the display of weather and flood signals for the benefit of agriculture, commerce, and navigation . . . gauging and reporting of rivers . . . for the benefit of commerce and navigation, the reporting of temperature and cotton interests . . . the distribution of meteorology information in

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[4]See <u>Multidisciplinary Studies of the Social, Economic, and Political Impact Resulting from Recent Advances in Satellite Meteorology</u>, Vols. I and II, Space Science and Engineering Center, University of Wisconsin.

the interests of agriculture and commerce" (15 U. W. C. A. sec. 313). The Bureau has developed, under NOAA, a complex system of organizations to gather, analyze and disseminate weather information and predictions.

On a broad scale weather prediction for the Northern Hemisphere flow patterns are reported at regular intervals by the National Meteorological Center (NC) in Suitland. At numerous regional locations, the National Weather Service (NWS) field stations collect data and send the data by teletype or radio to central stations which chart the current weather and forecast future conditions. The present weather and forecasts are then issued to the public primarily through commercial broadcasting. In a limited capacity, the National Weather Service does disseminate directly to the public or particular segments of the public.[5]

The use of photography and other sophisticated technical devices by way of satellite has greatly increased the accuracy and content of the weather information that can be acquired by the National Weather Service. The satellite acquisition of information tends to eliminate, and will continue to eliminate as its use broadens, speculation and hypothesizing about weather forecasts.

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[5] The National Weather Service operates VHF-FM Continuous Weather Transmissions Stations, which are used extensively by boating interests, making weather information available to the public at all times by means of VHF-FM weather forecasts. There are also Multiple Access Recorded Telephone Announcement Systems which provides the public, in varying degrees depending on the location, with instant telephone access to current warning, forecast and observation information on a demand basis. National Weather Service may in the future contemplate continuous weather forecasting on a national scale on easily accessible broadcasting frequencies.

In addition, as time lags are shortened for the availability of information, weather forecasts will change almost simultaneously with weather flux.[6]

It is asserted that satellite observations are becoming increasingly accurate. Regardless, the use of the satellite to improve short and intermediate range weather forecasting does not presently mean that the National Weather Service can predict the exact time and location rain will fall in a week nor the exact amount of rain that would fall. Major weather changes in weather conditions can be predicted now with precision, however. This aids in predicting fire storms, droughts or high air pollution or fog situations, and the changes of direction of cyclones or hurricanes. Other satellite observations will permit greater accuracy in telling wind speed, the possibility of hail or a tornado, and even the heat and moisture balance of soil to atmosphere, thus aiding agriculture.[7]

III. DISCUSSION

A. Nowcasting: A Discretionary Function

The "discretionary function" exception in the Federal Tort Claims Act, 28 U. S. C. A. sec. 2680(a) (1965), is designed to protect the separation of

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[6] It has been suggested that certain transports, such as ships along major shipping lanes, which can afford the equipment and personnel may be able to receive transmission of grided ATS satellite pictures via short wave radio signals to telecopies aboard ships and thus produce high quality weather pictures instantaneously.

[7] See The Windco System, Space Science and Engineering Center, The University of Wisconsin, October 1971.

powers between the legislative, executive and judicial branches of the government. The purpose of the exception, it has been argued, is to permit high level decision-making in the executive and legislative branches to proceed at a level exclusive of judicial intervention. Sovereign immunity of the government is in part eliminated by the Federal Tort Claims Act, but the exception continues the guaranty that an individual cannot challenge executive and legislative decisions, even though tortious in nature, by way of a tort action. Coates v. United States, 181 F. 2d 816, 19ALR2d840 (9th cir. 1950).

Although the underlying purpose of the "discretionary function" exception is clear, the implementation of the exception and its judicial development have been kaleidoscopic. At best, its application must be evaluated to the facts of each case. State of California v. United States, 151 F. Supp. 570 (D. C. Cal. 1957). Courts have made attempts to develop rules which will give some indication of what activities the government will maintain sovereign immunity protection as a discretionary function. Often the planning or policy stage is distinguished from the implementation or from the operational stage. State of California v. United States, supra; Hardy v. United States, 187 F. Supp. 756 (D. C. S. C. 1960). Administrative level decisions are distinguished from narrower decisions which carry out the administrative mandate. White v. United States, 317 F. 2d 13 (4th cir. 1963). The discretionary function has been held to mean "a function or duty which necessarily requires exercise of reason and adoption of means to an end;"

it is discretion as to "how, when or where an action shall be done and the course to be pursued in the attainment of congressional programs." Fahey v. United States, 153 F. Supp. 878 (D. C. N. Y. 1957).

The line between activities interpreted within the exception and those which are not is not as easily discernible as the above rules indicate. Consistency in judging where the "planning stage" stops and "operational stage" begins in most government projects appears mechanically impossible.[8] Courts, however, have attempted to deal with the problem of combining policy decisions and operational decisions by deciding that once policy discretion is exercised, the following negligence in performance of a project is not protected. Bulloch v. United States, 133 F. Supp. 885 (D. C. Utah 1957); Annotation, Federal Tort Claims Act, 99 ALR2d 1017, 1021. Thus the government's failure to provide a procedure instructing air controllers to furnish radar assistance by radio to "visual" flight (VFR) pilots is an allegation barred by the discretionary function exception. Rowe v. United States, 272 F. Supp. 788 (W. D. Penn. 1964); Kullberg v. United States, 271 F. Supp. 788 (W. D. Penn. 1964). In these cases the controller never attempted to aid the stricken pilot in the way required; therefore, no negligence

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[8] For example, a decision to allow a patient in a veterans' hospital freedom of the hospital grounds—which provided the patient the means to commit suicide—was not considered a discretionary decision and recovery for wrongful death was barred. White v. United States, 317 F. 2d 13 (4th Cir. 1963). Yet, a decision whether a patient in a veterans' hospital could safely be released for a trial visit home without an attendant, during which visit the patient stole a car and injured a third person, was a decision exercising discretion thus precluding government liability. Smart v. United States, 207 F. 2d 841 (10th Cir. 1953).

existed at the performance level. However, in Bulloch, supra, deciding in what manner to test a nuclear device was within the discretionary function exception. Sheep owners were allowed to recover under the Federal Tort Claims Act for damage proximately caused their herds by the negligent detonation of the device.

In light of the developing precedent defining the outline of the discretionary function, the crux of the issue of government liability for negligent nowcasting is whether increasingly accurate and sophisticated satellite observation will force nowcasting, as an activity, to cross from the administrative-planning level to the detailed-operational level. The theory that discretion has been exercised in creating the availability of observations by satellites but nevertheless that the government cannot negligently perform this program will, no doubt, figure prominently in any future decision to regard nowcasting as an operational activity.

Weather forecasting has been held a discretionary function in two leading cases: Bartie v. United States, 216 F. Supp. 10 (W. D. La. 1963), and National Manufacturing Co. v. United States, 210 F. 2d 263 (8th Cir. 1954) cert. den. 347 U. S. 967 (1954). In Bartie the plaintiff brought a wrongful death action against the United States under the Federal Tort Claims Act. The plaintiff had lost members of his family when the tidal wave of a hurricane struck the Louisiana Coast. He alleged that the Weather Bureau negligently failed to give adequate warning as to the intensity, location, path, speed, velocity, and existence, of an accompanying tidal wave, and failed to give the correct time the hurricane and the tidal wave would strike the Louisiana coast. After inferring that the plaintiff was partly negligent in not attempting to remove his family and himself earlier in the face of obvious danger, the court ruled that the plaintiff did not carry the burden of proving the Weather Service's negligence beyond a preponderance of doubt as required by Lousiana tort law. The court also noted that weather information was disseminated by private broadcasters who, being beyond the control of the government, tend to minimize alarming information. In addition, it was held that the initial evaluation of information by the Weather Service requires extensive judgment and discretion and that hurricane forecasting is even more difficult (especially as to velocity) because of the lack of certain data. The query remains whether meteorological satellite development will substantially change this conclusion. These conclusions, which mitigated any possible negligence on the Service's part, also led the court to rule that weather forecasting was a discretionary function.[9]

National Manufacturing Co. v. United States, supra, consolidated a series of district court rulings supporting summary judgments against plaintiffs who lost business property when the Kansas River overflowed its banks. The plaintiffs alleged that: (1) the government created a program of flood information causing local businesses on the river banks to rely on the govern-

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[9]The government raised this defense and also asserted the defense of misrepresentation. The court ruled that recovery for possible negligence on the part of the Weather Service was also barred by the misrepresentation exception in the Federal Tort Claims Act. 28 U. S. C. A. sec. 2680(n)(1965).

ment's information; (2) the negligence of forecasting created a false assurance immediately before the flood that the river would not overflow its banks; and (3) the Service omitted and failed to give the plaintiffs sufficient notice of impending danger, thus resulting in damage to the plaintiff's movable property. The circuit court affirmed summary judgment against the plaintiffs and added that the plaintiffs could not recover, in part, because the dissemination of information of river levels and possible flooding was a discretionary function.[10]

In the note, 99 ALR2d 1017, 1046, the author concludes that Bartie and the district court decisions that were upheld in National Manufacturing leads to the conclusion that, by way of the discretionary function exception, "no liability ordinarily attaches to the government as a result of inaccuracies in its weather forecasting." This conclusion is correctly qualified as "ordinarily" no liability will be found for inaccuracies. However, satellite observation has added new dimensions to weather forecasting. More importantly, it is questionable whether or not the courts have ever squarely faced the issue of forecasting or nowcasting as a discretionary function and, thus, whether even the qualified conclusion above is legitimately drawn from Bartie and National Manufacturing and its predecessors.

In National Manufacturing, the trial court first ruled that government

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[10] The circuit court also ruled that if there was negligence in informing the plaintiffs, it was barred by the misrepresentation exception to the Federal Tort Claims Act. See fn. 9, supra.

liability for damage by flood was denied by the Mississippi River Act, 33 U. S. C. A. Sec. 702(c)(1928), and later by the Flood Control Act, 49 Stat. 1570, 1588 (1936). The lower courts were especially cognizant of the policy to encourage expenditures for flood control that was historically behind these Acts. Even though the government had established an information system along parts of the Kansas and Missouri Rivers to keep individuals up to date on the rise of water levels, the court reasoned that any negligence in operating this program was immune from recovery because the Tort Claims Act did not expressly repeal the above Flood Acts. The court frowned on repeal by implication. Furthermore, since the Tort Claims Act did not create a new cause of action, allowing for recovery in such instances, the judiciary would have been creating a new liability in the face of the Flood Acts precedent.

National Manufacturing, viewed in light of its ruling on the effect of the earlier Flood Act, incorporates unnecessary language in ruling that recovery was barred by the discretionary function exception to the Federal Tort Claims Act. The Bartie decision follows the same pattern. It was unnecessary for the court to rule on the government defense of discretionary function after ruling that the plaintiff had not carried his burden of proving the defendant's negligence. The court's conclusion on this defense appears as a mere afterthought.

The rationale of Bartie deserves further attention. First, the court pointed out that it was dealing with the forecasting of hurricanes—a tenuous undertaking at best—at the time. What will be the result when satellite meteorology makes this a more certain activity? It is not clear that the courts' arguments would be equally compelling if the suit would have been brought by a citrus fruit grower in Florida who was led to believe a cold wave would not reach his area, but in fact did, and his reliance caused his plants to be unwarmed by smudgepots. Here there would be a direct economic loss by a business which could not be held to have taken insufficient steps to remove itself from danger. There would most likely be no partial negligence.

In coming to its ruling on the applicability of the discretionary function exception in Bartie, the court argued that extensive judgment, lack of control because of information dissemination by private broadcasters, and the inability to accurately observe tropical storms absolved the government of any possible negligence. If a meteorological satellite data distribution system can fill important voids in observing weather originating in ocean areas (and do so accurately and instantaneously) and satellite observations can be transmitted directly to ships or other transports, this would all but alleviate intermediaries such as broadcasting systems. If and when these technological improvements arise, it is possible that such a degree of reliance and control will be created that the discretionary function exception will no longer bar recovery in negligence suits and that elements of weather forecasting will pass to the mere operational-detail stage. The use of communications satellites together with cable communications systems may result in a distribution network where the mass media would not be involved in data interpretation. Thus, a determination would be made by the court based primarily on the degree of accuracy of the meteorological data dissemination and on the options available to the recipient of the data.

There are, however, policies concerning the above decisions which will be hard to ignore in the future if recovery is to be obtained for negligent meteorological satellite data dissemination. First is the policy against a parental government: As long as there is some judgment infused by the government in weather forecasting and nowcasting, and society realizes this, then society should not expect the government to substitute completely its judgment for society's. Western Mercantile Co. v. United States, 111 F. Supp. 799 (W. D. Mo. 1953), aff'd in National Manufacturing, supra (see concurring opinion). This type of reliance should not be encouraged, and the necessary steps should be taken to ensure that the judgmental nature of the activity is clearly defined.

Second, there is fear that allowing recovery for negligent weather forecasting or nowcasting would create overbearing recoveries against the government.[11] Extensive meteorological data distribution would become economically prohibitive as long as the potential for faults in judgment existed and recoveries resulted. Meteorological satellite development would have to be restricted and this, in turn, would limit the resultant benefits to society on the whole. Hence, any policy which led to the above conclusion should be limited so as not to discourage technological innovation. The development of innovative technology is encouraged by a liability-free situation, providing that large groups of people are not unreasonably put at a

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[11] If the plaintiff in Bartie succeeded, there were numerous other wrongful and analogous death actions resulting from the hurricane, and potential recovery if Bartie succeeded would have been devastating.

disadvantage either personally or economically.

Finally, some question has been raised as to whether private individuals can claim a duty owed to them, in particular, when the Weather Bureau was established to provide information for "agriculture, commerce and navigation" generally. Mid-Central Fish Co. v. United States, 112 F. Supp. 792 (W. D. Mo. 1953), aff'd in National Manufacturing, supra. The logic in Mid-Central Fish regarding this policy is questionable and was not supported in National Manufacturing. Nevertheless, this reluctance to provide a theory of recovery for one individual or business when the government attempts to provide a service, albeit at times inaccurately, to a broad segment of the population is a point worthy of consideration. See Angel-American and Overseas Corp. v. United States, 144 D. Supp. 635 (S. D. N. Y. 1956). This policy is often confused with the language in the Federal Tort Claims Act, 28 U. S. C. A. Sec. 2674 (1965): "The United States shall be liable . . . in the same manner and to the same extent as a private individual under like circumstances . . ." (emphasis added). Its purpose is to avoid creating new tort theories of liability when the ancient protection of sovereign immunity is washed away. If there is no private act which is closely analogous to the negligent act performed by the government then there is no recovery. National Manufacturing Co. v. United States, 210 F. 2d 263 (10th Cir. 1954), cert den. 347 U. S. 967 (1954). This language is, in effect, an attempt to protect executive and legislative decision-making from challenge through tort actions much the same as the discretionary function exception. Merely because the activities of the government are unique, however, does not mean the government cannot be held liable for negligent performance of its duty. In Bulloc v. United States, 133 F. Supp. 885 (D. C. Utah, 1955), the court rejected the argument that there was no private conduct analogous to nuclear testing and ruled that the government employees performed negligent acts while carrying out the test. Nevertheless, courts use this rationale to argue that services rendered to the public generally have no comparison to acts performed by a private individual and thus the government should not be liable for negligence in activities directed toward large segments of the public. In a sense, this position is an unconscious vestige of sovereign immunity which is supposed to be obliterated, except for specific areas, by the Federal Tort Claims Act.

One issue which arises here is whether the "narrowcasting" of meteorological data will result in a new standard of governmental liability. If the transmission means is cable television (CATV) and if the data are directed towards a segmented user group, will the "large segments of the public" argument be diluted? If individual users are able to obtain specialized weather data on a dial-access or similar basis, will this not create a need for a new judicial standard?

B. Nowcasting: Misrepresentation

It will be difficult to ignore the above policies if meteorological data distribution, or some of its aspects, reach the operational stage where the discretionary function exception is held inapplicable. No doubt, the above policies would prompt courts to rule that any recovery for negligent forecasting be barred by the misrepresentation exception. This exception, notably present in the two leading cases of Bartie and National Manufacturing Co., supra,[12] protects the sovereign immunity of the government when its employees make either willful or negligent misrepresentations. United States v. Neustadt 366 U. S. 696 (1961).

Exactly what distinguishes a negligent misrepresentation from a negligent act, which permits recovery, has not been consistently defined by the courts.[13] However, negligent dissemination of weather and flood reports has been classified as misrepresentation by both National Manufacturing and Clark v. United States, 218 F. 2d 466 (9th Cir. 1954).[14] On the other hand, in Otness v. United States, 178 F. Supp. 647 (D. C. Alaska 1959), a shipowner

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[12]See notes 9 and 10 above.

[13]Whether an act, or silence, or representation of already performed negligent acts, can be a misrepresentation has been struggled with by the courts. Angelo-American and Overseas Corp. v. United States, 144 F. Supp. 635 (S. D. N. Y. 1956); Coastwide Packet Co. v. United States, 277 F. Supp. 920 (D. Mass. 1968); Clark v. United States, 218 F. 2d 466 (9th Cir. 1954); Vaugn v. United States, 259 F. Supp. 286 (N. D. Miss. 1966); Hall v. United States, 207 F. 2d 563 (10th Cir. 1959); Jones v. United States, 207 F. 2d 563 (2nd Cir. 1953), cert. den. 347 U. S. 921 (1954), reh. den. 347 U. S. 940 (1954).

[14]The issue has been raised whether governmental sovereign immunity has been maintained for natural flooding only in the Federal Tort Claims Act. Guj F. Atkinson Co. v. Merritt, Chapman & Scott Corp. 126 F. Supp. 406 (S. D. N. D. Calif. 1954). This issue was resolved in McClasky v. United States, 261 F. Supp. 912 (D. C. Ore. 1966), where flooding caused by negligent levee construction was immune as a source of liability.

sued to recover for loss of a vessel due to a collision with a submerged channel light. The Coast Guard undertook to locate the light but failed to find it. The Coast Guard then announced that no part of the light remained above the bottom of the sea. The court in Otness ruled that, although the Coast Guard's bulletin contained a misrepresentation of facts, the case was not within the misrepresentation exception. This case led one court to conclude that, if the government assumes a duty and then performs it negligently, a party injured because of the negligence may recover damages from the United States even though the careless performance of duty may have been accompanied by some misrepresentation. United States v. Neustadt, 281 F. 2d 596 (1960) overruled 366 U. S. 702 (1961). This distinction was not given significant weight when Neustadt was overruled by the Supreme Court, however.

In conclusion, it can only be said that the courts have not heretofore been willing to separate negligence in obtaining and formulating meteorological data from the actual dissemination of negligently formulated data. Realizing the policies favoring governmental non-liability, it is doubtful that negligent meteorological data distribution in the future, even if substantially obviated at the observation and formulation stage by the technological intervention of the satellite, will be considered other than a misrepresentation which would thus exempt the government from liability.

C. Forecasting and Nowcasting: How Negligence Liability Might Arise

The Supreme Court has ruled that once the government assumes the position of a good samaritan and thereby induces reliance in the public,[15] it must perform its task in a careful manner. Indian Towing Co. v. United States, 350 U.S. 61 (1955). In Indian Towing the government had constructed a lighthouse. The plaintiff's cargo was damaged, and the court ruled the damage was proximately caused by the negligent maintenance of the lighthouse light. The dissent reaffirmed the discretionary function and misrepresentation exception rationale of National Manufacturing, supra.

The Indian Towing case has been used in attempts to skirt the discretionary function exception in a number of cases. In Indian Towing, however, the government conceded that the discretionary function defense was not applicable. If there was negligence on the government's part, it occurred at the operational level of maintaining a lighthouse. Thus, Indian Towing has been held to broaden the concept of what form of negligence creates governmental liability. However, the decision does not alter the limits of the discretionary function exception. Blaber v. United States, 311 F. 2d 629 (2nd Cir. 1964).

Indian Towing is important in defining particular areas of activity where

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[15] Application of the good samaritan doctrine is only appropriate if it is relevant to a particular state's tort law. United States v. Cline, 410 F. 2d 1337 (9th Cir. 1969). When the state law does not apply, common law furnishes the good samaritan doctrine. The negligence of the actor must worsen the condition of the plaintiff. United States v. DeVane, 306 F. 2d 182 (5th Cir. 1962).

the government could be held liable for negligence. These would be situations where the government acts as a good samaritan to a particular group, where it has control of the relevant technological mechanism, where it creates reasonable reliance that it will continue to so act, and where it performs its assumed duty in a negligent manner.

As noted above, it has been asserted that satellites could greatly help ship or other transportation systems by transmitting observations directly to the particular transport vehicle or its terminals instead of back to central accumulation and disseminating points, where the data would be processed and disseminated to the ultimate user. If this direct acquisition system proved desirable, it would be closely analogous to a lighthouse. If the government creates reliance as a result of continued observations which reasonably imply a high degree of accuracy and availability, then any malfunctioning that can be traced to improper "maintenance" of the satellite equipment and which may cause damage consequently creates a governmental liability.

A similar theory of recovery has been asserted against the government in its use of communication devices. It was held that a duty of due care exists for the government in its use of communications technology once the government has voluntarily adopted its use. Pennsylvania Railroad Company v. S. S. Marie Leonhardt, 320 F. 2d 262 (3rd Cir. 1963). The duty of due care may be satisfied in relation to meteorological satellite activity simply by monitoring the satellite activity, i. e. noting equipment dysfunctions, and notifying possible user groups of errors or omissions in observations.

Another area where the government occupies a similar position is that of air controllers at airports. The decisions in this area indicate that the government assumes an observational duty and creates reliance on this duty. Specific regulations or statutes are not needed to impose liability. Johnson v. United States, 183 F. Supp. 489 (E.D. Mich. 1960). The gratuity of the government's position does not excuse its negligence in failing to properly relay significant weather changes. Ingham v. Eastern Air Lines, 373 F. 2d 227 (2nd Cir. 1967). Not only does the government have the duty to "maintain" its mechanism properly,[16] but by placing itself in this samaritan position the government may have the duty to give the latest significant information, DeVere v. True Flite, Inc. 268 F. Supp. 226 (E.D.N.C. 1967), providing that the opportunity presents itself. Neff v. United States, 282 F. Supp. 910 (D. Wash. D.C. 1968). The information distributed by the government may also be required to be complete and exceptionally accurate. Gill v. United States, 285 F. Supp. 253 (E.D. Texas 1968).

Alternatively, the government is not to be expected to unreasonably foresee danger occasioned by extraordinary use of the observations it provides. See Allison v. United States, 264 F. Supp. 1021 (D.C. Ill. 1967). The question here would be what constitutes "extraordinary use." At present, it might be considered that making a basic economic decision based on now-

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[16](Indian Towing, supra; see also Jennings v. United States 178 F. Supp. 516 (D. Mary, 1959)).

casting data was an extraordinary use, while in the future the reliability may be such that these decisions would be made on a daily basis.

If the satellite were to be destroyed, as opposed to performing a dysfunction, the government would probably not be held liable for exercising its discretion in not sending up another similar satellite. Kline v. United States, 173 F. Supp. 298 (D. C. Tex. 1953). It is possible, considering the disarray of the law concerning the "misrepresentation" exception, that a court could rule that a dysfunction of a satellite meteorological observation caused by negligent "maintenance" of equipment might be called a misrepresentation. However, policy considerations do not compel this. If, for example, the satellite observations were directed to specific user groups, the receiver of the service is identifiable. The compulsion to deny recovery to specific individuals for a service rendered generally is lessened. Further, since the target of the service is small, liability would not be overbearing.

IV. CONCLUSIONS

At the present time, governmental weather data processing and dissemination receives sovereign immunity from tort liability. Suits for strict liability, breach of warranty, or product liability would also fail as the law now stands, because these types of claims have been consistently denied under the doctrine of sovereign immunity.[17]

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[17] The Federal Tort Claims Act contemplates circumstances of negligence by government employees either by act or omission to act. The Act does not

If, however, meteorological data collection via satellite, processing, and distribution become extremely accurate and reliable and thus are removed from the discretionary function exception, it is possible that the government could be held liable under the present Federal Tort Claims Act for negligence. However, there is reason to believe that inaccuracies caused either by negligent use of the satellite system as in negligent observations or by negligent processing may be considered misrepresentations and therefore still exempt from liability under the Tort Claims Act.

The utilization of "nowcasting" data coupled with an individualized distribution system wherein the accuracy is reasonably and consistently relied upon by the user may create liability for the government for negligence. This argument would be strengthened if the government has singular control of the degree of accuracy of the nowcasting presentation. Thus consideration should be given to exempting the government from liability in these situations by adding an exception to sec. 2680 of the Federal Tort Claims Act.

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include liability under theories of warranty, product liability or absolute liability. See United States v. Page 350 F. 2d 28 (9th Cir. 1965) cert. den. 382 U. S. 979 (1966); Allison v. United States, 264 F. Supp. 411 (D. C. Mont. 1967); Medlin v. United States, 244 F. Supp. 403 (D. C. S. C. 1965); Mann v. United States, 294 F. Supp. 691 (D. C. Tenn. 1968).

A STUDY OF COMPREHENSION AND USE OF WEATHER INFORMATION BY VARIOUS AGRICULTURAL GROUPS IN WISCONSIN

Jean Longenecker Smith*

Chapter I — Introduction

The research for this paper was done as part of a multidisciplinary study of the social, economic, and political impact of recent advances in satellite meteorology. The study was done by the University of Wisconsin Space Science and Engineering Center for the National Aeronautics and Space Administration (NASA). With improved satellite technology, it is expected that in the not too far distant future, weather can be predicted two weeks in advance with the same accuracy as the present one-day forecast. But this information is not worth the cost unless it can be passed on to, understood, and used to advantage by the various publics. Thus, it is important to determine whether current techniques are adequate for communication of the improved weather predicted data.

This paper is concerned primarily with the various groups of agricultural users in Wisconsin: potato and vegetable, fruit, seed grain and forage

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See also John E. Ross, "The Role of Technical Language and Communication Systems in Disseminating Meteorological Information Users" in Multidisciplinary Studies of the Social, Economic and Political Impact Resulting from Recent Advances in Satellite Meteorology, Vol. II, June, 1971.

growers, canners, and lime and fertilizer dealers. An effort was made to learn the preferred source of weather forecasts and the frequency of use. An attempt was made to measure knowledge of specific terms having to do with weather and comprehension of terms less often used but critical to all—involving varying intensities of weather. Respondents were given an opportunity to make value judgments as to which weather parameters were critical, useful, or of no help to them in their farm operations, and to point out information which would be useful to their operations but which they do not currently receive.

Before this research was undertaken, a study was made to learn about weather forecasts and information—the source, frequency, how disseminated, the raw data and the finished product, formats, content, and terms used. It was learned that local, state, and national Weather Bureau forecasts are expressed in an absolute minimum of words, and that these words are precisely defined in 'Service Operations', Volume III, Chapter B-56, <u>Glossary of Weather Forecasting Terms</u>.[23] A check of radio and TV weather announcers indicated that the format and wording could vary with each individual announcer and thus a content analysis would not be very useful or accurate.

Also, a search was made to see what studies in weather communication have already been done. Baskett Mosse, Professor of Journalism at Northwestern University, former news editor of NBC, served as consultant to the Environmental Science Services Administration (ESSA) for several years and wrote "Suggested Guidelines for Writing Weather Releases."[9] This is not based on any weather comprehension studies but is instead a manual in good writing techniques. A U. S. Department of Commerce, ESSA Bulletin, "Current Technical Studies in Agricultural Meteorology," 1968,[24] showed no communications research underway.

Thus it seemed appropriate and important to learn whether weather communication needs to be improved so that agricultural users can receive optimum benefits from such information.

Chapter II — Research Procedure

Questionnaire

Before a questionnaire could be developed it was necessary to learn which weather parameters are or could be important to the various agricultural user groups, and which terms are apt to be confusing. Background information was obtained from literature. Then the professors working on the various agricultural case studies for the NASA project were contacted to find out which parameters they consider important for the growth of fruits, vegetables, seed grain and forage. The State Climatologist helped supply information as to which terms are often confused by the lay person. Weather Bureau and American Meteorological Society glossaries provided the proper definitions of the terms used in the questionnaire.

A nine-page questionnaire was developed using a combination of multiple choice, matching and open-ended questions to see whether current techniques employed for communication of weather prediction data are adequate. In addition, the respondent was asked to check whether male or female, to state his occupation, and to say what type of agricultural enterprise he was engaged in.

It was recognized that the multiple choice approach in the definition of terms takes the term out of the context of reality, but it is faster than requiring written definitions, and time is an important factor when the respondent has to take time out from his regular activities to fill out a nine-page questionnaire. Also, according to Frederick and Powers, "educational specialists generally agree that multiple-choice tests are the most objective."[5] To eliminate bias, the four possible answers to each question were chosen randomly. Multiple choice questions were also used in the questionnaire for determining matters of fact—either to make sure that all alternatives would be considered, or more often, to make it easier to code the results and thus decrease the possibility of error in coding.

A few open-ended questions were used to eliminate possible bias in results. According to Krech, Crutchfield and Ballachey, the open-ended question is superior to the multiple-choice question in ascertaining the respondent's interpretations, in being less dependent upon specific wordings that might induce bias, and in providing fuller data for analysis.[6] The answers and comments are more meaningful since they are not suggested in any way by the questionnaire.

The questionnaire was divided into four parts. The first part is primarily concerned with the reception and usefulness of weather information and forecasts. It asks for the sources of weather information the respondent normally uses, the preferred sources, and the reasons for these preferences. An attempt is made to check how useful the individual finds weather forecasts, how often he plans his activities on the basis of these forecasts, and how often he seeks forecasts. The questionnaire gives the respondent a chance to express his interest in receiving a two-week forecast. It also measures his interest in receiving some sort of continuously available weather forecast and gives him an opportunity to place a dollar value on it. There is also an open-ended question which gives him a chance to list information he does not currently receive, but would like to have available.

The second part is a multiple-choice test to measure specific knowledge of terms having to do with weather. Seven of these terms—precipitation, relative humidity, cold wave, smog, degree day, condensation, and frost line—could be useful or necessary for an individual depending upon his type of operation. The other nine are more a measure of technical knowledge. These terms include anemometer, solar radiation, dew point, barometer, atmospheric pressure, isobar, evaporation, and air mass.

The third section offers an opportunity to make value judgments as to which weather parameters may be critical, useful, or of no help in farm operations. It may also serve as an indication of an individual's comprehension of how this information can be used—by comparing answers with the results of the case studies and with the value judgments of agricultural experts in the various fields. There is also another open-ended question about additional information individuals may be interested in receiving to see if the parameters listed suggested anything more to the respondents.

The last section includes two matching tests which attempt to measure comprehension of terms less often used but critical to all. These involve varying intensities of weather, for example, the series of blizzard, blowing snow, snow flurries, snow squalls, drifting snow, and heavy snow.

Pretest

The original questionnaire was pretested by thirty students (twenty-six male and four female) in an agricultural news writing class taught by Professor John Ross. Of these, seventeen had agricultural backgrounds. The questionnaire was also pretested by nine farm couples at a group meeting in Hartford, Wisconsin. Following the pretest, one of the terms and several of the multiple choice alternatives were changed. One term was discarded from the matching test and two questions about the frequency of wanting weather information were added.

Selection of Sample

Addresses were collected for individuals within specific agricultural groups in Wisconsin in order to tie in better with the NASA case studies. Sixty of the larger growers were selected from a list of those belonging to the Wisconsin Certified Seed Association. The executive secretary of the Wisconsin Canners and Freezers Association provided the names and addresses of the individuals who probably make the weather decisions for each of the 108 canning and freezing factories in Wisconsin. Questionnaires were sent to forty-nine vegetable growers known to the University of Wisconsin Agricultural Extension and to twenty-five of the larger fruit growers and forty-seven of the top forage farmers known to the University of Wisconsin. The Secretary of the Potato and Vegetable Growers' Association provided thirty names and addresses, and forty-eight addresses were taken from a list of lime and fertilizer dealers in the state—since these dealers are doing more and more custom application and thus are also dependent upon proper weather conditions.

This research is not concerned with the relation of socioeconomic factors to comprehension and use of weather information though comparisons are made between the types of operations. However, because of the way the sampling was done, the probable effect of the bias should be pointed out. It can be assumed from the type and sources of the sample that the respondents are among the larger operators. Since they either belonged to an organization formed around their specialty or were on University mailing lists, one can assume that they are more concerned and hence probably more knowledgeable.

Previous research done on Wisconsin farmers shows that the amount of education is positively related to comprehension. Sperback in his "Comprehension of Dairy Terms by Wisconsin Farmers," 1967,[14] and Ross, Min, and Bemis in their "Communications Patterns Among Rural Wisconsin Residents on Pesticide Use," 1967,[12] found that education was an important factor in comprehension. Baxter in his "Study of the Comprehension of Swine Terms and Concepts by Wisconsin Farmers," 1967,[2] found that while education levels made the most significant difference in test scores, there was also a significant difference between age groups. Geographically he found no differences in comprehension. Sorenson in his study, "Knowledge and Understanding of Soils by Wisconsin Farmers," 1966,[13] also found that education had the greatest association with soils knowledge. Age, farming experience, size and type of farm, geographical location, and listening to farm radio programs made no significant difference. But soils knowledge also increased with extension contacts, reading farm magazines and belonging to farm organizations. Thus, this sample has a built-in bias and the scores will probably tend to be higher than in a random sample.

The advantages of the type of sampling used here are not only to tie the results in with the case studies, but also to insure a higher rate of return and to lower the cost. This sample would have a greater motivation to fill out and return the nine-page questionnaire. (When Meade, investigating "Farmer Understanding of Technical Words," 1947,[8] sent out short questionnaires involving twenty-five multiple-choice questions randomly to 2500 people living on rural routes, he received only a 19.8% return.) Mailing the questionnaire rather than using the interview technique also lowered the cost and made possible a larger sampling over a larger geographic area. An attempt was made to get a good mix of addresses from the entire state.

Questionnaire Returns

A total of 367 questionnaires were mailed out in December of 1969. Six were returned with no address: 4 canners, 1 fruit grower and 1 vegetable grower. Each questionnaire had a code letter for the group and a number for the individual in the upper left corner so that a record could be kept of those who returned the questionnaire and those who did not. When the returns seemed to have stopped at 55%, a reminder letter was sent out 15 January 1970 to those who had not responded. A total of 258 returns were received or 71.5%, but a few of the questionnaires had some unanswered sections. When figured by groups, the fruit growers had the highest percent return—91.6%. (There was no apparent reason for the fruit growers' returns being significantly higher than the 56% returned by the vegetable growers since both lists were obtained from University of Wisconsin Extension—perhaps extension maintains greater contact with the fruit growers.)

Table 1

Percent Returning Questionnaires

Group (number in sample)	% Returned
Fruit growers (24)	91.6
Seed grain growers (60)	78.0
Canners (104)	73.0
Potato and vegetable (30)	70.0
Lime and fertilizer dealers (48)	68.7
Forage growers (47)	68.0
Vegetable growers (48)	56.0
Total of all groups (361)	71.5

Analysis of Data

Percentage tabulations were made of all answers both according to the various groups (the vegetable growers were put together with the potato and vegetable growers) and the combined total. In some instances, one group was significantly different compared to the combined total of the rest. Records were kept of the responses to the open-end questions by group. A number of voluntary comments were made in the margins having to do with the lack of accuracy of the forecasts or the desire for greater accuracy. These comments were also recorded by group and tabulated. In addition, the responses were coded and run through the computer for cross tabulations to check for any interesting or significant correlations.

Copies of the third section of the questionnaire having to do with making value judgments as to which weather parameters may be critical, useful, or of no help in farm operations were given to Hazel Shands, University of Wisconsin Professor of Agronomy, to fill out from the viewpoint of seed grain growers and to Professor Theodore Tibbitts, University of Wisconsin Horticulturist, to fill out from the viewpoints of both fruit and vegetable growers. Both of these men participated in the multidisciplinary NASA project in their respective fields. Their responses were used as a basis of comparison with the respondents by group.

Chapter III — Results and Discussion

Comprehension of Weather Terms

The multiple-choice test developed to measure specific knowledge of weather included sixteen terms. The terms, with the four possible choices for each and the number incorrectly marking each wrong response, are shown in the appendix. The terms are listed in Table 2 in the order of the most to the least percent error, including all 252 responses.

The most confusion existed about the terms "cold wave," "relative humidity," "degree day," and "frost line." There were significant differences between groups of respondents in some instances. With the term "frost line," 57.1% of the fruit growers gave the incorrect response compared to 36.4% error for all the respondents. The lime-fertilizer dealers' error of 45.5% on the term "isobar" was much greater than the

Table 2

Comprehension of Specific Weather Terms

Term	% Wrong
Cold Wave	48.8
Relative Humidity	47.6
Degree Day	42.1
Frost Line	36.4
Front	31.9
Isobar	27.0
Anemometer	20.8
Condensation	18.3
Atmospheric Pressure	14.7
Smog	12.8
Dew Point	8.7
Air Mass	5.6
Barometer	5.2
Precipitation	4.8
Solar Radiation	3.6
Evaporation	2.8

27.0% error over-all. And with the term "degree day," the seed grain and forage growers and lime-fertilizer dealers had a combined error of 54.5% compared to the combined error of 32.7% for the canners, and fruit and vegetable growers. This difference probably occurs since the term is more useful for the latter group than the former—it is often used by growers to help determine when fruit and vegetables will be ready for harvest, and, even so, one-third of them were still unaware of the proper definition.

Table 3 shows the number wrong scored by each group in percentages. The number of responses from each group is shown at the top of the table. The fruit growers scored significantly higher than the other groups with over half scoring no more than one wrong. In the total sample, only one-fourth scored no more than one wrong and the forage growers scored significantly lower with over one-half getting four or more wrong compared to about one-third of all those responding.

Comprehension of terms involving varying intensities of weather were measured in two matching tests, one containing eight and the other nine terms. The terms are listed in Table 4 according to the percent error in the 248 responses.

The lime-fertilizer dealers were more confused by the terms "thick fog" and "dense fog" than the other respondents, since 33.3% of them answered incorrectly compared to 16.8% over-all. The errors seem fairly low at first glance, but when one considers that about one-fourth of

Table 3

Percent of Error by Group on Comprehension of Specific Weather Terms

Number Wrong	74 Canners	21 Fruit	33 Lime-fert.	45 Seed	47 Vege-table	32 Forage	252 Total
0-1	29.7%	52.4%	27.3%	11.1%	29.2%	21.9%	26.9%
2-3	41.9	19.0	36.4	51.5	31.3	25.0	36.8
4-5	13.5	9.5	12.1	15.6	22.9	31.3	17.4
over 5	14.9	19.0	24.2	22.2	16.7	21.9	19.0
0-3	71.6	71.4	63.6	62.2	60.5	46.9	63.6
4 or more	28.4	28.6	36.4	37.8	39.5	53.1	36.4

these supposedly more knowledgeable respondents did not know the difference between "tornado watch" and "tornado warning" nor "ice storm" and "freezing rain," there is cause for concern.

Table 5 shows the number responding in each group and the number wrong scored by each group in percentages. The fruit and forage growers had the best scores with 46.2% and 43.8% having no more than one wrong compared to 34% of the total group of 248.

It is interesting to note that while the forage growers scored significantly lower on the multiple-choice test (53.1% had four or more wrong compared to 36.4% over-all) they scored significantly better on the terms involving varying intensities of weather where only 21.8%

Table 4

Comprehension of Terms Involving Varying Intensities of Weather
(248 responses)

Terms	% Error
Blowing Snow	24.9
Ice Storm	24.5
Tornado Warning	24.4
Freezing Rain	24.1
Tornado Watch	22.8
Drifting Snow	18.5
Snow Squalls	17.3
Thick Fog	16.8
Blizzard	14.5
Dense Fog	14.4
Snow Flurries	13.7
Drizzle	10.0
Frost	4.8
Showers	4.4
Tornadoes	3.6
Heavy Snow	3.2
Severe Thunderstorm	3.2

Table 5

Percent Error by Group on Comprehension of Terms Involving Varying Intensities of Weather

Number Wrong	32 Forage	71 Canners	33 Lime-fert.	21 Fruit	44 Seed	47 Vege-table	248 Combined total
0-1	43.8%	35.2%	24.2%	47.6%	20.9%	38.3%	34.0%
2-3	34.4	36.6	45.5	19.0	41.9	23.4	34.4
4-5	15.6	18.3	15.2	10.0	20.9	21.3	18.6
over 5	6.3	9.9	15.2	14.3	16.3	17.0	13.0
0-3	78.2	71.8	69.6	66.6	62.8	61.7	68.4
4 or more	21.8	28.2	30.4	33.4	37.2	38.3	31.6

had four or more wrong compared to 31.6% over-all. The scores on the matching test were uniformly slightly higher than those on the multiple-choice test. This means even more when you realize that any error in the matching test is ordinarily a double error, whereas each error on the multiple-choice test is independent of the others. On the matching test 31.6% of the 248 had four or more wrong compared to 36.4% of the 254 on the multiple-choice test. Table 6 compares the mean scores on the multiple-choice and matching tests.

Sources of Weather Forecasts

The questionnaire asked respondents to check all their usual sources

Table 6

Comparison of Mean Scores on the Two Comprehension Tests

Group (number responding)	Mean Scores Multiple Choice	Mean Scores Matching Test
Canners (74)	81.39	85.97
Vegetable (47)	80.26	84.28
Fruit (21)	80.03	83.43
Seed (45)	77.34	81.32
Lime-Fertilizer (33)	77.08	81.81
Forage (32)	76.56	88.10
Combined Total (252)	79.19	84.39

of weather forecasts, to rank three in order of importance, and to check all the reasons why they preferred the source ranked first. All normal sources were listed plus a space was left for any source that may have been omitted. Six possible reasons for their first preference were listed to make it easier to code the responses, plus a space was left so they could list any other reasons. The order of the choices on the questionnaire seemed to have no effect on the responses.

Usual source or sources of weather <u>forecasts</u>—check all that you use regularly.

__a. newspaper	e. own observations
__b. radio	f. telephone weather service
__c. TV	g. private meteorological service
__d. farm publications	h. other (list)__________________

Table 7

Regularly Used Sources of Forecasts (258 responses)

Source	% using regularly
Radio	95.7
TV	94.6
Own observations	50.8
Newspaper	46.9
Farm publications	26.0
Telephone weather service	22.1
Other	5.0
Private meteorological	2.7

Radio and TV far outranked the other regularly used sources of forecasts. All of the fruit growers use both radio and TV regularly to obtain forecasts. All of the forage growers use radio forecasts regularly, but only 21.9% use the newspaper compared to 46.9% of the combined total. Half of the respondents use their own observations to help make forecasts compared to 72.7% of the fruit growers, and 39.5% of the canners use telephone weather service compared to only 6.3% of the forage growers and 10.6% of the seed grain growers. This difference could occur for a number of reasons, chief among them being either lack of access or lack of knowledge of the service. The "other" responses included mainly telephone forecasts from the airport weather bureaus.

The respondents were asked "Which sources do you prefer? Rank three in order of importance," and the same list was given. When a weighted rank percentile was figured for the responses, radio and TV still came in as close first and second choices, and newspaper and farm publications dropped significantly in importance as sources for weather forecasts. This is logical because of the time lag involved in publishing the information—farmers need the most up-to-date information possible. Private meteorological service is not significant to any of the groups. It is not readily available and is costly.

Thirty-five percent of the respondents listed their "own observations" as one of the three preferred sources of weather forecasts. Of these, 71.9% scored three or fewer wrong on the multiple-choice test compared to 63.6% of those over-all, and 77% had three or fewer wrong on the matching tests compared to 68.4% of all the respondents. There was no significant difference in the percent making comments on the lack of accuracy in weather forecasts between this group and the combined total of all the respondents.

The respondents were asked to check all applicable reasons from the six listed for preferring their primary source of weather forecasts. In addition, they were given an opportunity to list any other reasons. Only 4.3% gave a variety of other reasons. Availability seemed the prime concern. Only about one-fourth chose their prime source because they thought it was more accurate, or they could understand it better.

Table 8

Preferred Sources of Weather Forecasts (258 responses)

Source	Weighted Rank Percentile
Radio	69.4
TV	67.6
Telephone	16.3
Own observations	14.8
Newspaper	11.9
Farm publications	2.7
Private meteorological	1.9

Table 9

Reasons for Preferred Source of Weather Forecasts

Reason	% Checking as a Reason
Available when I need it	54.7
It is the latest word	46.5
More information is given	45.0
It is more convenient	43.0
It is more accurate	25.6
I can understand it better	24.4
Other	4.3

Frequency of Obtaining Weather Forecasts

One of the concerns of the NASA study was the possible use in the future of some sort of continuously available weather forecasting service. To tie in with this, the respondents were asked how often they try to get forecasts during the season when weather information is the most important to their business, and why they do not try to get information oftener. They were also asked about their interest in receiving some sort of continuously available forecast. As a measure of their actual interest, they were asked if they would be willing to pay for such a system, and, if so, they were asked to check an amount.

Three-fourths (77%) of the 257 respondents get the weather at least twice a day, and 42% try to get forecasts three times or more per day. Of the 134 (51.7%) making open-ended responses as to why they do not try to get forecasts oftener, one-third said they do not get forecasts more frequently because the forecasts they got were sufficient—that it was not necessary to have more frequent forecasts. Almost another third said that it was not convenient to do so. About 13% recognized that new information is not available. (Forecasts are presently changed every six hours, but there are also occasional revised forecasts.) It was not possible to code 12.7% of the responses because of their variety, so they were lumped together.

When the respondents were asked which they would prefer if it were available—forecasts continuously available by telephone, radio, TV, other,

Table 10

Reasons Forecasts Not Sought Oftener (134 responses)

Reason	%
Sufficient, not necessary	34.3
Not convenient	32.1
New information not available	12.7
Forecasts not that accurate	8.2
Miscellaneous responses	12.7

or none—half of the 257 respondents preferred radio and about one-third preferred telephone. TV came in a poor third with about 15%. Radio, of course, is the most readily available source for farmers since many, if not most, have radios in their trucks and barns and some even have them on their tractors. Yet it is surprising that telephone came out so far ahead of TV since 94.6% use TV as one of their sources compared to only 22.1% using telephone weather service, and on the weighted rank percentiles of the three preferred sources, TV ranked 67.6% compared to only 16.3% for telephone. Of course, telephone weather service is not presently available locally in all parts of the state. Apparently more farmers would use it if it were available. Also, phones may be more readily available than TV since many farmers have phones in their barns.

When the respondents were asked if they would be willing to help pay for some sort of continuously available forecasting system, 83% of the 224

Table 11

Preferred Source of Continuously Available Forecasts (257 respondents)

Source	%
Radio	49.4
Telephone	32.4
TV	15.3
Other (print, teletype)	4.9
None of the above	1.6

Table 12

Willingness to Help Pay for a Continuously Available Forecasting System

Group	Yes	Maybe	No
224 farmers	31.7%	51.3%	16.1%
33 lime-fertilizer dealers	9.1%	57.6%	33.3%

Table 13

The Most Willing to Pay for Continuous Forecasts

Amount	% Willing to Pay
$1 - $2 per month	31.9%
$5 per month	21.4
Over $5 per month	12.5

farmers said either they would or might help pay, compared to 66.7% of the lime-fertilizer dealers. There were occasional voluntary qualifications written in the margin of the questionnaire saying that it would depend upon the accuracy of the forecasts, but the response shows great interest in and strong support for such a service.

Two-thirds of the 257 respondents went a step further and actually put a dollar value on a continuously available weather forecasting service by answering the question "Check the most you would be willing to pay: a. $1 - $2 per month; b. $5 per month; c. over $5 per month." About one-third of all respondents would be willing to pay $1 - $2 per month. Another fifth would be willing to pay $5 per month, and 12.5% would be willing to pay over $5 per month—only one lime-fertilizer dealer and one forage grower were willing to pay over $5 per month.

Helpfulness of Weather Forecasts in General

An attempt was made to learn whether the respondents view weather forecasts as helpful, whether or not they try to play their activities on the basis of forecasts, and which forecasts are helpful: one-day, two-day, five-day, and/or thirty-day. In addition, they were asked how helpful a two-week forecast with the accuracy of the present one-day forecast would be. A later section deals with the usefulness of specific weather information.

When the respondents were asked to check whether they found the forecasts, in general, usually helpful, occasionally helpful, seldom helpful, or never helpful, 80.5% of the 226 farmers excluding the forage growers said they find the forecasts usually helpful whereas only 62.5% of the forage growers said they find them so. However, 71.9% of the forage growers said they usually try to plan their activities on the basis of the forecasts. This can probably be accounted for by the fact that it is almost impossible to forecast local showers and this information is most important to forage growers during haymaking. Since these showers cannot be forecast accurately, the forecasts are not as helpful—but the forage growers still try to plan on the basis of the forecasts for lack of anything better.

All of the 257 respondents find that the forecasts are either usually or occasionally helpful— and 60% of them usually try to plan their activities on the basis of the forecasts. Only 2.4% seldom or never plan their activities accordingly.

When the respondents were asked which forecasts were helpful— the one-day, two-day, five-day, and/or thirty-day forecasts—only about one-third thought the thirty-day forecasts were helpful; only 12.5% of the forage growers thought the thirty-day forecasts were helpful. With the exception of the forage growers, a larger percent from every group of respondents thought the five-day forecast helpful than thought the two-day forecast was helpful.

It is predicted that with the new satellite technology, it will some

Table 14

Helpfulness of One-day, Two-day, Five-day, and Thirty-day Forecasts

Forecast	% Finding helpful
One-day	91.5%
Two-day	74.8
Five-day	81.8
Thirty-day	33.3

Table 15

Helpfulness of Two-week Forecast with Accuracy of One-day Forecast

Degree of Helpfulness	%
Extremely helpful	65.8
Very helpful	26.5
Occasionally helpful	6.6
Probably not helpful	1.2

day be possible to forecast the weather two weeks in advance with the accuracy of the present one-day forecasts. The respondents were asked whether this would be extremely, very, occasionally, or probably not helpful to them. Fewer of the lime-fertilizer dealers thought it would be helpful, but even so 54.5% of them thought such information would be extremely helpful. Over 90% of all the 257 respondents thought the forecasts would either be extremely or very helpful to them—although occasional comments were made in the margin of the questionnaire regarding concern for accuracy.

Usefulness of Specific Weather Information

The respondents were given forty-seven weather variables which now show up on some weather reports and forecasts, and were asked to check whether the information could make a critical difference, would be useful, or would be of no help in planning their activities. Included were variables of temperature, frost, moisture, storm warnings, wind cloud cover, warm air masses, and cold fronts. In addition, the terms relative humidity, barometric pressure, dew point temperature, solar radiation, high and low pressure systems, soil moisture, and soil temperature were given. Of the 250 responses, 52.1% checked eleven or more as critical, and 63.4% said that fewer than ten were of no help. Of the 27.1% checking only one to five variables as critical, 46.6% had four or more wrong on the multiple-choice test compared to 36.4% of all the respondents.

The first weather variables considered concerned temperature—the current temperature, the low for the day, the high for the day, and the duration of the current range. The lime-fertilizer dealers were the least concerned with the temperatures, and the forage growers were only slightly more concerned, whereas 63% of the fruit growers and 46.7% of the canners felt that

Table 16

Percent of Weather Parameters Critical and No Help

Number of Parameters	% Critical	% No Help
1-5	27.1	41.2
6-10	20.8	22.2
over 10	25.1	36.6

low temperature information could be critical. Professor Theodore Tibbitts, University of Wisconsin Horticulturist, feels that all four pieces of information about temperature could be critical for vegetable growers and that the low temperature and the duration of the current temperature could be critical for fruit growers. Knowledge of temperatures help the farmer estimate harvest dates. He can anticipate blights and pests and prevent them by spraying. There are optimum weather temperatures for some sprays, and flooding or irrigation in advance can prevent frost or heat damage of some fruit and vegetable crops. Professor Hazel Shands, University of Wisconsin Agronomist, feels that while the temperature information is useful to seed grain growers, it is not critical.

Only about a third of the lime-fertilizer dealers thought any of the frost information could be critical. The forage growers' main concerns were the time of arrival and whether the frost would be early or late. Professor Tibbitts says that the time of arrival and duration of the frost,

Table 17

Importance of Temperature Information

Temperature Information	% Canners Critical	% Fruit Critical	% Total Critical	% Total (249) Critical & Useful
Current	17.3	31.7	14.4	83.2
Low for day	46.7	63.6	37.6	90.8
High for day	37.3	22.7	18.8	86.0
Duration of current	33.3	31.7	23.2	90.8

whether it will be early or late, and what the lowest temperature will be could be critical for both fruit and vegetable growers, and that knowing when the ground will freeze for good and the depth of the frost in the ground is of no help to either group. The fruit growers are either more knowledgeable or go along with his assessment to a greater extent than do the vegetable growers and canners. Seventy-two percent of the seed grain growers agreed with Professor Shands that it is critical to know the time of arrival of the frost, 60.5% that it is critical to know the lowest temperature, and 48.8% that it is critical to know whether the frost will be early or late.

The lime-fertilizer dealers seem more concerned with information about moisture than with any of the other variables. The percentage of dealers who think some of this information is critical is a bit higher than the percentage of the 250 respondents. All in all, though, none of the groups varied significantly from the percentages of all the respondents.

Table 18

Importance of Frost Information

Frost Information	% Forage Critical	% Fruit Critical	% Total Critical	% Total (250) Critical & Useful
Time of arrival	56.3	81.8	64.0	98.4
Duration	9.4	59.1	35.2	88.0
Lowest temperature	25.0	81.8	48.8	91.2
Early or late	46.9	54.5	44.5	91.2
When ground freezes	25.0	9.1	22.0	72.4
Depth of frost in ground	6.4	4.5	5.2	58.0

Professor Tibbitts feels that none of the moisture information is critical for fruit growers, whereas rain, drizzle, time of arrival, how much, duration, and how long between measurable rains can be critical for vegetable growers. This information is necessary in timing of field operations: knowing when to plant and when to fertilize; whether to irrigate or not; whether to spray with insecticides and fungicides or not, and whether to spray by air or ground; what the drying conditions will be; and whether to harvest early or late. Professor Shands checked rain, snow, amount of snow cover, length between measurable rains and drying conditions as being critical information for some seed grains. Over half of the total respondents felt that information about rain and the time of arrival could be critical, and, as with temperature and frost variables, the vast majority

Table 19

Importance of Moisture Information

Weather Information	% Critical	% Critical & Useful
Rain	52.0	99.2
Sleet	17.2	68.8
Freezing rain	18.0	72.0
Drizzle	14.4	79.6
Freezing drizzle	17.2	69.6
Fog	8.8	70.0
Dew	5.2	62.0
Hail	49.6	85.2
Snow	16.4	82.0
Time of arrival	59.4	97.6
How much	49.4	96.8
Duration	48.2	94.8
Amount of snow cover	6.0	74.3
Length between measurable rains	26.5	89.2
Drying conditions	34.9	91.6

thought all the moisture information, if not critical, at least useful. Table 19 shows the percentage of the 250 respondents who think the information could be critical and the combined percentage of those who think it could be critical and those who think it could be useful.

The next variables considered were storm warnings, wind, cloud cover, warm air masses, and cold fronts. Professor Tibbitts did not mark any of these as critical information for fruit growers. However, 54.4% of the fruit growers felt that knowing the wind speed may be critical and 45.5% feel that the duration of the wind is important. Professor Tibbitts did check the direction the storm is traveling, duration and speed of the wind, amount and duration of cloud cover, and when warm air masses arrive as possible critical information for vegetable growers. Knowing wind speeds and direction is especially important in the spraying of crops, and blowing soil can be prevented by previous irrigation. However, less than 10% of the canners checked wind speed as critical information compared to 43% of the other vegetable growers. Professor Shands checked that having information about the severity of storms, when warm air masses would arrive and with what effects, and information about the effects of a predicted cold front, could be critical for seed grain growers.

The last seven weather variables on the questionnaire were relative humidity, barometric pressure, dew point temperature, solar radiation, high and low pressure systems, soil moisture and soil temperature. Professor Shands said that relative humidity information could be critical for

Table 20

Importance of Storm, Wind, Cloud Cover, Warm Air Masses, and Cold Front Information (249 respondents)

Weather Information	% Critical	% Critical & Useful
Wind:		
Speed	28.9	92.0
Direction	11.2	80.7
Duration	15.3	85.1
Cloud cover:		
Amount	9.2	74.7
Duration	10.8	79.1
Direction moving	5.2	60.6
Warm air masses:		
Where	10.0	87.1
When arrive	11.6	90.0
What effects	10.8	82.3
Cold fronts:		
Where	28.1	90.4
When arrive	33.3	94.0
What effects	22.1	86.3

small grains at harvest time and solar radiation at weed spray time. Only 11.6% of the seed grain growers checked relative humidity information as critical but 79% thought it could be either critical or useful. None of the seed grain growers thought solar radiation information critical, and less than one-third even thought it useful. This indicates a lack of comprehension of what the term means in terms of usefulness even though 98% of the seed grain growers were able to choose the right definition in the multiple choice test. Professor Tibbitts did not mark any of these as critical information for fruit growers but checked relative humidity and dew point temperature as possible critical information for vegetable growers. Only 4% of the canners and about 25% of the other vegetable growers recognized relative humidity information as occasionally critical. Only 3% of the canners and 18% of the other vegetable growers checked dew point temperature as possibly critical, but 55% of the canners and 75% of the other vegetable growers thought the information at least useful. Vegetable growers often take soil temperatures themselves according to Professor Tibbitts so they can plant when the soil temperature is optimum for seed germination. Over one-fourth of all the 249 respondents thought soil moisture information could be critical, and 86.2% thought it either critical or useful; however, Professor Tibbitts points out that the soil moisture varies with the location, type of soil, amount of cultivation, irrigation, and local showers, so accurate information is difficult if not impossible to provide.

Usefulness of Information About Pollutants

In addition, the respondents were asked if it could be critical, useful, or of no help to their operation to know the amounts present of various air pollutants—sand or dust, sulphur dioxide, soot or fly ash, ozone, nitrous oxides, carbon monoxide, fluorides, PAN, and any others. Over four-fifths of the 246 respondents either said the information would be of no help, or did not answer the question. Those checking pollutant information

Table 21

Importance of Miscellaneous Weather Information

Weather Information	% Critical	% Critical & Useful
Relative humidity	12.1	80.6
Barometric pressure	4.9	68.7
Dew point temperature	4.9	54.1
Solar radiation	4.9	45.9
High and low pressure systems	7.7	78.9
Soil moisture	28.0	86.2
Soil temperature	26.4	86.6

as critical or useful did not have test scores significantly different from those either checking all pollutant information as no help or not answering. Professor Tibbitts noted on his questionnaire that there is not enough technology available to make this useful at the present time, but there will be in the future—probably in three to five years. And he checked sulphur dioxide, ozone, nitrous oxides, fluorides, and PAN information as possibly critical to vegetable growers.

Respondents were asked: "If at the present time you don't know how to make use of the information on the amount of air pollutants present, but would nevertheless like to receive the information in the future—circle those pollutants you would be interested in." Fifteen percent circled sulphur dioxide, and 13% each circled ozone, nitrous oxide, and carbon monoxide. There was even less interest in the other pollutants.

Additional Weather Information Desired by Respondents

Two opportunities were given in the questionnaire for respondents to list any weather information they do not currently receive but would like. Of the 257 respondents, 34.2% listed additional weather information they would like to have. They scored a bit higher on the multiple-choice test than the over-all group since 72.7% scored three or fewer wrong compared to 63.6% over-all. However, they scored a bit lower on the matching test with only 60.6% getting three or fewer wrong compared to 68.4% for the total group. The fruit growers were the most interested in receiving additional information with 68.2% listing at least one item compared to only 15.2% of the lime-fertilizer dealers and 19.1% of the seed grain growers. Sixty-five percent of those listing additional information desired checked eleven or more weather parameters as critical to their operation.

The actual information requested is listed in the appendix by group. Following each bit of requested information are the numerical scores for first the multiple choice and then the matching test of the person making the request.

The most frequent request or comment made by all groups was regarding the accuracy of the forecasts. Comments were also made in the

Table 22

Percent by Group of Those Listing Additional Weather Information Desired

Group	% Listing Additional Information Desired
Fruit (22)	68.2
Vegetable (48)	43.8
Canners (76)	35.5
Forage (31)	35.5
Seed (47)	19.1
Lime-fertilizer (33)	15.2
Combined total (257)	34.2

margins on other parts of the questionnaire regarding accuracy. When a frequency count was made of these remarks, it was learned that 22.7% of the 257 respondents and 31.3% of the forage growers made voluntary comments regarding the lack of accuracy of forecasts or their desire for greater accuracy. There was no significant difference in their test scores from the scores of the over-all group. Of those making comments on accuracy, 50.9% rated eleven or more weather parameters as critical to their operation, and 54.4% rated only one to ten as of no help in their operation.

Chapter IV — Conclusions

Comprehension of Weather Terms

Because of the way the sampling was done, there is a probable bias among the respondents toward the larger operators, and since the respondents either belong to an organization formed around their specialty or are on University mailing lists, one can possibly assume that they are more concerned and hence probably more knowledgeable than the average Wisconsin farmer. The high rate of return (71.5%) of the long nine-page questionnaire also shows their concern.

Thus, it is especially significant that almost half of all 257 respondents missed the terms "cold wave" and "relative humidity"; 42.1% missed the term "degree day"; 36.4% missed the term "frost line" and about one-third missed the term "front." These are all terms regularly used in forecasts with the possible exception of "degree day," but fruit and vegetable growers should be familiar with and use the "degree day" method to help determine when crops will be ready to harvest.

Perhaps even more important is the fact that about one-fourth of 248 respondents did not know the difference between "tornado watch" and "tornado warning" in spite of the efforts of the United States Weather Bureau to make this clear through pamphlets, flyers, articles in the newspapers, and explanations on the radio. In a state like Wisconsin where tornadoes occur fairly frequently with attendent loss of life and property, this assumes special importance.

About one-fourth were confused about the difference between the terms "ice storm" and "freezing rain," and about one-fourth got the term "blowing snow" confused with either "drifting snow," "blizzard," or "snow squall."

Of 257 respondents, 36.4% got four or more wrong of the sixteen technical weather terms given in the multiple-choice test, and 31.6% of 248 respondents got four or more wrong of the seventeen terms involving weather intensity in the two matching tests. When you consider that these are probably among the better educated, most aware and concerned farmers in Wisconsin and when you realize what vital importance weather has in all types of farm operations, this is a high percentage. There is obviously a need for more explanation and education in weather terminology along with the forecasts.

Relation of Comprehension to Usefulness

The comprehension of technical weather terms by groups may be positively related to the usefulness of the information for that group. For example, the seed grain and forage growers and lime-fertilizer dealers had a combined error of 54.5% for the term "degree day" compared to the combined error of 32.7% for the canners and fruit and vegetable growers. The "degree day" method is often used to help determine when fruit and vegetables will be ready for harvest. In fact, Professsor Tibbitts marked it as critical information for vegetable growers and useful for fruit growers, whereas Professor Shands recorded it as no help for the seed grain growers.

The term "anemometer" was missed by 40.6% of the forage growers compared to only 20.8% of all the respondents. Wind velocity seems to be more important to all the other groups, since it is vital knowledge before spraying or dusting fruit and vegetables. Blowing soil which kills young seedlings, reduces the quality of lettuce and aids the spread of certain plant diseases, can be prevented by irrigating. The speed and direction of wind is useful in placing irrigation pipes. If high winds are expected, small grains can be harvested before they lodge, and apples can either be harvested before they fall and are bruised, or stick-on sprays can be applied. Wind velocity seems to be of less importance to forage growers and thus perhaps their lesser knowledge of the term "anemometer."

It is harder to account for the fact that 57.1% of the fruit growers failed to mark the correct response for "frost line" compared to 36.4% of all respondents, since the knowledge of the maximum depth to which the ground becomes frozen is not particularly useful to any of the groups.

The theory that comprehension of weather terms may be positively related to the usefulness of the information may help explain why the forage growers scored the lowest of any of the groups in their knowledge of technical weather terms but the highest of any of the groups on those terms involving intensities of weather. (On the test involving specific weather terms, only 46.9% of the forage growers scored three or fewer wrong compared to 63.6% over-all, while 78.2% of the forage growers scored three or fewer wrong on the terms involving intensity compared to 68.4% over-all.) The technical weather terms used—other than "precipitation," for which the forage growers had less error than the respondents over-all—have less application for forage growers than for the other groups, whereas the forage growers are probably more concerned with the intensity of the weather throughout the year than the other groups. Their farm operation is rarely, if ever, limited to the growth of forage. In fact, all except three of the respondents listed dairy as their main enterprise. One listed cattle and hogs, and the other two did not answer.

As a matter of fact, every group scored slightly better on the terms involving intensity of weather than on the terms involving specific knowledge, and this in spite of the fact that the test involving weather intensities was a matching test where any error was ordinarily a double error, whereas the test involving specific terms was multiple-choice where each error was independent of the other. Here, again, the better comprehension of the terms involving intensity of weather may be because their usefulness and importance are more obvious to the farmer.

Little, if any, prior research has been done specifically relating comprehension of information to the usefulness of that information. Further research should be done in this area.

Source and Frequency of Obtaining Weather Forecasts

Radio and TV far outranked the other regularly used sources of forecasts with 95.7% of all the respondents using radio regularly and 94.6% using TV. When the respondents were asked to rank three in order of importance, radio and TV still came out way ahead with weighted rank percentiles of 69.4 and 67.6, respectively. However, when the respondents were asked which they would prefer if it were available—forecasts continuously available by telephone, radio, TV, other, or none—one-half of the 257 respondents preferred radio and about one-third preferred telephone. TV came in a poor third with about 15%.

This difference may be explained by the fact that the prime reasons marked for their preferred sources of weather information were availability, latest word, more information, and convenience—and weather information is not now available by telephone in many parts of the state, and where it is available, farmers may not be aware of it. (Only 22.1% of the respondents presently use telephone weather service.) Both radio and telephone are more readily available to farmers than TV since most have both radios and phones in their barns and many have radios in their trucks and even on their tractors. Checking for information on TV other than at mealtimes and in the evening would mean special trips into the house. Unless the farmer had some free time or was especially concerned about some aspect of the weather, he would be less likely to make use of a continuously available weather service by TV. This assumes importance in light of the fact that NASA is considering new formats, especially using TV. It might be both less costly and of more benefit to the farmer either to expand the telephone weather service or to set up a radio station with continuous weather information.

When the respondents were asked if they would be willing to help pay for some sort of continuously available forecasting system, 83% of the 224 farmers and 66.7% of the lime-fertilizer dealers either said they would or might help pay. Two-thirds of the 257 respondents went a step further and checked the maximum amount they would be willing to pay. About one-third would be willing to pay $1 to $2 per month. Another one-fifth would be willing to pay $5 per month; one-eighth would be willing to pay over $5 per month.

The response shows great interest in and support for a continuously available weather service. This is interesting since only 42% of the 257 respondents try to get forecasts three or more times per day, and of the 134 making open-ended responses as to why they do not try to get forecasts more often, one-third said the forecasts they got were sufficient, that it was not necessary to have more frequent forecasts. However, another one-third said that it was not convenient to get forecasts more frequently, and about 13% recognized that new information is not usually available more often than four times a day.

Usefulness of Weather Forecasts

All of the 257 respondents find that forecasts are either usually or occasionally helpful, and 69% of them usually try to plan their activities on the basis of the forecasts. Only one-third find the thirty-day forecast helpful compared to 91.5% who find the one-day forecast helpful. With the exception of the forage growers, a larger percent from every group of respondents thought the five-day forecast helpful than thought the two-day was helpful. Over 90% thought a two-week forecast with the accuracy of the present one-day forecasts would be either extremely or very helpful, although occasional comments were made in the margin regarding concern for accuracy.

Usefulness of Specific Weather Information

When the respondents were given forty-seven weather variables which now show up on some weather reports and forecasts, and were asked to check whether the information could make a critical difference, would be useful, or would be of no help in planning their activities, 52.1% checked eleven or more as critical, and 63.4% said that fewer than ten were of no help.

The information considered to be the most critical by the farmers is the time of arrival of frost (64%). The time of arrival of moisture is next with 59.4% marking it critical. About half marked hail, the amount of moisture, and the duration of precipitation as critical, and the lowest temperature was marked as critical information by 48.8%. About 45% thought knowing whether frosts will be early or late is critical to their operation, and one-third were concerned about anticipating the severity of storms.

When it comes to information that is either critical or useful to their operation, 99.2% checked rain, with their main concern being the time of arrival (97.6%), how much (96.8%), the duration (94.8%), and drying conditions (91.6%). Frost information is another prime concern with 98.4% marking the time of arrival as critical or useful. They were also concerned about the duration of the frost (88%), the lowest temperature (91.2%), and whether the frost would be early or late (91.2%). Almost three-fourths wanted to know when the ground would finally freeze. and 58% wanted to know the depth of frost in the ground. Along with this, 94% wanted to know when cold fronts would arrive, 90.4% wanted to know where the cold fronts were, and 86.3% wanted to be told what the effects of these cold fronts would be. There is almost equal concern over warm air masses—where, when they will arrive, and with what effects, and 86% wanted to know the high temperature for the day. Wind information was another vital concern with 92% marking speed, 85.1% marking duration of the wind, and 80.7% marking direction as information critical or useful to their operation. About 90% were also concerned with receiving storm warnings—to know the expected severity of the storm and the direction of its travel.

Among the less usual weather information, about three-fourths thought it critical or useful to know about cloud cover: the amount, duration and direction of its movement. Eighty-six percent of the respondents wanted to know the soil temperature and an equal number thought it critical or useful to know the soil moisture. The latter is difficult or impossible to give since it varies so locally with scattered rainfall, irrigation, type of soil, amount of tillage, and many other factors that can vary from field to field. It may be beneficial to educate farmers in techniques for figuring soil moisture and taking soil temperature.

More than four-fifths of the respondents either did not respond or marked information about the amount and type of pollutants in the air as no help. This can be due to a number of reasons. They may not be aware of pollutants presently in rural air. They may not be aware of the damage certain pollutants can do to some plants, and/or they may not know what farmers can do to limit such damage. Only 15% of the respondents marked that they would be interested in receiving any pollutant information in the future. As technology improves, the farmers will need to be educated both as to what harm various pollutants can cause and what can be done to prevent or limit this damage.

About one-third of the 257 respondents listed additional weather information they would like to receive. The most frequent request or comment made by all groups regarded the accuracy of the forecasts.

When these comments were combined with the voluntary comments written in the margins concerning the lack of accuracy of forecasts or the desire for greater accuracy, it was learned that 22.7% of the respondents showed a special concern for the accuracy of forecasts.

This concern along with the high percentages who considered various weather details either critical or useful to their agricultural operation point to the importance and necessity of accurate weather information for agriculture. (According to Noffsinger (p. 94),[10] weather contributes to three-fourths of the annual farm production loss. From 1942-1951, this loss averaged more than $13 billion per year.)

Farmers recognize the need for and try to make use of the available weather information. They would like to have complete information more readily available in some form of convenient continuous service and would be willing to help pay for such a service depending upon its accuracy. In some areas they need a better understanding either of specific terminology, or of practical applications of the information that is available. A specialized agricultural weather service such as is found in some parts of the country would be of great help to Wisconsin farmers and they would probably be willing to help pay for such service, especially if tangible benefits could be demonstrated.

ACKNOWLEDGMENT

I would like to acknowledge and express my appreciation to the following individuals:

—Professor John Ross for his help and guidance throughout the project.

—Hans Rosendal, State Climatologist, for background information on weather.

—Professor Hazel Shands and Professor Theodore Tibbitts for their special assistance in the fields of Agronomy and Horticulture.

—And to the many others both within and without the University who supplied me with bits and pieces along the way.

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APPENDIX

Weather Information Considered Critical, and Critical and Useful; Percents by Group

Table 23

Importance of Weather Information to Fruit Growers (22)

Weather Information	% Critical	% Critical and Useful
Temperature:		
Current	31.7	90.8
Low for the day	63.6	81.8
High for the day	22.7	77.2
Duration of current range	31.7	86.2
Frost:		
Time of arrival	81.8	100.0
Duration	59.1	95.5
Lowest temperature	81.8	100.0
Early or late	54.5	90.0
When will ground freeze for good	9.1	59.1
Depth of frost in ground	4.5	45.4
Moisture (kind of):		
Rain	54.5	94.5
Sleet	18.2	63.7
Freezing rain	9.1	72.7
Drizzle	18.2	86.4
Freezing drizzle	9.1	63.6
Fog	4.5	59.0
Dew	0.0	54.5
Hail	59.1	90.9
Snow	22.7	95.4
Moisture:		
Time of arrival	59.1	90.9
How much	45.5	91.0
Duration	54.5	86.3
Amount of snow cover	9.1	50.0
Drying conditions	27.3	86.4
Storm warnings:		
Lighting or not	4.5	45.4
Severity	40.9	90.9
Direction traveling	45.4	91.0

(cont. next page)

Table 23 (cont.)

Weather Information	% Critical	% Critical and Useful
Wind:		
Speed	54.4	95.4
Direction	31.8	90.9
Duration	45.5	100.0
Cloud cover:		
Amount	18.2	72.7
Duration	22.7	81.8
Direction moving	9.1	50.0
Warm air masses:		
Where	22.7	81.8
When arrive	22.7	72.7
What effects	13.6	68.1
Cold fronts:		
Where	54.5	81.8
When arrive	59.1	100.0
What effects	36.6	77.5
Relative humidity	27.3	81.8
Barometric pressure	22.7	72.7
Dew point temperature	22.7	72.7
Solar radiation	9.1	31.8
High and low pressure systems	18.2	86.4
Soil moisture	22.7	68.2
Soil temperature	13.6	59.1

Table 24

Importance of Weather Information to 76 Canners

Weather Information	% Critical	% Critical and Useful
Temperature:		
Current	17.3	86.6
Low for the day	46.7	100.0
High for the day	37.3	94.6
Duration of current range	33.3	94.6
Frost:		
Time of arrival	64.5	98.7
Duration	35.5	85.5
Lowest temperature	51.3	92.1
Early or late	43.4	90.8
When will ground freeze for good	9.2	55.3
Depth of frost in ground	2.6	47.3
Moisture (kind of):		
Rain	51.3	94.5
Sleet	10.5	60.5
Freezing rain	10.5	61.8
Drizzle	13.2	80.3
Freezing drizzle	7.9	60.5
Fog	11.8	65.7
Dew	10.5	63.1
Hail	51.3	88.1
Snow	5.3	61.9
Moisture:		
Time of arrival	58.7	100.0
How much	50.7	98.7
Duration	48.3	96.3
Amount of snow cover	0.0	58.7
How long between measurable rains	28.0	89.3
Drying conditions	25.3	90.1
Storm warnings:		
Lightning or not	4.0	56.0
Severity	25.3	89.3
Direction traveling	17.3	86.6

(cont. next page)

Weather Information	% Critical	% Critical and Useful
Wind:		
Speed	9.3	84.0
Direction	4.0	70.7
Duration	4.0	72.0
Cloud cover:		
Amount	6.7	72.0
Duration	8.0	76.0
Direction moving	2.7	62.7
Warm air masses:		
Where	12.0	85.3
When arrive	13.3	88.0
What effects	10.7	81.4
Cold fronts:		
Where	21.3	92.0
When arrive	25.3	92.0
What effects	20.0	86.7
Relative humidity	4.1	74.3
Barometric pressure	2.7	67.6
Dew point temperature	2.7	55.4
Solar radiation	5.4	50.0
High and low pressure systems	6.8	77.0
Soil moisture	29.7	89.2
Soil temperature	35.1	89.2

Table 25

Importance of Weather Information to 25 Vegetable Growers

Weather Information	% Critical	% Critical and Useful
Temperature:		
Current	16.0	84.0
Low for the day	32.0	42.0
High for the day	20.0	92.0
Duration of current range	16.0	96.0
Frost:		
Time of arrival	68.0	100.0
Duration	48.0	84.0
Lowest temperature	56.0	92.0
Early or late	44.0	84.0
When will ground freeze for good	32.0	84.0
Depth of frost in ground	0.0	68.0
Moisture (kind of):		
Rain	40.0	100.0
Sleet	20.0	72.0
Freezing rain	20.0	72.0
Drizzle	16.0	72.0
Freezing drizzle	20.0	72.0
Fog	8.0	64.0
Dew	4.0	60.0
Hail	52.0	80.0
Snow	20.0	88.0
Moisture:		
Time of arrival	52.0	100.0
How much	64.0	96.0
Duration	48.0	92.0
Amount of snow cover	4.0	80.0
How long between measurable rains	28.0	84.0
Drying conditions	36.0	96.0
Storm warnings:		
Lightning or not	12.0	76.0
Severity	28.0	92.0
Direction traveling	16.0	84.0

(cont. next page)

Weather Information	% Critical	% Critical and useful
Wind:		
Speed	48.0	96.0
Direction	28.0	84.0
Duration	32.0	88.0
Cloud cover:		
Amount	16.0	88.0
Duration	12.0	91.0
Direction moving	16.0	72.0
Warm air masses:		
Where	12.0	88.0
When arrive	16.0	92.0
What effects	16.0	88.0
Cold fronts:		
Where	36.0	84.0
When arrive	40.0	96.0
What effects	24.0	80.0
Relative humidity	24.0	72.0
Barometric pressure	8.0	64.0
Dew point temperature	9.0	41.0
Solar radiation	8.0	52.0
High and low pressure systems	4.0	76.0
Soil moisture	24.0	72.0
Soil temperature	16.0	72.0

Table 26

Importance of Weather Information to 20 Potato and Vegetable Growers

Weather Information	% Critical	% Critical and Useful
Temperature:		
Current	10	70
Low for the day	45	90
High for the day	15	90
Duration of current range	20	95
Frost:		
Time of arrival	75	100
Duration	30	100
Lowest temperature	55	95
Early or late	40	95
When will ground freeze for good	45	100
Depth of frost in ground	5	70
Moisture (kind of):		
Rain	60	100
Sleet	20	75
Freezing rain	20	75
Drizzle	25	95
Freezing drizzle	30	70
Fog	00	75
Dew	5	90
Hail	60	95
Snow	5	75
Moisture:		
Time of arrival	70	100
How much	70	100
Duration	70	100
Amount of snow cover	30	100
How long between measurable rains	45	100
Drying conditions	40	95
Storm warnings:		
Lightning or not	10	85
Severity	40	100
Direction traveling	20	90

(cont.)

Weather Information	% Critical	% Critical and Useful
Wind:		
Speed	35	100
Direction	10	90
Duration	25	100
Cloud cover:		
Amount	5	85
Duration	10	85
Direction moving	5	60
Warm air masses:		
Where	10	95
When arrive	15	100
What effects	20	85
Cold fronts:		
Where	40	95
When arrive	60	100
What effects	40	100
Relative humidity	20	95
Barometric pressure	0	70
Dew point temperature	10	80
Solar radiation	5	65
High and low pressure systems	10	75
Soil moisture	35	90
Soil temperature	30	100

Table 27

Importance of Weather Information to 42 Seed Grain Growers

Weather Information	% Critical	% Critical and Useful
Temperature:		
Current	11.6	81.4
Low for the day	37.2	90.7
High for the day	7.0	83.7
Duration of current range	23.3	86.1
Frost:		
Time of arrival	72.1	100.0
Duration	46.5	90.7
Lowest temperature	60.5	93.1
Early or late	48.8	93.0
When will ground freeze for good	21.4	77.2
Depth of frost in ground	9.3	51.2
Moisture (kind of):		
Rain	48.8	100.0
Sleet	18.6	53.5
Freezing rain	20.9	72.1
Drizzle	9.3	72.1
Freezing drizzle	18.6	72.1
Fog	9.3	76.7
Dew	4.7	65.2
Hail	53.5	81.4
Snow	25.6	79.1
Moisture:		
Time of arrival	58.1	93.0
How much	48.8	95.3
Duration	39.5	90.7
Amount of snow cover	4.7	74.5
How long between measurable rains	25.6	83.7
Drying conditions	46.5	93.0
Storm warnings:		
Lightning or not	4.7	72.4
Severity	44.2	88.4
Direction traveling	28.6	82.1

(cont.)

Table 27 (cont.)

Weather Information	% Critical	% Critical and Useful
Wind:		
Speed	30.4	95.5
Direction	9.3	81.4
Duration	7.0	80.7
Cloud cover:		
Amount	7.0	72.1
Duration	11.6	79.0
Direction moving	4.0	55.2
Warm air masses:		
Where	0.0	83.7
When arrive	4.7	81.1
What effects	7.0	74.4
Cold fronts:		
Where	30.2	90.7
When arrive	37.2	88.4
What effects	20.9	83.7
Relative humidity	11.6	79.0
Barometric pressure	2.4	66.7
Dew point temperature	0.0	66.7
Solar radiation	0.0	31.0
High and low pressure systems	4.8	81.0
Soil moisture	16.7	85.7
Soil temperature	21.4	95.2

Table 28

Importance of Weather Information to 32 Forage Growers

Weather Information	% Critical	% Critical and Useful
Temperature:		
Current	6.3	84.4
Low for the day	25.0	93.5
High for the day	9.4	91.0
Duration of current range	6.3	93.8
Frost:		
Time of arrival	56.3	96.9
Duration	9.4	40.7
Lowest temperature	25.0	84.4
Early or late	46.9	100.0
When will ground freeze for good	25.0	81.3
Depth of frost in ground	6.4	65.8
Moisture (kind of):		
Rain	56.3	96.9
Sleet	21.9	78.2
Freezing rain	21.9	84.4
Drizzle	15.4	84.2
Freezing drizzle	21.9	81.3
Fog	9.4	78.2
Dew	0.0	71.9
Hail	40.6	75.0
Snow	18.8	87.6
Moisture:		
Time of arrival	62.5	100.0
How much	34.4	100.0
Duration	37.5	100.0
Amount of snow cover	3.1	84.4
How long between measurable rains	40.6	97.2
Drying conditions	62.5	93.8
Storm warnings:		
Lightning or not	9.4	68.8
Severity	43.8	93.9
Direction traveling	25.0	93.1

(cont.)

Table 28 (cont.)

Weather Information	% Critical	% Critical and Useful
Wind:		
Speed	40.6	93.7
Direction	15.6	84.4
Duration	15.6	90.6
Cloud cover:		
Amount	15.4	90.4
Duration	18.8	96.9
Direction moving	5.4	77.3
Warm air masses:		
Where	15.4	93.5
When arrive	12.3	100.0
What effects	12.3	96.7
Cold fronts:		
Where	21.9	87.5
When arrive	21.9	96.9
What effects	12.3	87.3
Relative humidity	18.8	93.8
Barometric pressure	3.1	78.1
Dew point temperature	0.0	56.3
Solar radiation	6.3	59.4
High and low pressure systems	12.5	87.5
Soil moisture	31.3	90.6
Soil temperature	21.9	93.8

Table 29

Importance of Weather Information to 32 Lime-Fertilizer Dealers

Weather Information	% Critical	% Critical and Useful
Temperature:		
Current	9.4	81.3
Low for the day	12.5	74.5
High for the day	0.0	65.5
Duration of current range	18.8	85.4
Frost:		
Time of arrival	37.5	93.8
Duration	21.9	56.6
Lowest temperature	18.9	74.5
Early or late	35.5	85.5
When will ground freeze for good	37.5	81.3
Depth of frost in ground	9.4	66.0
Moisture (kind of):		
Rain	56.6	100.0
Sleet	25.0	75.0
Freezing rain	31.3	81.3
Drizzle	15.6	78.1
Freezing drizzle	25.0	75.0
Fog	9.4	71.9
Dew	3.1	34.4
Hail	35.0	88.0
Snow	28.1	87.1
Moisture:		
Time of arrival	59.4	96.4
How much	40.6	93.7
Duration	50.0	98.8
Amount of snow cover	9.4	71.9
How long between measurable rains	15.6	90.6
Drying conditions	15.6	90.6
Storm warnings:		
Lightning or not	6.3	56.3
Severity	25.0	93.8
Direction traveling	21.9	87.5

(cont.)

Weather Information	% Critical	% Critical and Useful
Wind:		
Speed	21.9	93.8
Direction	0.0	84.4
Duration	12.5	81.3
Cloud cover:		
Amount	3.1	53.1
Duration	0.0	56.3
Direction moving	0.0	37.5
Warm air masses:		
Where	3.1	87.5
When arrive	3.1	84.4
What effects	3.1	84.4
Cold fronts:		
Where	15.6	93.7
When arrive	18.4	75.0
What effects	15.6	90.6
Relative humidity	6.5	83.9
Barometric pressure	3.2	64.5
Dew point temperature	0.0	38.7
Solar radiation	3.2	29.0
High and low pressure systems	3.2	71.0
Soil moisture	38.7	87.1
Soil temperature	32.3	83.9

Importance of Weather Variables to Vegetable, Fruit and Seed Grain Growers—According to Tibbitts and Shands

Table 30

Importance of Weather Variables to Vegetable, Fruit and Seed Grain Growers—According to Tibbitts and Shands

Weather Information	Vegetable	Fruit	Seed[1]
Temperature:			
Current	critical	useful	useful
Low for the day	critical	critical	useful
High for the day	critical	useful	useful
Duration of current range	critical	critical	-
Frost:			
Time of arrival	critical	critical	critical
Duration	critical	critical	useful
Lowest temperature	critical	critical	critical[2]
Early or late	critical	critical	critical[2]
When will ground freeze for good	no help	no help	critical
Depth of frost in ground	no help	no help[3]	useful or no help
Moisture (kind of):			
Rain	critical	useful	critical
Sleet	no help	useful	no help
Freezing rain	no help	no help[3]	no help
Drizzle	critical	useful	useful
Freezing drizzle	no help	no help	no help
Fog	useful	useful	useful
Dew	useful	useful	useful
Hail	useful	useful	useful
Snow	no help	no help[3]	critical
Moisture:			
Time of arrival	critical	useful	useful
How much	critical	useful	useful
Duration	critical	useful	useful
Amount of snow cover	no help	no help	critical[4]
How long between measurable rains	critical	useful	critical[5]
Drying conditions	useful	useful	critical[6]
Storm warnings:			
Lightning or not	no help	no help	no help
Severity	useful	useful	critical
Direction traveling	critical	no help	no help

(cont.)

Weather Information	Vegetable	Fruit	Seed
Wind:			
Speed	critical	useful	useful
Direction	useful	useful	useful
Duration	critical	useful	useful
Cloud cover:			
Amount	critical	useful	useful
Duration	critical	useful	useful
Direction moving	useful	useful	no help
Warm air masses:			
Where	useful	useful	useful
When arrive	critical	useful	critical
What effects	?	?	critical
Cold fronts:			
Where	useful	useful	useful
When arrive	critical	useful	useful
What effects	?	?	critical
Relative humidity	critical	useful	critical[7]
Barometric pressure	useful	useful	no help
Dew point temperature	critical	useful	no help
Solar radiation	useful	useful	critical[8]
High and low pressure systems	useful	useful	useful
Soil moisture	no help	no help	useful
Soil temperature	useful	useful	useful

1. Professor Tibbits marked the importance for vegetable and fruit growers and Professor Shands marked the importance for seed grain growers.
2. For corn
3. Useful for strawberries
4. For winter grains
5. At spring grain planting time
6. At harvest
7. Small grains at harvest
8. Weed spray time

Specific Additional Weather Information Requested, Listed by

Group with Individual Test Scores

GROUP A. Certified Seed Grain Growers

An accurate one-week forecast would be invaluable. Wind is especially important during the spraying season—the month of June. Would like three- and five-day forecasts. Do most radio listening on WTMJ and WHBL because the best reception—not much agricultural type forecast. What station would you suggest? (81 1/4 - 100)*

Long-range frost or severe freeze forecast. The most valuable information to us would be a long advance notice of and duration of severe freeze. (87 1/2 - 40)

I would like to know the number of heat units each day in the spring through to the fall. (62 1/2 - 76)

Six-day forecast. (43 3/4 - 52)

We receive all the information we need but it isn't very accurate. (93 3/4 - 100)

More accurate long-range forecast. (81 1/4 - 88)

It would be interesting and helpful at times if weather forecasts for Canada were included—that part of Canada directly north of Wisconsin, Minnesota and Michigan. When visiting in Canada, we hear weather forecasts for the States. (87 1/2 - 88)

More accurate temperature in fall as to frost. Degrees humidity. Heat units per day—and total to date. (81 1/4 - 64)

Frost information. (50 - 76)

Nine out of forty-seven answered—19.1%.

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*First score is knowledge of weather terms and second is knowledge of weather intensities.

GROUP B. Vegetable Growers

Any improvement in 30-60 day forecasts from the standpoint of accuracy would be most beneficial to us. (87 1/2 - 76)*

Monthly weather probability to plan agricultural work. (90 - 52)

Frost warnings and wind velocity—are available but seldom accurate. (100 - 76)

I want accurate information, not longer range. (93 1/2 - 100)

Need a more accurate wind forecast. May-June 15 wind velocity is critical. 20 mph is OK but 35 mph if after two dry days can cause a crop failure. Most forecasts are 10-20 mph, 20-35 mph, etc. (93 3/4 - 100)

Percent area to receive precipitation in place of or in addition to percent chance. (93 3/4 - 100)

Present availability okay—need more accuracy. (81 1/4 - 88)

Anything would be better than the weather reports this summer (1969). It's done just the opposite all summer. (62 1/2 - 100)

They read the same forecast over and over even though it says 30% chance and it's raining. (81 1/2 - 76)

Present daily weather as related to normal as well as record high and lows. Also to use a moving average for past year's moisture instead of average for year to date. Early in the year the information for the year since 1 January does not give any information as to soil moisture, etc. (93 3/4 - 100)

I am principally concerned with percent chance of precipitation, but it would be helpful if forecasts included anticipated quantities of rain. (93 3/4 - 100)

Would like accurate five-day forecast. Would be very valuable and would be willing to pay up to several hundred (approximately $300) yearly for it if it was accurate. Need to know amount of rainfall expected within reasonable levels—also weekly reports of total precipitation. (81 1/4 - 58)

In spring would like to hear wind forecast more often. (31 1/4 - 64)

Thirteen out of twenty-seven answered—48.1%.

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*First score is knowledge of technical weather terms and second is knowledge of weather intensities.

GROUP C. Fruit Growers

Relay system by growing areas, very helpful. Cranberry growers should receive "30-day Forecast Maps" as shown in the Milwaukee Journal. (50 - 46)*

Have very good television picture on three stations plus radio. The "Today" show in weekday mornings has the best and most accurate weather forecast—plus evenings—3, 6, and 10 very good. (14 1/2 - 8)

A five-day forecast on telephone—could be available on a different weather telephone number as the other one is in Milwaukee that is recorded and changed every hour. It would be interesting and sometimes helpful to have soil temperature. Temperature at ground level at the same location official temperatures are taken. (93 3/4 - 88)

Frost warning service. (81 1/4 - 100)

A forecast pertaining to fireblight in apples—check with Prof. George Klingfeil on this for data. (93 3/4 - 100)

Since 1915: Field digging in March twice—two separate years.
Field digging began April 1-22 remaining fifty-two years.
This fact is very important to our business (orchard and nursery). (56 1/4 - 34)

Forecasts of dew point, wind velocity daytime and night, humidity. (93 3/4 - 100)

Wind direction and velocity. (81 1/4 - 70)

Predicted low temperature several days ahead. (93 3/4 - 88)

Thirty- to sixty-day accurate forecasts of extreme weather—such as excessive rainfall or unusually dry conditions for the period April through October. A means of determining when a forecast is radically revised—as when rain is predicted in twenty-four hours and it arrives in six hours. Lack of accurate reports limits use. (96 3/4 - 100)

Sixty- and ninety-day weather forecast. (68 3/4 - 70)

More accurate—my own barometer is better than many past forecasts. (68 3/4 - 76)

Dew point. (93 3/4 - 88)

Record temperatures for given data. (93 3/4 - 76)

More detail to the frost and freeze warnings in the spring. Also the wind speeds for daytime and nighttime hours to help us pick the best hours to spray. (93 3/4 - 100).

Fifteen out of twenty-two answered—68.2%

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*First score is knowledge of technical weather terms and second is knowledge of weather intensities.

GROUP D. Canners

Weather report year ago today. (62 1/2 - 12)

Anticipated rainfall. (12 1/2 - unanswered)

Road information for deliveries and receiving. (68 3/4 - 70)

Time of night which dew is expected and intensity. This could be forecast in a twenty-four-hour, forty-eight-hour, and five-day forecast. Accurate long-range forecasts. (81 1/4 - 88)

Accurate forecast of rain during summer. (93 3/4 - 88)

Same as now only for longer period of time and more accuracy. (81 1/4 - 75)

We are mainly interested in weather for our business from April 1 - December 1. (87 1/4 - 58)

Low temperatures for other fruit-growing areas spring and winter. (87 1/4 - 76)

Accuracy. (81 1/4 - 88).

Wind speeds for next day. (87 1/2 - 76)

Continuously available forecasting system. (56 1/4 - 76)

Solar radiation. (87 1/2 - 100)

Some sort of written report for longer (two-week) forecasts—too long to handle verbally. More accurate intermediate range (to thirty days) forecasting of high, low, and mean temperature and precipitation by days. (93 3/4 - 100)

High and low temperature previous day. High and low temperature forecast at least two days in advance. Monthly publication giving daily temperatures and rainfall for the month. (100 - 94).

Soil temperature. (93 3/4 - 100)

Length of daylight hours. (81 1/4 - 88)

Five-day forecast over TV in evening. (62 1/2 - 100)

More accuracy for this area (Sister Bay). (81 1/4 - 100)

More accurate information. (68 3/4 - 100)

Telephone service daily. (62 1/2 - 76)

The accuracy of the report is most important. We receive several reports of weather but not accurate in many cases. (75 - 76)

Mainly interested in temperature and precipitation forecasts. (93 3/4 - 88)

The type of information is O. K., but the accuracy of weather forecasts leaves a bit to be desired. Would be very interested in six-week forecasts on total rainfall—date of possible freezing temperatures. (87 1/2 - 76)

Forecasts for our particular area of operation. Measurement of solar intensity and duration. (81 1/4 - 100)

Hours sunlight expected—actual sunshine as against cloudy condition—as percent total daylight. (87 1/2 - 100)

A weather reporting service over TWX or Western Union similar to the system available to the Florida citrus growers would be very helpful to the Wisconsin canners.

Twenty-seven out of seventy-six answered—35.5%.

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*First score is knowledge of technical weather terms and second is knowledge of weather intensities.

GROUP E. Potato and Vegetable Growers

Two-week forecasts—reasonably accurate.
Development of hail storms.
Accurate frost warnings—one-day and two-week. (87 1/2 - 88)*

Upper air flows.
Daily deviations from norms. (93 3/4 - 100)

Accuracy. Our main concern is having information about the conditions that are favorable for blight during the potato growing season. (68 3/4 - 88)

Accurate local weather conditions.
Precipitation and temperature are very important in raising potatoes. (62 1/2 - 76)

Five-day and thirty-day too inaccurate. (93 3/4 - unanswered)

Always need relative humidity—not always given. (75 - 100)

Present forecasts are adequate enought; but not accurate enough. (93 3/4 - 100)

If it were possible to forecast, months in advance, the amount of sunlight that might be expected during the growing season, I am sure that this could be useful to many people. The amount expected might be compared to a normal or average year. A person might plant an earlier or later maturing variety of a crop if he knew how much sunlight (without clouds) might be expected during the coming growing season. Summer rains in our area can be very spotty. Knowing exactly where the rains are going to fall and how much could be a tremendous help to agriculture, in planting, growing, harvesting, etc. (87 1/2 - 100)

Eight out of twenty-one answered—38.1%.

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*First score is knowledge of technical weather terms and second is knowledge of weather intensities.

GROUP F. Lime and Fertilizer Dealers

Often enough on radio and TV if accurate. (93 3/4 - 82)*

Twenty-four-hour wind velocity forecast. (81 1/4 - 88)

Specific <u>local</u> information (fifteen-mile radius) as to time and amount of rain during crop season to use in planning custom fertilizing and spraying operations. (87 1/2 - 100)

Wind, more accurate low temperature. We have our own auto-temperature continuously. We feel Wisconsin forecasts are right 56% of the time. We allow 9° for temperature error. (93 3/4 - 100)

Comparison to previous year and year before that; not ten-year average or fifty-year averages. (87 1/2 - 100)

Five out of thirty-three answered—15.2%.

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*First score is knowledge of technical weather terms and second is knowledge of weather intensities.

GROUP G. Forage Growers

Accurate two-week forecasts—even accurate one-week forecasts would be helpful. (68 3/4 - 100)*

Our weather forecasts are not accurate enough. (81 1/4 - 88)

More accurate five-day or longer forecasts. (100 - 88)

Would like to get weather report for more specific area, especially at harvesting time. (56 1/2 - 88)

Accurate in regard to rainfall over two-day to three-day period. If there are any basic cycle changes in weather patterns in regard to moisture and temperature. (93 3/4 - 88)

Longer range forecast plus weather patterns. (68 3/4 - 64)

Weekend weather Friday night. (62 1/2 - 76)

More detail into the causes of various weather patterns. (100 - 88)

Monthly temperature (daily highs and lows) graphs and rainfall charts to show past month's weather. (87 1/2 - 100)

Telephone weather service. (62 1/2 - 88)

More localized information—whether the "scattered showers" will scatter on my farm. (93 3/4 - 100)

Eleven out of thirty-one answered—35.5%.

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*First score is knowledge of technical weather terms and second is knowledge of weather intensities.

THE ECONOMIC IMPACT OF LONGER-RANGE WEATHER INFORMATION ON THE PRODUCTION OF PEAS IN WISCONSIN

Kenneth R. Smith*
Allan W. Torkelson*

Introduction

In considering whether or not improved weather forecasts would yield benefits in the production of peas, a number of factors stand out. Most obvious is the fact that the pea crop in Wisconsin is of considerable commercial importance, ranking among the top four vegetables grown in the state for commercial processing. In 1970, for example, more than 140,000 acres were planted to peas, with the total value of the harvested crop exceeding $15 million. This total amounts to about one-third of the value of the pea crop for the entire country, and thus reflects the extent to which both farmers and processors are committed to pea production. In addition to its commercial importance, the pea crop is notable because its success or failure is often dependent upon the weather conditions during certain critical periods. Thus, as with sweet corn, a crop whose problems are remarkably similar to the problems encountered in the production of peas, it

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seems reasonable to expect that improved weather forecasts might be utilized in order to prevent or reduce weather-connected losses. Lastly, pea production would seem to be a subject worthy of note because of the existence of a relative abundance of information about past production levels and past losses, which might be related to weather conditions. This last assumption arises out of the fact that peas are a commercial crop, grown almost entirely for the purpose of being processed and marketed, and that one can expect the processing companies to maintain production records which are reasonably accurate and which can serve as the basis for an empirical study. Given, then, that the pea crop is commercially significant, that weather-related losses may be prevented by improved weather forecasts, and that relatively accurate records of pea production and pea losses probably exist, the purpose of this paper shall be to determine the extent of the benefits which would be realized in the pea industry as a result of improved weather forecasts.

Before proceeding to the actual analysis it is necessary to specify the assumptions which form the basis of this study. Actually, one could approach the problem in two different ways, both of which have been considered previously in a similar paper on sweet corn, and which will be discussed only briefly here. According to the first approach, one would assume that weather forecasts could continue to be accurate for as long a period as they are at the present time (i. e. about one day), but that the communication of this weather information would be greatly improved. In view of the fact that the technology which could be used to improve the communication of weather information already exists, and that the present system for the distribution of weather information is not always adequate, this approach would seem to form a reasonable basis for an evaluation of the impact that improved forecasts would have on peas. As in the sweet corn paper, however, the information to be gained from such an evaluation would probably be of limited value, for the pea operations which are most flexible (e. g. fertilizer and insecticide application) and which thus stand to gain the most from improved weather communications represent only a small part of the total costs of production whereas those operations which require planning over an extended period of time (planting and harvesting) and which do not stand to benefit greatly from improved communications account for a large part of the losses which are normally incurred in the production of peas. On the whole, therefore, a study of the benefits which improved weather communications would bring to the pea industry would probably show no significant deviations from current levels of production. A study based on a different approach, however, one which assumes that weather forecasts will be improved so that they will be accurate from seven to fourteen days, could be expected to yield more substantial results. Although forecasts of this nature do not exist at the present time, it is conceivable that they will be available in the near future, especially in view of recent advances in satellite meteorology. Moreover, it appears likely that if benefits are to be found, they will come about as the result of longer-range, more accurate planning of the planting and harvesting operations, the type of planning, in short, which the information from seven- to fourteen-day forecasts would make possible. For practical reasons, then, a study of the impact of longer-range, seven- to fourteen-day forecasts on the production of peas would probably yield more worthwhile results, and so it is toward the effects of the longer-range forecasts that this report will be directed.

The Framework of the Analysis

Pea and sweet corn growers, who must shape their production to processors' requirements, encounter problems which are remarkably similar. It will be recalled from the earlier paper on sweet corn that the effects of longer-range weather information on the production of sweet corn were examined on the basis of three periods (planting, mid-summer growing, and harvesting), which were selected because they were critical times during which the sweet corn was vulnerable to adverse weather conditions and during which improved weather forecasts could be used to decrease losses. Pea production is not faced with an identical situation, since peas are grown during the spring and the early part of the summer and thus do not have to contend with the shortages of moisture which often characterize the growth period of the sweet corn crop. But in the sense that the planting and harvesting operations are critical to the success of both peas and sweet corn, the two crops exhibit similar characteristics. In accordance with these similarities, then, pea production will be approached on the basis of the two critical periods—the planting period and the harvesting period—

in order to determine the effects that longer-range weather information may have.

Beginning early in April, the planting operation for peas is usually carried out with two constraints in mind. First of all, the peas must be planted early enough in the spring so that their growth and maturation are not interfered with by hot, dry summer weather. This is because peas grow best in cool, moist conditions, and a satisfactory yield (1-1.5 tons/acre) cannot be attained if these conditions are not met. The second and probably most important constraint on the planting operation comes about as a result of the limitations of the processing operations. Because of this constraint, the entire pea crop cannot be planted at the same time in the spring. Rather, the dates of planting for different fields must be staggered so that the pea crop matures over an extended period of time, and the processing factories will receive a steady, uninterrupted supply of peas. The implication which these constraints have for the planting operation is significant. Above all, it means that the planting of peas cannot be a simple, flexible operation, conducted on a short-term basis. If the only consideration during the planting period were the maximization of the ultimate yield, it might be possible to finish all of the planting in the first few weeks of April, thus reducing the complications associated with advance planning to a minimum. Unfortunately, this cannot be done, for it would result in the entire pea crop maturing at about the same time, thereby making the harvesting operation difficult and placing the processing companies in an impossible situation. The alternative, then, is to try to balance the factors involved, to map out the planting in advance in order to achieve as high a yield as possible and at the same time to assure the processors of the steady flow of peas which will allow them to operate at maximum efficiency. In terms of actual procedures, this means either that planting schedules must be staggered correctly—an operation which requires a considerable amount of pre-planting preparation—or that different varieties of peas, each of which matures at a different rate, must be used. This latter procedure, incidentally, requires no less advance preparation than the first, owing to the fact that pea seeds are shipped from the far western states and must be ordered well in advance of the expected planting date. On the whole, therefore, it cannot be avoided that the planting of peas is not (just as the planting of sweet corn is not) a haphazard operation, but rather is a long-term project, which requires careful planning in advance of the actual operation.

In view of the long-range, planned nature of the planting operation, it is reasonable to predict that longer-range weather forecasts would function to make the planting aspect of pea production easier and more accurate. Instead of interrupting planting schedules and causing the loss of time and effort, poor weather conditions could be foreseen and measures taken to work around them. Processing companies often possess their own planting equipment, for example, and given adequate advance notice this equipment could be moved into or out of an area in order to speed up or slow down the planting operation, all of this depending upon the weather conditions which are expected in the near future. What is lacking at the present time is the accurate, long-term knowledge which would be needed in order to allocate these machines effectively in response to weather conditions. Presumably, a seven-to-fourteen-day forecast would serve to fill this gap and thus make the planting operation more flexible.

The second area which will be used in the evaluation of pea production is the harvesting operation. Lasting from June through August, the harvest is a critical time in the production of peas, during which the pea crop is especially vulnerable to damage as a result of adverse weather conditions. This vulnerability at harvest time does not reflect any inherent weakness on the part of the pea crop. Rather, it is a reflection of processing requirements, which dictate that the peas must be of a certain quality and which thus severely restrict the time during which the peas can be harvested successfully. Peas which are grown for the purpose of being processed, for example, are generally harvested in a green succulent stage, at which time they have a relatively high water and sugar content and are capable of giving relatively high yields. Peas which are harvested in an earlier, less mature stage are usually high quality, but they yield poorly. Conversely, peas which are not harvested until they are too mature may yield well, but they are usually of too poor a quality to be of any commercial value. On the whole, then, the range of maturity which is acceptable for processing is fairly narrow, and the rate at which the peas progress through this period is extremely rapid. If the weather conditions are not extreme, there is usually a twenty-four-hour period during which the peas can be harvested successfully and after which their quality declines significantly. In the event of extreme weather conditions, however, the period during which the harvest can occur can be altered drastically. If the weather should become cool and the ground moist, for instance, the peas will mature at a slower rate and harvest may take place over a two-to four-day period. On the other hand, the occurrence of hot, dry weather during the harvest period will cause the peas to mature at a much faster rate and will thus decrease the period in which the harvest can take place to as little as twelve hours. At the present time, this latter situation is potentially dangerous, since it can catch the farmer unprepared and force him to pass over parts of the crop which mature before they can be harvested. Heavy rains during the harvesting period can also contribute to losses because of overmaturity. Although the rain will tend to slow down the rate at which the peas mature, it can also make the fields impassable to heavy harvesting equipment (tractors weigh 10,000 lbs., mobile viners weigh 18,000 lbs.) and thereby slow down the harvest enough so that some of the crop is lost because of overmaturity. The problem at harvest time, therefore, grows out of the fact that the harvest period itself is so short that farmers and processers are unable to adapt to rapid, unexpected changes in the weather.

The manner in which longer-range weather forecasts would affect the pea harvest would be essentially identical to the manner in which such forecasts would affect the planting of the peas. More precisely, the seven-to-fourteen-day forecasts would provide the farmers and processors with both the time and the information which would be needed in order effectively to counteract the effects of adverse weather at harvest time. In terms of the actual harvesting operation, for example, longer-range forecasts of poor weather conditions would provide enough time to allow for the allocation of the men and machinery, which in turn would make it possible to speed up the harvest so that it could be completed before any part of the crop could become overmature. Likewise, the longer-range forecasts would allow the processors to arrange for the extra processing facilities which would be needed to handle the increased harvest loads. Once again, in short, the situation is such that the resources which would be needed to decrease weather-related losses in the pea industry are available, and that what is lacking is the type of information which would be supplied by a longer-range weather forecast.

Empirical Findings

Having determined that improved weather information could probably be used in order to decrease losses during the planting and harvesting periods, it now becomes necessary to determine the extent of these savings. In the case of the planting period, the initial indications are that only a relatively small number of losses occur at this time and that the amount of savings which would be realized as a result of improved weather forecasts would not be significant. According to processing company records which have been received so far, the abandonment of pea acreage commonly occurs in the later stages of the growing period and not early in the year during the planting operation. In fact, the losses and inconveniences which do occur during the planting period are apparently of such insignificant extent that they are usually not even cited explicitly in annual production records. This is to be expected perhaps, since losses during the planting period would not be expected to manifest themselves in a large, easily recorded manner (such as the abandonment of the crop), but rather would take less spectacular forms, such as the destruction of seed or the loss of time because of unexpected, weather-connected delays.

In contrast to the insignificance of the losses at planting time, the losses which occur as a result of adverse weather during the harvest period often take place in large numbers. One would expect this on theoretical grounds, since the difficulties which are experienced during the harvest are usually manifested by the abandonment and thus the obvious loss of at least part of the crop, and to some extent this expectation is borne out by the available data. At the present time, however, the importance of the losses occurring at or around the pea harvest in relation to the total number of losses in an entire growing season is not entirely clear. In the experience of one company, for example, the abandonment of pea acreage before the harvest because of water damage, weed growth, frost, or hail constitutes a more serious loss (as much as 30% in some locations, and in some years) than does the abandonment of acreage at harvest time, which rarely exceeds 1%-2% of the total crop. The records of another processing company, on the other hand, indicate that pea acreage is very seldom abandoned before harvest, that instead the majority of their abandonments occur during the harvest period. Furthermore, of the abandonments which occur at harvest time, by far the largest amount is usually attributable to overmaturity, although in a given year other reasons for abandonment may predominate. This last point is important, because it indicates that preventable losses (i.e. losses due to overmaturity) do on occasion constitute a large portion of the total losses, and that the potential for savings as a result of better weather information may thus also exist on occasion. Since the losses because of nonharvested acreage have been relatively high in the last few years (5%-10% of the planted acreage worth $1 million-$2 million has not been harvested), this could then mean that the savings resulting from longer range weather forecasts would assume significant proportions. On the whole, however, because of the uncertainty surrounding the importance of overmaturity as a cause of abandonment, it is difficult to make a general statement about the level of savings which a seven-to-fourteen-day forecast would bring about. The most that can be said is that significant savings (i.e. 5%-10% of the planted crop) may be forthcoming, given the condition that overmaturity proves to be a primary factor in the abandonment of peas.

Table 1

Wisconsin Pea Abandonments (1951-1970)

Year	Acres Abandoned or Passed-Over (total and % of planted acres)	Yield (tons/acre)	Number of tons abandoned	Value of Nonharvested Acreage		
				per ton	per acre	total
1970	7,900 (6.2%)	1.61	9,164	110.00	127.60	1,008,040
1969	12,900 (10.1%)	1.18	15,222	104.00	132.72	1,583,088
1968	10,100 (7.2%)	1.20	12,120	100.00	121.21	1,212,000
1967	7,800 (5.8%)	2.48	19,344	106.00	262.88	2,050,464
1966	13,200 (9.6%)	2.06	27,192	100.00	206.00	2,719,200
1965	6,700 (5.1%)	2.54	17,018	95.60	242.82	1,626,920
1964	3,500 (2.8%)	2.17	7,595	93.70	203.33	711,651
1963	3,600 (3.2%)	2.14	7,704	82.60	176.76	636,350
1962	2,100 (1.8%)	2.45	5,145	81.40	199.43	416,745
1961	1,700 (0.7%)	2.52	3,984	77.00	194.04	306,768
1960	3,500 (4.3%)	2.70	9,450	74.40	200.74	699,300
1951-59	5,600 (4.5%)	2.23	12,488	84.60	188.66	1,071,480

Source: "Annual Summary of Vegetables-Processing," U.S.D.A. Reporting Service—Crop Reporting Board, Washington, D.C., 1961, 1963, 1965, 1967, 1970.

Table 2

Causes of Pea Abandonments at Harvest

Year	Acres By-passed Overmature	Acres By-passed Rain, mud, weeds, etc.
1970	10.0	196.5
1969	358.9	210.2
1968	1061.2	217.6
1967	515.3	181.8
1966	507.0	0
1965	98.3	0
1964	255.7	0
1963	357.4	21.6
1962	36.8	45.0
1961	152.0	0
1960	0	0
1959	4.1	0
1958	0	112.9
1957	153.0	0
1956	0	0
1955	301.0	0
1954	106.5	2.7

Source: Correspondence of May 24, 1971 with Paul E. Schulz, Associate Director of Agricultural Research, Libby, McNeill and Libby.

Table 3

Costs and Returns Per Acre of Peas

I. Receipts*	
1. Gross Returns Per Acre	$150.00
2. Net Returns Per Acre	30.39
II. Variable Costs	
1. Fertilizer and Lime Cost	11.27
2. Seed	25.00
3. Insecticide and Herbicide	4.00
4. Machine Operation	25.70
5. Interest (6 months at 8%)	2.64
6. Total Variable Costs	68.61
III. Fixed Costs	
1. Machinery and Equipment	5.00
2. Land—annual charge at 8%**	40.00
3. Labor—3 hrs/acre at $2/hr.	6.00
4. Total Fixed Costs	$ 51.00

*Based on a yield of 1.5 tons/acre and a harvest-time price of $100.00 per ton.

**Land charges allow 6% for interest and 2% for taxes and repairs.

Source: "Costs and Returns per Acre of Peas," Wisconsin Farm Enterprise Budgets: Field and Forage Crops (Department of Agricultural Economics, University of Wisconsin, June 1969), p. 13.

A REVIEW OF MULTIDISCIPLINARY CASE STUDIES ON THE IMPACT OF METEOROLOGICAL SATELLITES

D. W. Martin
C. B. Tanner

The introduction to the case studies presented in the interim report on Multidisciplinary Studies outlines the approach used to assess the impact of improved forecast capability due to meteorological satellites. A key step is the identification of relationships between meteorological parameters and weather sensitive factors. Case study investigators suggested such relationships, but because their expertise lay outside of meteorology, there is need for a review of each case study from a meteorological perspective, both to verify the relationships between meteorological parameters and weather sensitive factors, and to refine the definition of controlling meteorological parameters. It is a second purpose of this review to gauge, on the basis of the completed case studies and a limited number of additional interviews, the impact of improved weather forecasts and of increased use of current weather information nowcast.*

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*A nowcast in this paper covers the period out to half a day: a short-range forecast covers the period from one to two days; and a long-range forecast covers the period from five days to two weeks.

Case studies finding real benefits from better forecasts are summarized in a series of tables. Information in the tables includes general areas within the process or operation being studied, weather-sensitive factors within the general areas, meteorological parameters which control individual factors and their time scale as indicated in the study, and meteorological parameters which the meteorologist judges to be controlling. Page numbers reference each factor to its discussion in the Interim (Volumes I and II; June 1971). Meteorological variables and the extent to which they can be inferred by means of present satellite sensors are summarized in two concluding tables.

Water Resources

The case study on water resources management (Willeke) covers the general areas of power generation, flood damage reduction, water quality management, municipal and industrial water supply, irrigation, and navigation (Table 1). Except for flood damage reduction, sewer flow diversion, the effects of storms on navigation, and possibly loads on power generation caused by certain extreme conditions, the important time scale for forecasts is middle and long range. The experience of one of the present authors (Tanner) suggests that irrigation demand is independent of short-term forecasts—unless an operator is certain that a forecast of rain is accurate—irrigation will proceed according to schedule. By and large, the parameters indicated by Willeke do control the listed weather sensitive factors. The most important is precipitation—as rainfall rate, duration, and extent—and as snowpack equivalent water depth and extent. Air temperature is important to

Table 1. Water Resources Management—Willeke

Area		Weather sensitive factor		Page	Controlling parameter and time scale (study)	Controlling parameter (actual)
1.	Power generation	Water availability		235, 243 Vol. I	precipitation	precipitation—evapotranspiration (assuming storage is zero): temp., humidity, wind speed, insolation
2.				235, 243	snow pack	equivalent water depth
3.				235, 243	soil moisture content	soil moisture: insolation, humidity, wind speed, temp.
4.				240 242	long range 10-14 days	
5.		load	heating & cooling	235, 236, 243	temperature	temperature
6.			heating	235, 237, 243	wind velocity and direction	chill factor—wind speed and temperature
7.			lighting	235, 243	cloudiness	cloudiness
8.			pumping for watering and irrigation	235, 243	precipitation	rain
9.		maintenance—need for low loads (see 5-8)				
10.	Flood damage reduction	flooding		250	precipitation space-time intensity, 12-24 hr (small areas), p. 250 long range, pp. 245, 246	rain: rate, duration, areal extent; soil moisture: insolation, humidity, wind speed, temp.
11.						snow pack (equiv. water depth); temperature, humidity, wind speed
12.						
13.						
14.	Water quality management	streamflows—assimilative capacity		251		See (10), (11)
15.		excessive sewer flows		252		See (10), (11)
16.		inventory of waste treatment plants		252	temperature, long range	temperature
17.		sewer flow diversion		252	forecasts of precipitation, 12-24 hr.	rain: rate, duration, areal extent
18.						
19.	Municipal & industrial water supply	run of river withdrawal—streamflow		253		See (10), (11)
20.						
21.						
22.	Irrigation	supply of water		256, 261	quantitative precipitation	See (1), (2)
23.				256, 261	temperature—snow melt	temperature; humidity, wind speed
24.				256, 261	snow amount: areal extent, depth, water equivalent	snowpack (equivalent water depth)
25.						
26.		demand		155, 261	radiation, precipitation	rain: evapotranspiration; See (1)
27.						
28.						
29.	Navigation	depth of water		257, 258, 259	precipitation, several days esp. heavy rains; also temperatures	See (10), (11)
30.		ice		258, 259	temperature, several days	temperature; humidity, wind speed
31.		storms		258, 259	"storms"	wind: speed & direction
32.		waves and steering		259	wind	wind speed: low level instability, wind direction

timing and rate of release of snowpack moisture, the occurrence of heavy loads on power generation capacity, and the length of the ice-free navigation season. Of lesser importance are wind speed, cloudiness, and relative humidity.

Recreation

Gilligan and Gow have analyzed two vastly different recreational activities—skiing and boating—by means of questionnaires directed at operators of ski resorts and boat rental conessions.

Skiing

The study on skiing is divided into three parts: use, forecast parameters important to operators, and effects of improved forecasts on present operations (Table 2). Of these, use is the key item, because benefits from improved forecasts are predicated on a knowledge of user response to specific conditions allowing more efficient management. Snow, the obvious choice for most important parameter, is being relegated to a secondary position by the increasing use of snowmaking equipment. Temperature then becomes critical, not only because of its control on melting, but because snowmaking is limited to a certain range of temperature. Rain on top of snow produces a glaze which is disastrous for skiing. Strong winds can increase the chill factor to intolerable levels, and reduce visibility through blowing and drifting of snow. Fog and clouds are an occasional problem. The operation of ski resorts, therefore, is highly sensitive to weather; however, the sizes of

Table 2. The Skiing Industry—Gilligan & Gow

	Area	Weather sensitive factor	Page	Controlling parameter and time scale (study)	Controlling parameter (actual)
1.	Skiing use	skiing conditions	365, 367 Vol. I	winter rain & prolonged snow melting temperatures/ freezing temperatures leading to icing and/or subcritical snow depth	freezing rain; rain, temperature; humidity
2.			365-67	prolonged very cold temperatures	temperature
3.			365-67	insufficient snow	snow: rate & duration; temperature; wind speed; temp., insolation, humidity.
4.			365-67	fog	same
5.			365-67	rain	same
6.			366-68	high winds	wind speed
7.			366-68	blowing snow	high wind speed, temperature, new snow cover
8.			365-67	prolonged snow melt temperatures	superfreezing temperature
9.			365-67	excessive snow	heavy snow: rate & duration
10.			366-68	wind direction	same
11.	road conditions				precip.: rate & duration; wind speed; fog
12.					
13.	Forecast parameters important to operators		368-69	temperature (82%)*	Available information is insufficient to refine statement on the controlling parameter (applies to 13–16)
14.			368-69	precipitation (82%)	
15.			368-69	wind velocity (49%)	
16.			368-69	cloud cover (31%)	

benefits from improved forecasts are difficult to judge. Of the parameters which affect skiing, only snow is to any extent controlled by the operator, and the economics of snowmaking are such that "...most areas have found that it pays to make snow whenever conditions permit, regardless of the amount on the slopes" (Hovey, 1970). Because the major benefits of improved forecasts would come through anticipation of numbers of skiers, the reaction of the skiing public to improved forecasts is the key variable. It is perhaps because they do not know how the skiing public would react to five- to ten-day forecasts that 30 % to 40% of the operators interviewed said that no changes were likely in skiing use as a result of improved forecasts and therefore they would make no changes in their operation. Clarification of these points, and the value of a nowcast, depends upon an assessment of public reaction to improved forecasts.

Boating

Although locally there are some deviations, the most important weather parameters to operators of boating concessions are wind speed, rain, wind direction, temperature, and cloudiness (Table 3). As for skiing, the effect of these parameters is indirect, operating on potential users, and the important time scale for forecasts was given as one to five days.

Gilligan and Gow noted the existence of short-wave radio storm warning networks on some lakes, but did not explicitly consider the impact of severe local storms. The involvement of some concession operators in warning nets suggests that this impact is substantial, and the benefits of short-range

Table 3. Recreational Boating — Gilligan & Gow

Area	Weather sensitive factor	Page	Controlling parameter & time scale (study)	Controlling parameter (actual)
Boat Rental	Season opening	415, Vol. II		
	Season closing	415	Wind direction, wind velocity, and rain—most important in <u>present forecasts</u> (1-5 days) (see pp. 409-11)	
	Equipment and facilities maintenance	415		Windspeed, rain, wind direction, temperature, cloudiness.
	Number of boats	415		
	Number of employees	415	Temp., rainfall, wind, sunshine most important in <u>improved forecasts</u>	<u>Note</u>: The existence of warning networks suggests that nowcasting may be of great value in reducing hazards from severe local storms.
	Stocking of gas & oil	415		

forecasts may therefore be large. This is an area where nowcasting could be of value.

Home Construction

Store's excellent analysis of weather sensitivities in single family home construction identified, for the northern midwest, precipitation (rain or snow) and subfreezing temperatures as important parameters (Table 4). Freezing rain, which fortunately occurs infrequently, is a particularly costly event. Stone notes that the "... severity of the weather in most cases determines to what extent the events are hampered." Builders are vulnerable during the first third of the construction period. Their losses, computed by means of a numerical model based on data for Milwaukee in 1968, amount to about 1% of the total value of new housing. The year 1968 was excessively dry and somewhat warmer than normal during January, February, and March and otherwise, except for heavy rains in June, was close to the long-term average. Therefore the estimated loss of 1% is more likely to be an underestimate than an overestimate of average annual losses.

Because of contractor inflexibility, only 5% of these losses (which in this study are limited to wages) are recoverable, assuming the contractor is able to take advantage of present weather data and services. The use of anticipated long-range forecasts to increase savings requires "... long-range planning not generally found in home building." In a follow-up conversation Stone reported that his experience in the mortgage contractor business subsequent to the writing of the case study reinforces this conclusion: contractors are locked into a system which for the present, at least, lacks the flexibility needed for effective use of long-range forecasts.

This is to a large extent true also of short-range forecasts. If nowcasting were to be useful it would be in the areas of concrete pouring and minimizing on-site and local environmental damage from high winds and heavy rains.

Common Carrier Trucking

Alfrey's study of the Gateway Transportation Company produced a finding similar to that for home construction: Gateway, and probably the common carrier trucking industry, "... bear(s) significant costs due to adverse weather conditions, but only a very small portion of these costs would be avoidable with improved weather prediction information."

Highway Construction and Maintenance

Kuhn's study of highway benefits shows rain, particularly heavy rain, to be an important weather factor (Table 5). Although temperatures close to freezing also affect most construction operations, their occurrence is limited to the beginning and end of the construction season. In the northern and mountain states, snow is a critical factor for highway maintenance. Wind speed and direction are important during and immediately after a snowfall; temperature is also important because of its control on melting.

Table 4. Single Family Home Construction—Stone

	Area	Weather sensitive factor	Page	Controlling parameter and time scale (study)	Controlling parameter (actual)
1.	Earthmoving and excavation	layout (1/2)*	252, 255-6 Vol. II	precip.: heavy within 2-3 days; moderate throughout workday; light with freezing temps.; temp. below 15° F	precipitation: rate & duration; subfreezing temperature
2.		bulldozer operations (1/2)	252, 255	precip.; temp: ground freeze	See (1); also windspeed and snow cover
3.		footing excavation (1/2)	252, 255	precip.; temp: ground freeze	See (2)
4.		staking out footing grades (1/2)	252, 255-6	See (1)	See (1)
5.		placing footing concrete (1/2)	252, 255-6	See (1)	See (1)
7.	Foundation work	garage block (1)	252, 256	precip. (any amount); freezing rain: ground freeze (freezing temps)	precipitation, especially freezing rain; temperature, wind speed, snow cover
8.		house foundation block (3 days—1 of 2 possible activities)	252, 256	See (7)	See (7)
9.	Closing in the house structure	plates and girders (1/2)	253, 257	light freezing rain, moderate to heavy precip. temp below 15°F	freezing rain; precip.: rate & duration; subfreezing temperature
10.		floor framing and sub-floor (1/2)	253, 257	See (9)	See (9)
11.		close house (1 - 1/2)	253, 257	See (9)	See (9)
12.		fascia and eaves (1/2 day—1 of 4)	253, 257	See (9)	See (9)
13.		roofing (3 days—1 of 5)	253,257	See (9)	See (9)

*normal time for completion in days

Table 5. Highway Benefits—Kuhn

	Area	Weather sensitive factor	Page	Controlling parameter and time scale (study)	Controlling parameter (actual)
1.	Construction	Earthwork—delay or postponement of work; flooding and erosion; washout of seed, sod and topsoil; laborer "show up"	211-14 Vol. II	heavy rain (24-48 hrs)	rain: rate and duration
2.		Work scheduling	214-15	heavy rain (10 days-2 weeks)	See (1)
3.		Base course—stabilization	215-19	rain, temperature	See (1), also temperature
4.		Surface course—			
		concrete	219-22	temperature (40°F, 35°F)	temp., esp. fluctuations close to freezing
		bituminous	222-26	rain, temperatures	See (3)
5.		Calendar restrictions	226-27	temperature	temperature
6.		Structures	227-33	rain, temperature (esp. sharp falls)	rain: rate, duration, and (upstream) extent; temperature (esp. sharp falls)
7.	Maintenance	Snow clearing	233-34	winter storms	snow: rate & duration; wind: speed & direction; temperature
					Note: For most factors within construction and snow clearing within maintenance, benefits from nowcasts would be substantial.

For most of the operations considered, short-range (24-48 hour) forecasts would be sufficient. This, the author notes, is especially true for "impending severe weather occurrences" such as heavy rain and winter storms. Short-range forecasts would also be useful in the increasingly important area of minimizing environmental damage. Longer-range forecasts of ten days to two weeks are useful primarily as aids to work scheduling. Although nowcasts were not considered, it is likely that most of the benefits obtainable from short-range forecasts would also accrue to nowcasts.

Nowcasts

Agricultural crops are represented by individual case studies of lettuce, peas, sweet corn, hay, and a general study of horticulture, which includes (in addition to lettuce) tomatoes, snap beans, cucumbers, potatoes, apples, cranberries, floriculture, and ornamental horticulture. These crops are all grown in Wisconsin or adjacent states. By and large, they are evaluated in terms of conditions in the midwest which for some crops—tomatoes, for example—may differ substantially from conditions in other production areas.

Horticulture.

Under horticultural crops Tibbits and Meier consider ornamental horticulture, floriculture, two fruits (cranberries and apples), two fresh vegetables (potatoes and lettuce), and three processing vegetables (tomatoes, snap beans, and cucumbers). See Table 6.

Table 6. Horticulture—Tibbits & Meier

	AREA	WEATHER SENSITIVE FACTOR	PAGE	CONTROLLING PARAMETER TIME SCALE (STUDY)		CONTROLLING PARAMETER (ACTUAL)
					TABLE 1	
1.	Ornamental horticulture	Spring peak production period —determination of labor procurement needs	Vol. II 24/67	thawing of soil	Precip.: kind, duration (2 wks)	thaw: superfreezing temp., insolation, nighttime cloudiness, windspeed, dew-point temp., rain
2.				drying of soil	Frost: duration	drying: relative humidity, insolation, wind speed
3.		—when to stop taking orders	24	fair days	(up to one month)	rain >0.1" per day (daylight hours)
4.		Plant protection	25	freezing temperatures	(1 day)	subfreezing temp., dewpoint temp. nighttime cloudiness
5.		Work scheduling; labor procurement	25/27	rain	Frost: duration (1-5 days) Rain: amount, duration	rain: rate, duration; subfreezing temps.: duration
6.		Planting	25/27	dry periods		rain, insolation, relative humidity
7.		Spraying and pest control	26/27	wind	rain: duration; wind: speed (7-10 days), temp.: amount, duration	rain: rate, duration; wind: speed, direction; temperature
8.		Digging stock	26-27/67	frost; freezeup	rain: amount, duration; frost: duration, time of winter freeze (3 day - 2 wk)	rain: rate, duration; subfreezing temps., incl. duration; snow
9.		Sales requiring travel (i.e., bad road conditions)	27	snow storms, icy highways		snow: rate, duration; wind speed: temperature
10.		Transplanting trees	27	heavy snow, extreme cold, thaws	snow: amount; very low temps. duration (1-5 days)	snow; temperature
11.	Floriculture				TABLE 2	
12.	Bedding plants	Personnel	28, 29/69	fair weather weekends	Temp.; rain: amount, duration (1-2 wk)	rain; temperature; cloudiness
13.		Sales	28, 29/69			
14.		Customer service	28, 29/69			
15.	Cut flower, potted plant	Flowering	29/68	light-cloudiness high temperature	Temp.: very high, duration (1-2 wks) cloud cover: amount, duration	temperature, cloudiness
16.		Field crops	30/68	frost, sudden drops in temp.	temp.: frosts, very high duration (1 day - 2 wks)	frost: see (4); sharp falls of temperature
17.				drying (gladiolas)		rain, relative humidity, insolation, wind speed
18.		Ordering flowers	21-30/68		temp.: frosts; rain: excess amounts in production areas (1-2 wks)	frost: see (4); rain: rate, duration
19.		Production activities out of doors		hurricanes, freezing or near freezing temperatures		wind speed; rain: rate and duration; temperature
20.		Spray schedule, pest control	31/68		rain: amount, duration; temp.: amount, duration; wind: speed (1 day - 2 wks)	wind speed and direction; rain: rate and duration; temperature
21.		Protection during shipping	31-32/68	subfreezing temperatures	temp.: frosts in areas shipping to and through	subfreezing temperatures: duration, extent
22.						
23.	Fruits—cranberries	Removal of flood water	33	no post-removal hard freezes no pre-removal warm spells		temp.: subfreezing and abnormally high
24.		New plantings	24-33/70	high humidity; rain (no heavy rain)	rain: amount; wind: speed, temp. (3-7 days)	rain: rate (esp. heavy), duration; relative humidity, temperature, wind speed
25.		Growth	34/70 34/36	frosts and freezes hail; high temps.	temp.: frost time; cloud cover time, duration (1-3 days)	see (4); hail; high temperature
26.		Flowering	35-36	warm sunny days		insolation; temperature, wind speed
27.		Pesticides	35/70	dry spell, warm nighttime temperatures	rain: amount, duration; temp.: duration; wind: speed, direction (3-10 days)	rain; temperature, wind speed and direction
28.		Herbicides	36/70		rain: amount; wind: speed, direction (3 days)	rain: rate, duration; wind: speed and direction
		Harvesting	37/70	first hard freeze	temp.: duration; rain: amount, duration (1-7 days)	subfreezing temps.; rain: rate, duration
		Bedding	37/70	first prolonged cold weather	temp.: very low, duration (1-2 wks)	subfreezing temps.; snow: rate and duration

Table 6 (cont.)

29.	Apples	Blossoming	37-38/ 71	freezing temperatures, dew-point temperatures	TABLE 3 temp.: frost time and duration, cloud cover: time, duration (hourly at night, 1 day - 2 wk)	See (4)
30.		Dormancy	39/71	rapid decrease of temp. to -5°F or below	(3-5 days)	subfreezing temperature, especially rate of change
31.		Pollination	39/71	temperature, rain, wind	temp.; rain: duration; wind: speed (1 wk)	temperature, cloudiness, wind speed, rain
32.		Thinning	39-40/ 71	wind, temperature	temp.: duration; cloud cover (1-5 days)	wind speed and direction, temperature
33.		Apple scale	40/71	rainy periods	rain: amount, duration (1-7 days); temp.: duration; wind speed	rain, duration; relative humidity; temperature; wind: speed and direction
34.		Moth	40-41/ 71	warm nights		
35.		Early spring insect and disease control	41/71	temperatures below 20°F		
36.		Harvest	42/71	high winds (15 mph & more)	wind: speed (1-7 days)	wind speed
37.						
38.	Fresh Vegetables—Potatoes	Field operations	42/72	rain	TABLE 4 rain: amount, duration (1-5 days)	rain: rate, duration
39.		Irrigation	42-43/ 72	rain/no rain	rain: amount, duration; wind: velocity, direction (2-10 days)	see (38); also, wind: speed and direction
40.		Disease control (blight)	44-45/	cool wet nights and warm moist days; winds and rain-free periods	rain: duration; temp.: duration; wind: velocity, direction (2-10 days)	see (33)
41.		Harvest	45/72	rain, severe freezing	rain: amount, duration; temp.: frosts (1-4 days)	see (5)
42.						
43.	Lettuce	Planting schedule	46/72	quick storms; sudden heat; rain; high wind	rain: amount, duration; temp.: duration (1 day - 2 wk)	rain: rate and duration; temp.; wind speed
44.	Dismissed as insignificant in following case study	Leaf hopper control	46-47	winds		wind:speed and direction
45.		Downy mildew	47	damp cloudy weather		relative humidity; cloudiness
46.		Spraying, irrigation	47-48	wind velocity		wind: speed and direction; rain: rate and duration
47.		Sales (maturity)	47/72	temperature and rainfall	temperature: frosts; rain: duration (1-4 days)	temperature; rain: rate and duration
48.	Processing vegetables—Tomatoes	Seeding	53, 54	soil temperatures; heavy rain	(10 day - 2 wks)	temp.; insolation; nighttime cloudiness; rain: rate and duration
49.		Plantings—frost protection, incl. irrigation	54/72	frost	temp.: frost; wind: direction, velocity (1 day - 2 wks)	see (4)
50.		Disease control - blight	55-56/ 72	warm rainy weather; cool rainy weather	rain: duration; temp: duration; wind: velocity, direction (2-10 days)	see (33)
51.		Harvesting	56/72	rain	rain: amount, duration (1-4 days)	rain: rate and duration
52.	Snapbeans	Planting	56-57	soil temperature and moisture		see (48), also (2)
53.		Blight - sprays	57-58	high temperatures, low temperatures, rain; high wind	(1 day ?)	temperature; rain: rate and duration; wind: speed and direction
54.		Mildew	58	continuous high moisture		relative humidity, cloudiness
55.		Blossoming	58-59	hot dry conditions		temperature, insolation, wind speed
56.		Harvest	59	wet weather, frost		see (5)
57.	Cucumbers	Seeding	59	soil temperature		see (48)
58.		Disease	60	rain		rain: rate and duration
59.		Herbicide application	59/72	rain	rain: amount; wind: velocity, direction; temperature (1-3 days)	rain: rate and duration; wind: speed, direction; temperature
60.		Harvest - maturity	60	temperature	(several days to 1 week)	temperature
61.		Installing bees for pollination	59-60	cool temperatures	(long range)	temperature

With regard to beans, J. Hammes, Director of Agricultural Research, Green Giant Company, remarked in an interview that although the growing of snap beans on predominantly sandy soils in the midwest avoids some of the severity of planting and harvest problems related to soil moisture, sandy soil and the extended harvest period (which in the midwest may continue into September) increases the danger of damage from frost. A nowcast of frost permits early harvest with some loss of quality, but less loss than, for example, with peas.

Considering the horticulture study as a whole, of all the weather parameters noted, subfreezing temperatures and rain are the most critical. Subfreezing temperatures are important because of their potential for damage to most of the outdoor crops discussed and, to a lesser extent, because of their interference with any operation involving digging. Where protection from subfreezing temperatures is available, and increasingly this is the case, the forecasting problem is short term. In a few situations long-range forecasts give additional benefits. Rain is important because of the pervasiveness of its influence. Although direct crop damage from rain is infrequent, most field operations are adversely affected. The largest benefits from improved forecasts would occur in the short- to medium-range through more efficient scheduling of field operations (primarily in rescheduling, land preparation, planting, and harvest). Long-range forecasts would yield additional benefits in labor procurement, planting, irrigation, and disease control.

Short- to medium-range forecasts of wind speed and direction have value in the spraying of herbicides and pesticides. Long-range forecasts of unseasonably high temperatures would have utility in planting, controlling bloom and disease, irrigation, and harvesting.

Lettuce

One of the crops discussed under horticulture has been expanded by Tibbits and Petersen into a case study (Table 7). Lettuce production is most sensitive to high temperatures, which may accelerate maturation beyond the sales and harvest capability of the grower. Rain is also important: rain may delay the harvest, splash dirt on the lettuce, wash pesticides from the lettuce, and in large amounts may cause losses in yield. A five- to seven-day forecast is needed to prevent losses from high temperatures; however, a nowcast of rain would be beneficial in any of the areas affected by rain. These parameters, as Tibbits and Petersen point out, apply explicitly to lettuce production in Wisconsin, and—by extrapolation—Michigan and New York. They may not apply in those states (California, Arizona, Texas, and New Mexico) which grow the largest part of U. S. production. There frost, strong winds causing blowing dust, and high temperatures with low humidities causing burning of seedlings are likely to be important.

Peas

In many respects the weather related problems associated with the production of peas are similar to those of lettuce (Table 8). Gritton's study shows that temperature is important to the rate of maturation of peas. Harvest

Table 7. Lettuce Production—Tibbits & Petersen

	Area	Weather sensitive factor	Page	Controlling parameter and time scale (study)	Controlling parameter (actual)
1.	Harvest	Maturation	79-81/80 Vol. II	temperature (5-7 days)	temperature
2.		Dirty lettuce	81-2/80	rain (1 day)	rain rate; wind speed)
3.		Impassable fields	83/80	heavy rain (1 day)	rain: rate & duration
4.	Growth	New plantings/ germination loss due to standing water	83/80	heavy rain (1 day)	See (3)
5.		Loss of quality and yield due to standing water	83/80	heavy rain (1 day)	See (3)
6.					
7.		Spray schedules	84/80	rain	See (3)
8.		Blown dirt	84-5	wind	wind: speed and direction; rain
9.		Lettuce quality	85	frost, temp. inversion	subfreezing temp.; nighttime clouds; wind speed; dewpoint temperature
10.		Burning of seedlings	85	extreme drying conditions	temp.; insolation; relative humidity, wind speed

Table 8. Pea Cultivation and Processing—Gritton

	Area	Weather sensitive factor	Page	Controlling parameter and time scale (study)	Controlling parameter (actual)
1.		plowing, soil moisture, drying	93 Vol. II	amount of moisture in the soil, date of thaw, precip., wind and sun or radiation; also cloudiness (at least 3-4 days)	post thaw-precip.: rate, duration; relative humidity; insolation; wind speed
2.		freeze up	93		subfreezing temperatures
3.	Operation of processing plants at capacity	maturation	94-95	temperature (heat units)	temperature
4.		planting—interruption of the schedule	96	rain—amount, duration, location, date & time (1-2 days helpful, 1-2 weeks much better)	rain: rate, duration, extent
5.	Growth	herbicides	96	rain	See (4)
6.		rate of development, yield, soil pathogens	97	soil temperature	temp., insolation, (nighttime) cloudiness, rain, relative humidity
7.		air pollution	97	inversions	thermal stability, wind speed and direction
8.		spraying—ground equipment	97-98	soil moisture, rain, temp.	rain: rate, duration; relative humidity, insolation, wind speed
		aircraft	98-99	wind, rain, temp. (1 day to 1 week)	wind speed & direction; rain: rate & duration; temp.
9.		disease development	99	splashing rain & runoff, humidity, strong wind with rain or sand	rain: rate, duration; humidity, wind speed
10.	Harvest	procurement of labor, supplies, etc.	99-100	temp., moisture	temperature; see (4)
11.		crop reports	100-101	temp., precip., radiation, cloud cover, humidity, soil moisture, wind speed (1-2 mo., 1-2 weeks)	temp.; rain: rate, duration; cloudiness, relative humidity, wind speed
12.		tenderometer value; planning, cutting	101-104	temp., soil moisture (1-2 weeks)	See (11)
13.		cutting & threshing	102-	rain, heavy dew (1 day—several days)	rain; nighttime cloudiness, relative humidity, wind speed
			103	heavy rain, prolonged wet periods	See (4)
14.		highway movement of machines	104	storms	See (4); also wind speed, cloudiness, fog
15.		labor, equipment, and supply needs	104-105		See (11)
16.		deterioration of shelled peas	105	temperature	temperature
17.	Conversion of plant	peas to sweet corn corn	106	temperature, moisture	See (11)
18.	Shipment	spoilage	106	freezing temperatures	subfreezing temperatures
19.		can rust	106	temperature change	temperature and dewpoint temperature

operations are sensitive to rain, especially rain of such intensity and duration as to reduce field trafficability. Rain also affects planting schedules and the application of herbicides and pesticides.

The areas listed below were reviewed in discussions with Hammes of Green Giant.

Planting and land preparation: As stated in the report (p. 96, Vol. II), a nowcast of precipitation would change management decisions in that if the day were fine and precipitation were predicted, more area would be planted than originally planned, provided the operators had the additional equipment. This would move some land preparation and planting ahead in scheduling. However, a precipitation nowcast would not help much if the soil were already wet.

The spatial resolution of nowcasts must be exceedingly good if, as indicated in the report, operations could be moved advantageously from one region to another within a 15- to 75-mile radius of the packing plant.

Pesticide application: Reliable nowcasts of precipitation would be important since either the type of pesticide could be varied (some are best for dry conditions, others for moist conditions), or application could be delayed.

Wind seems to be less important than precipitation but needs further examination.

Frost: Because peas are subject only to early frosts and prevention is not feasible, frost is not an important factor.

Maturation: Although maturation and quality are highly dependent on temperature and soil water, the state of soil water is known by the operators and temperature is one of the better-forecasted parameters (up to five days). This information is used now. The question of nowcast advantage is problematical since much depends on the extent that present temperature forecasts can be improved.

Deterioration following harvest: The value of a nowcast is problematic in view of the accuracy of present temperature forecasts. However, if temperatures are high, nowcast improvement may be useful to management in adding trucks and decreasing loads to shorten the time between picking and processing.

Harvest operation: A nowcast of precipitation would be important, in that harvesting schedules could be accelerated during fine weather if rain were predicted. This would cause loss in yield; however, a delay might mean such poor quality that the field is simply not harvested. Heavy dew is not the same problem as rain. Dew may reduce the efficiency of the viner, but it also is helpful in maintaining pea turgor and quality.

Shifting operations within a 15- to 75-mile radius is of doubtful feasibility (harvesting at all stages usually occurs in all areas about the packing plant) except as noted for accelerated harvests above. Greater advantage may obtain if the company has several packing plants. Even so, some plants would be overtaxed and others idle. Also, high spatial resolution would be needed in the nowcast.

Condensation and rusting of cans: Hammes felt that there is little to be gained from a nowcast. If the problem becomes acute, the equipment needed to solve it would be run continuously or turned on at short notice. Some savings might accrue through dew point and dry bulb temperature forecasts in areas where cans are being stored and shipped.

Freeze during transport: Arrangement of special cars has a time lag beyond the nowcast period.

Insects and disease: Soil temperature, pathogen transport, and either plant injury or dew (high humidity) in predisposing susceptibility are part of a larger insect and pathogen problem which deserves further study.

Corn

Many of the remarks directed toward peas also apply to the studies on sweet corn by Andrew and by Smith and Torkelson, including land preparation and planting, pesticides, shipping and storing, and pests and disease (Table 9). Other areas discussed with Hammes are listed below.

Fertilizer: On a short-term basis the operator would not change fertilizers in response to forecasts.

Frost: Hammes had no knowledge of anyone raising temperatures over corn fields by means of smudge fires, heaters, fans, or irrigation. The economics of corn growing make it prohibitively expensive except in rate circumstances. Frost on corn is not so crucial as on some plants, because it only kills the leaves—the grower still has three to four days to pick the ears, which do not freeze.

Table 9. Sweet Corn Cultivation & Processing—Andrew

	Area	Weather sensitive factors	Page	Controlling parameter and time scale (study)	Controlling parameter (actual)
1.	Preplanting	schedule	114-116 Vol. II	soil moisture, precipitation, cloud cover, temperature	precip.: rate, duration; relative humidity, insolation, wind speed
2.					
3.					
4.	Growth	pesticides aerial spraying	116 116-17	rainfall, temperature rainfall, crucial wind pattern	rain: rate, duration; temp. wind: speed & direction
5.		fertilizer e.g. anhydrous ammonia	116 116	soil moisture, temperature rainfall, temp., relative humidity	See (1), temperature
6.		disease	117-118	humidity, cloud cover, precip., temp.	relative humidity, cloudiness, rain: rate & duration, temp.
7.		irrigation	118	rainfall	rain: rate & duration
8.		frost	118	temperature	temp.; nighttime cloudiness, wind speed, dewpoint temp.
9.	Harvest	initiation & rate	118-119	temperature*	temp.; rain: rate & duration (esp. heavy)
10.		yield forecasts	119	temp. & rainfall (2 weeks)	temp.; rain: rate & duration
11.		stalk lodging (field corn)	121	severe winds	wind speed
12.		frost	121		See (8)
13.		ear, kernel & stalk rot	122	fall rains	See (7), also relative humidity, wind speed, temperature

*Smith and Torkelson list rain also.

Smith and Torkelson's dollar analysis for sweet corn in Wisconsin shows modest savings with seven- to 14-day forecasts. They argue, however, that the nature of sweet corn cultivation precludes equivalent benefits from a nowcast. Per acre savings from field corn would be less than for sweet corn.

Alfalfa

The meteorological aspects of drying hay are complex. In the absence of rain (the most important parameter), drying rates will be affected by a number of variables, including wind speed, cloud cover (sunshine), relative humidity, and soil moisture (Table 10). Wind direction may also be important because flow perpendicular to the windrows of hay will generate stronger turbulent mixing in the surface layer.

The investment of dairy farmers in hay crushers and silos is some measure of the farmers' vulnerability to adverse weather during drying. Since the disastrously wet June of 1968, such investment in Wisconsin has increased substantially (Rosendal, 1971; Bruhn, 1971), to a level now where it should be considered in any economic analysis of haying. The study of Smith, Boness, and Smith is discussed below in light of this investment trend. Information on present haying practices was provided by Professor Ham Bruhn, a hay harvesting specialist in the University of Wisconsin Agricultural Engineering Department.

The model of Smith, Boness, and Smith upon which estimates of benefits are based, predicts for two cases the expected costs of supplemental feed

Table 10. Hay—Smith, Boness, & Smith

Area	Weather sensitive factor	Page	Controlling parameter and time scale (study)	Controlling parameter (actual)
Harvest	drying	151	rain, temperature, humidity, cloud cover, wind (2-3 days)	rain: duration; relative humidity, wind speed, cloud cover, wind direction

required to raise the nutritional value of hay to a high but achievable level. The first case is for no forecast information; the second case is for perfect forecast information. In the first case the farmer cuts hay on the second day of the first two-day dry period to occur in the harvest period. In the second case (which has two variations), he cuts hay on the first day of the first four (or three) day drying period to occur, and therefore—given the wet- and dry-day sequences which have been observed to occur—always makes the best possible decision. Because it is the difference between these two costs that determines real benefits, any circumstance that decreases the cost of supplement for the no-weather data case, or increases the cost of supplement for the perfect-weather data case, will reduce the real benefits. One such circumstance—the assumption of perfect weather forecasts—has been discussed briefly by Smith, et al.

The authors say that hay must be dried to a moisture content of 20% (p. 148); however, with present haying practices, a good share of Wisconsin's hay is baled at 25% to 30% moisture. Additionally, most hay is crushed so that drying is a full day shorter than it otherwise would be. This implies that the two-day model for drying (three days counting the cutting day) is most appropriate for the first (June) crop and a one-day model should be used for second and third crops. Silage can no longer be ignored as an alternative. The percentage of alfalfa made into silage is now, according to Bruhn, about 25% of Wisconsin's hay acreage; this hay is ensiled at 60% to 65% water content. Furthermore, because the farmer knows June is likely to be wet, he usually is prepared to ensile if drying conditions are bad.

Although these trends in modern haying practice decrease the vulnerability of farmers to adverse weather (at substantial expense to the farmer); they simultaneously increase the importance of accurate nowcasting.

Nowcasting Overview

Our earlier review indicates that horticultural crops offer the greatest opportunity for nowcasting benefits. This is because they have a high value per acre and their value depends strongly upon quality features which are weather dependent. Moreover, the intensive management offers more opportunities for change than for agronomic crops, so that decision-making based on nowcasting could be important. Since the interim report was based almost entirely on Wisconsin conditions, it is essential that the national perspective be assessed in at least a preliminary way. Accordingly, one of the authors (Tanner) visited with Professor Warren Gabelman of the Department of Horticulture, University of Wisconsin, on 26 January 1972 regarding nowcasting benefits on a larger scale. The discussion was general, with slightly greater emphasis on lettuce than on other crops, but illustrates the need for a national appraisal. The major points are summarized below.

Nowcast parameters: We reviewed first the summary of nowcasting parameters and weather-sensitive factors as abstracted from the interim report and presented in modified form below. Note that these are based on obtaining accurate six-hour forecasts with declining accuracy to about 15 hours. Operations where decisions required time leads greater than 15 to 24 hours have been omitted.

We also considered present temperature forecasts to be among the better forecasts with improvement largely derived from either frost prediction, slight improvement in forecasting excessive temperature, and possibly improvement in predicting the time-course of rapid, large changes of temperature (usually drops).

Sensitive factors, decisions and parameters:

1. Land preparation and planting schedules are mainly affected by precipitation. Schedules of preparation and planting may be changed. It often is better to increase the area planted beyond that planned than to risk a delay which sets the planting schedule behind. The time and amount of precipitation are the required parameters.

2. Intermediate tillage: Schedules of fertilization and weed control (if done by tillage) may be advanced or delayed.

3. Frost prevention: (a) Heating and/or irrigation are essential in many small fruits and tree fruits to prevent crop loss; (b) If solid-set irrigation is available, it may be used on some vegetable crop; (c) Some crops may be harvested early, particularly machine-harvested crops.

4. Pesticide application: (a) The mode of application (ground-based or airplane); and (b) advancing or delaying schedules may be changed according to rain and wind nowcasts; (c) The kind of pesticide and vehicle may be determined by rain nowcasts (some pesticides depend on moisture and others

are best for dry conditions); (d) Occasionally wind-humidity interaction is important (e.g., Stoddard solvent).

5. Quality degradation from high temperatures: (a) This may be offset on some crops where mist-spray or irrigation is available, and generally requires solid-set (note that mist-spray recently has become a topic of considerable interest); (b) Harvesting operations may be changed (e.g., the number of trucks increased to prevent delays and excess loads); (c) Harvesting schedules of crops which lose quality if overheated may be advanced.

6. Harvesting: The relation to frost and high temperatures was considered earlier. Harvesting schedules also may be advanced or delayed depending upon rain nowcasts. Rain affects trafficability of soils for heavy harvesting machines and may cause soil puddling and persistent degradation of structure.

7. On specific crops, other aspects not listed above may become important and should be considered as data are collected on each crop.

8. Plant disease propagation is of particular interest, although it probably should be regarded separately from the above nowcast considerations.

Conclusions

Although there are dangers in generalizing from so diverse a group of studies, on the basis of frequencies of occurrence (Table 11) and economic significance in the studies, we conclude that overall the three parameters most important to benefits from improved forecasts are precipitation,

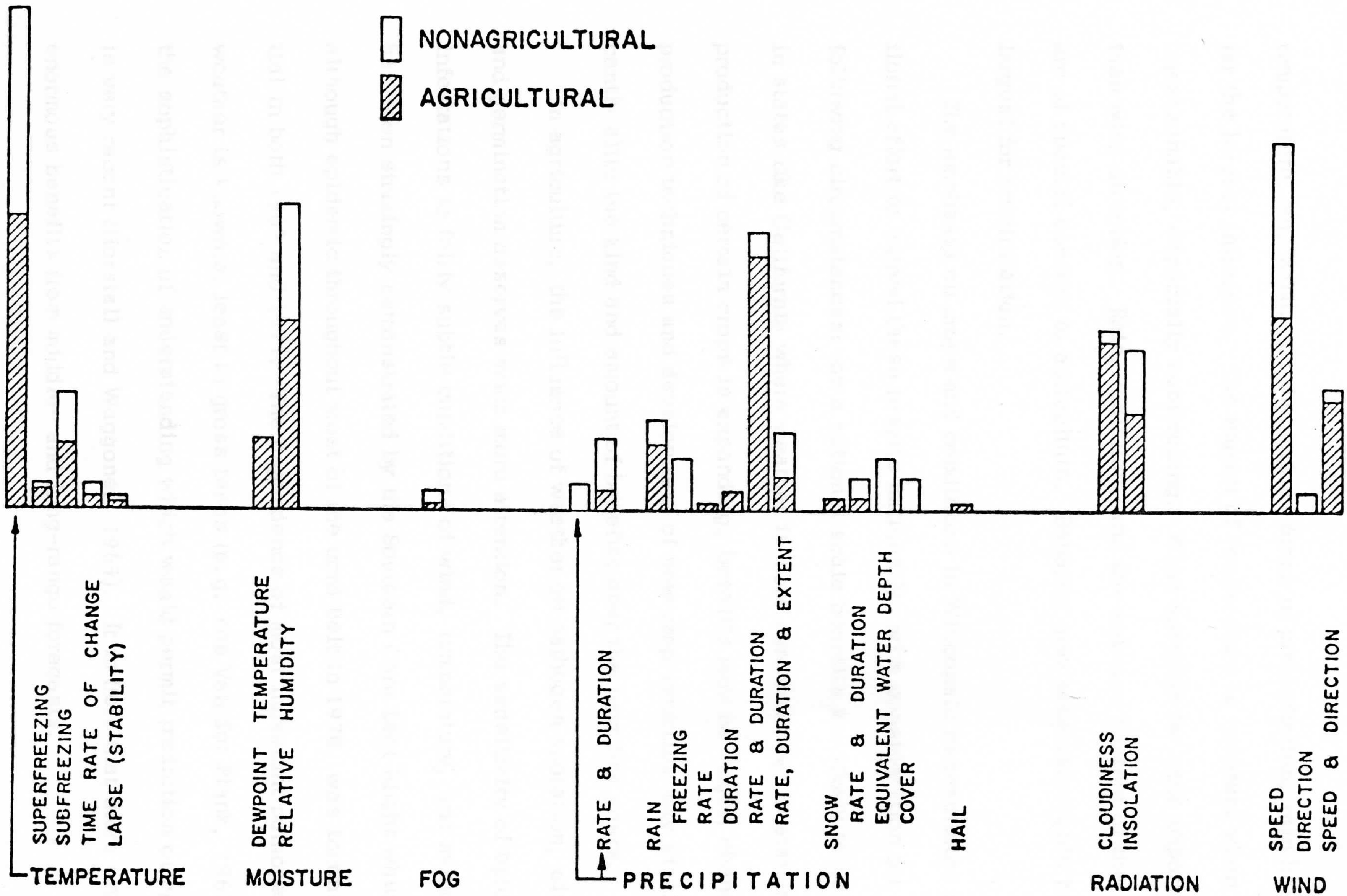

Table 11. FREQUENCIES OF OCCURRENCE OF VARIOUS METEOROLOGICAL PARAMETERS

temperature, and wind. Of the various forms of precipitation, rain has by far the largest influence. The impact of temperature is greatest when it is unseasonable, especially subfreezing. Wind speed is far more important than wind direction. Rain, radiation, and the moisture content of the air are of special concern to agriculture. Benefits from nowcasts would be largest for precipitation.

The emphasis on crops and conditions in Wisconsin necessitates additional effort to extend these results nationally, with consideration for the following circumstances: on a national scale benefits are likely to be smaller in states like California where weather is more conservative; in states where production of certain crops is expanding, benefits may be larger; changes in production techniques and development of new crop varieties may significantly alter the kind and amount of benefits over the next few years.

In agriculture, the influence of weather on pathogen sporation, dispersal, and germination deserves much more attention. The sensitivity of epidemic infestations to fairly subtle conditions of wind, temperature, and moisture has been strikingly demonstrated by the Southern Corn Leaf Blight which, although epidemic throughout most of the corn belt in 1970, was inconsequential in both 1969 and 1971. The dependence of most important pathogens on weather is known at least in gross terms (e.g. see Van der Plank, 1967), but the sophistication of understanding which would permit prediction of epidemics is very recent (Horsfall and Waggoner, 1969). It is here that there may be enormous benefits from middle- and long-range forecasts.

In many of the public oriented areas of business, benefits from improved forecasts would be substantial. However, assigning numbers to the value of forecasts is difficult because businessmen know too little about public reactions to better forecasts to predict changes in their operations. Therefore, Nelson's study of the effects of improved forecasts on demand for outdoor recreation should be extended to a general assessment of public reaction to improved forecasts.

The present limited operational use of satellite data is a poor indicator of its potential for specifying the values of the survey parameters: over most of the northern hemisphere, satellite data duplicate more digestible conventional data and are ignored. Present capabilities for inferring study parameters are summarized in Table 12. However, the development of infrared and microwave sounders, very high resolution scanners, satellite radars, and automated real-time data processing systems promises to greatly improve such capability over the next few years.

Table 12. Present Satellite Capabilities for Inferring the Values of Meteorological Parameters Important to Users

PARAMETER	INFERENCE BY SATELLITE
Temperature	direct: remote soundings, window infrared;
superfreezing	indirect: large-scale flow (long wave troughs and ridges, thermal troughts and ridges)
subfreezing	vortices, frontal bands, cloudiness, snow cover
time rate of change	
lapse (stability)	low level cloud type (cumulus or stratiform)
dewpoint	see temperature and relative humidity
Relative humidity	direct: remote sounding (with temperature); indirect: fog, cloudiness, cloud type, vortices, frontal bands, large-scale flow
Frost	see temperature
Fog	direct observation; also indirect: cloud type, frontal bands, vortices, large-scale flow
Rain	see precipitation
freezing	
rate	
duration	
rate and duration	
rate, duration, and extent	
Snow	synoptic interpretation: frontal bands, vortices, large-scale flow, Great Lakes lee clouds; also cloud density (enhancement)
rate	
duration	
rate and duration	
equivalent water depth	
cover	persistent high albedo
Hail	squall lines, isolated large cumulonimbi; also cloud density (enhancement)
Precipitation	synoptic interpretation: cumulonimbi, squall lines, frontal bands, vortices; also cloud density (enhancement)
rate	
duration	
rate and duration	
Cloudiness	cloud cover, cloud brightness, cloud type
Insolation	daytime cloudiness, cloud brightness
Wind	cloud displacements, sunglint; also synoptic and mesoscale interpretation: vortices, frontal bands, large-scale flow, banded clouds, lee waves, sea breeze, cumulonimbus plumes, anomalous cloud lines, island effects, ice movements
speed	
direction	
speed and direction	