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ECONOMIC CONSEQUENCES OF IMPROVED TEMPERATURE FORECASTS: AN EXPERIMENT WITH THE FLORIDA CITRUS GROWERS

(CONTROL GROUP RESULTS)

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FINAL

ECONOMIC CONSEQUENCES OF IMPROVED TEMPERATURE FORECASTS: AN EXPERIMENT WITH THE FLORIDA CITRUS GROWERS (CONTROL GROUP RESULTS)

Prepared for

National Aeronautics and Space Administration
Office of Applications
Washington, DC

Contract No. NASW-3047

November 30, 1977

ABSTRACT

NASA is planning a demonstration experiment (to be initiated in late 1977) to show that frost and freeze prediction improvements are possible utilizing timely Synchronous Meteorological Satellite (SMS/GOES) temperature measurements and that this information can affect Florida citrus grower operations and decisions so as to significantly reduce the cost for frost and freeze protection and crop losses. As part of this effort, ECON, Inc. has designed and conducted the first phase of an economic experiment which will monitor citrus growers' decisions, actions, costs and losses, and meteorological forecasts and actual weather events and will establish the economic benefits of improved temperature forecasts. The economic experiment is designed to measure the change in annual protection costs and crop losses which are the direct result of improved temperature forecasts.

To estimate the benefits that may result from improved temperature forecasting capability, control and test groups have been established with effective separation being accomplished temporally. The control group, utilizing current forecasting capability, was observed during the 1976-77 frost season. The test group, benefiting from improved temperature forecasting capability expected to result from the utilization of SMS/GOES data in combination with forecast models being developed by the University of Florida, will be observed during the 1977-78 and possibly following frost seasons. The economic benefits of the improved forecasting capability will then be the difference between normalized costs and losses of these two groups extrapolated across the State of Florida.

This report presents a summary of the economic experiment, the results obtained to date, and the work which still remains to be done. Specifically, the experiment design is described in detail as are the developed data collection methodology and procedures, sampling plan, data reduction techniques, cost and loss models, establishment of frost severity measures, data obtained from citrus growers, National Weather Service, and Federal Crop Insurance Corp., resulting protection costs and crop losses for the control group sample, extrapolation of results of control group to the Florida citrus industry and the method for normalization of these results to a normal or average frost season so that results may be compared with anticipated similar results from test group measurements.

ACKNOWLEDGEMENTS

ECON, Inc. acknowledges the contributions of Chris Braen, Edward Gallagher, Joel S. Greenberg, Keith Lietzke, Dr. Dan Nikodem and Dr. Francis Sand who performed the analyses and authored this report. Technical assistance was also provided by Peter Stevenson. The economic experiment described in this report could not have been accomplished without the close cooperation of the National Weather Service, Florida County Extension Service, Federal Crop Insurance Corp., and the University of Florida. Particular appreciation is extended to the fifty-two Florida citrus growers who provided the crop protection and damage data which is the very essence of this experiment, and John Jackson, Tom Oswalt, Ed Richards, Jack Hayman, Bill Phillips and Tim Hurner, the county extension agents, who played a key role in the overall data-gathering process. The reported experiment was under the technical direction of Mr. Ernest Neil at NASA's Goddard Space Flight Center.

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Vice President

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1. EXPERIMENT OVERVIEW

1.1 Introduction

NASA is planning a demonstration experiment (to be initiated in late 1977) to show that frost and freeze prediction improvements are possible utilizing timely Synchronous Meteorological Satellite (SMS/GOES) temperature measurements and that this information can affect Florida citrus grower operations and decisions so as to significantly reduce the cost for frost and freeze protection and crop losses. As part of this effort, ECON, Inc. has designed and conducted the first phase of an economic experiment which will monitor citrus growers' decisions, actions, costs and losses, and meteorological forecasts and actual weather events and will establish the economic benefits of improved temperature forecasts. The economic experiment* is designed to measure the change in annual protection costs and crop losses which are the direct result of improved temperature forecasts. This report describes the experiment and the results obtained to date. It should be noted that the reported economic experiment must, of necessity, encompass data collection during several frost seasons, only one of which has occurred. Therefore, no conclusions can yet be drawn relative to the magnitude of the economic benefits which may result from improved temperature forecasts provided to the Florida citrus growers.

In order to estimate the benefits that may be realized by the citrus growers as a result of improved temperature forecasting capability, control

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*Described in "A Plan for Application System Verification Test--The Value of Improved Meteorological Information," ECON, Inc. Report No. 76-108-2, August 31, 1976, prepared under NASA Contract No. NASW-2558.

and test groups have been established. Effective separation between the two groups of sample growers is accomplished temporally. The control group, utilizing current forecasting capability, was observed during the 1976-77 frost season. The test group, benefiting from the improved temperature forecasting capability that will result from the utilization of SMS/GOES data in combination with forecast models being developed by the University of Florida, will be observed during the 1977-78 and possibly following frost seasons. The economic benefits of the improved forecasting capability will then be the difference between the normalized costs and losses of these two groups extrapolated across the state of Florida.

During the previous year's activity, the details of the experiment design* were developed, data collection methodology and procedures were determined, control group data collection was undertaken and completed, data reduction techniques developed and implemented, and economic analyses undertaken. The previous year's work also resulted in the development of the experiment sampling plan, the methodology for establishing protection costs and losses resulting from inadequate protection in terms of temperature forecasting capability, and the development of the means for collecting data which would demonstrate the economic (and fuel conservation) consequences of improved temperature forecasting.

ECON established a sampling plan concerned with the determination of the specific growers (and groves) who would participate in the conduct of the

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*Particular attention and care has been devoted to the design of an experiment which allows temporal separation of control and test groups and which will provide valid results even though there may be significant differences between the weather events encountered during the control and test group frost seasons.

experiment. Specific grower selection considered the desired number of samples to be included in the test and control groups. This included consideration of the accuracy of the data and the segmentation requirements (in terms of geographic location, frost protection practices, soil types, citrus crop types, etc.). A major consideration was County Extension Service experience with growers and the population of growers which was expected to be cooperative. The sampling plan concept was developed and reviewed with the county extension agents and resulted in a selection of growers who would participate in the experiment. After completion of the determination of grower data requirements and data forms, discussions were held with the growers to make a final determination of which growers would participate in the experiment. As part of this initial effort the specific procedures for data gathering were determined, including the roles of the National Weather Service, the County Extension Service, the University of Florida, the Federal Crop Insurance Corporation and the citrus growers.

Preliminary cost and loss determination methodologies were determined and detailed citrus grower and National Weather Service data requirements were determined. These data requirements were reviewed with the County Extension Service and National Weather Service. The result was the determination of the specific data needs matched with the availability of data from the growers and the National Weather Service. Finally, data forms were developed which placed major emphasis upon minimizing the data collection burden on the grower. Three data forms were developed: one to gather data which may be considered as invariant during the frost season; one to gather data on the daily protection costs, events, decisions and actions; and one to gather data on fruit and tree damage. These forms were filled out for each of the groves in the sample. Sources were also developed and data obtained for citrus spot and future prices, and fuel prices.

Cost and loss determination methodologies have been developed and result in the determination of the average cost and loss per frost event per grove. The methodology allows a "normal" or average frost season to be defined in terms of number of days of different levels of frost severity at each grove. Normalized annual costs and losses for both the control and test groups are to be established, the difference between these costs and losses will be the annual benefit of the improved forecasts to the citrus growers comprising the sample. Procedures have also been developed for extrapolating these results across the Florida citrus industry, taking into account such factors as citrus type, grove location, frost protection practices, frost occurrences, and Federal Crop Insurance Corporation indices.

Methods and procedures have been developed for establishing a frost severity index based upon the duration of different levels of frost and its impact (damage) on fruit and trees. This requires knowledge of the grove temperature (as a function of time) that would have occurred in the grove if protective action were not taken. To accomplish this, methods were devised for relating National Weather Service control thermometer thermographs to grove temperature (for each grove in the database) which are then used to establish the grove frost severity index for each night of frost.

The developed data collection procedures were implemented for a control group consisting of 245 groves operated by 52 growers. With the assistance of the county extension agents, Grove Background Reports were obtained for the 245 groves. Approximately 2150 Nightly Frost/Freeze Protection Activity

Reports and several hundred Damage Reports were obtained. Additional data was provided by the Florida Crop and Livestock Reporting Service and the Federal Crop Insurance Corporation. The NWS has provided all necessary weather forecasts and control thermometer thermographs. In addition, the NWS has provided detailed temperature records of the past thirty years so that a "normal" or average year can be ascertained for control and test group comparisons.

The collected data forms have been reviewed, data transformed and entered into a computerized database. This database (of the control group) is utilized in the determination of events and average annual costs and losses. Daily costs and losses have been established for each grove and classified by event type, citrus grower type, and frost severity. Average costs and losses have been determined and annual costs and losses established for this control group. The developed capability, with suitable modifications to take into account price variations between control and test group years, will allow the results of the control and test groups to be compared and the annual demonstrated benefits to be established. These benefits, based upon the sample population, will be extrapolated to total Florida citrus industry annual benefits, taking into account grower geographic locations, geographic temperature patterns, grower crop protection capabilities, and crop type. The net result will be the establishment of demonstrated benefits and extrapolated (from the measured benefits) benefits which are the direct result of improved frost protection decisions made possible by improved temperature forecasting capability.

To summarize, the experiment for measuring the economic value of improved temperature forecasts to the Florida citrus growers has been designed, data requirements and data collection methods and procedures have been determined, and control group data collection completed. The data has been entered into a computer database. The methodology for establishing annual costs and losses has been established and initial control group analyses completed. Preliminary control group results have been extrapolated to all applicable protected citrus acreage in Florida. It is this economic value (protection costs plus economic crop losses) which is to be compared with similar data to be obtained from the experiment test group. It is anticipated that the test group results will be established during the 1977-78 and 1978-79 frost seasons.

The remainder of this report is concerned with a description of the economic experiment, the results obtained to date, and the work which still remains to be done (i.e., test group data collection and analysis and comparison of control and test group results). Sections 1.1 and 1.2 present an overview of the experiment and a summary of the experiment (control group) results obtained to date, respectively. The following sections present the pertinent details of the experiment. Section 2 describes the general value of frost forecasts to the Florida citrus industry and includes the geographical distribution and production values of citrus-producing regions, the weather sensitivity of citrus, the role of the National Weather Service (NWS), and citrus grower frost protection methods and decision processes.

Section 3 is concerned with the design of the experiment, including the concept, methodology, measurement and data collection techniques. This includes the concept of establishing control and test groups, the sampling plan, extrapolation from the sample to the Florida citrus industry and normalization of results to a standard weather pattern. Also described are the grower data collection forms and techniques; the NWS data including control thermometer thermographs, weather forecasts and minimum temperature records; and the methods used to establish citrus grove temperature profiles, frost/freeze severity measures, and the susceptibility of groves to frost/freeze damage.

Section 4 presents an analysis of costs and losses, including the cost model and loss model (fruit losses and tree losses). Also discussed is the expansion of costs and losses from the experiment sample to the Florida citrus industry and the normalization of costs and losses to a standard weather pattern. Section 5 presents an assessment of the control group results and includes additional control group experiment results (1976-77 frost season). Section 6 presents the tasks and schedules for the 1977-78 and 1978-79 test group measurements and analyses.

1.2 The Economic Experiment

The citrus grower, upon receipt of a forecast for temperatures below approximately 28°F, must decide whether or not to protect his crop. Normal protective measures (see Section 2.5) include the firing of diesel heaters or the use of electrically operated wind machines. Decisions must be made with respect to when to call in crews, when to turn heaters and/or wind machines on and off and how many heaters to utilize. These decisions affect citrus crop protection costs and losses resulting from inadequate protection measures. The purpose of the economic experiment is to determine the magnitude of the benefits which may result from improved temperature forecasts to the citrus growers. The benefits may result from cost reductions, loss reductions, and improved marketing decisions which may be the result of improved knowledge of previous nights' temperature distribution across the state. This latter benefit area, though possibly large, is not considered in the current experiment and will not be discussed further. Cost reductions will result from improved scheduling of crews due to false alarm (forecast for temperatures which would normally require the initiation of protective measures but, in actuality, the potentially damaging temperatures do not occur) reductions and improved timing of the initiation and termination of protective measures. Loss reductions will result from improved scheduling of crews due to probability of miss (the likelihood of forecasting temperatures for which protective action is not required when, in actuality, temperatures occur at which protective action is required) reduction and improved timing of the initiation and termination of protective measures.

Table 1.1 illustrates, through the use of a hypothetical though typical example, the costs and losses which may result from a grower's protection decision and actual freeze severity given a freeze forecast for minimum temperatures less than 28°F. Two situations are shown and compared, namely, (a) the grower's decision was not to protect, and (b) the grower's decision was to protect. In each case the results are illustrated, given that no freeze developed, a moderate freeze developed, and a severe freeze developed. Indicated in the table are the cost of protection, the price before the freeze, the price after the freeze (this price is a function of the freeze severity since it is assumed that, independent of the specific grower protection decision, damage will be inflicted by the freeze on other groves throughout the state of Florida and will, therefore, affect supply which in turn affects price), the expected yields before and after the freeze and resultant physical losses.

Table 1.1 An Illustrative Example of Costs and Losses In Terms of Grower's Protection Decisions and Freeze Severity*

	No Protection			Protection		
	No Freeze	Moderate Freeze	Severe Freeze	No Freeze	Moderate Freeze	Severe Freeze
Cost of Protection ($/Acre)	0	0	0	3.26	15.85	67.52
Price Before Freeze ($/Box)	2.50	2.50	2.50	2.50	2.50	2.50
Price After Freeze ($/Box)	2.50	3.00	3.25	2.50	3.00	3.25
Change in Price Due to Freeze ($/Box)	0	0.50	0.75	0	0.50	0.75
Yield Expected Before Freeze (Box/Acre)	350	350	350	350	350	350
Yield Expected After Freeze (Box/Acre)	350	170	50	350	330	300
Physical Losses (Box/Acre)	0	180	300	0	20	50
Revenue Gains or Losses** ($/Acre)	0	-365	-712.50	0	+115	+100
Economic Gains or Losses+ ($/Acre)	0	-365	-712.50	-3.26	+99.15	+32.48
Value of Protection to Grower This Night++ ($/Acre)	--	--	--	-3.26	+464.15	+744.98

*It is assumed that on this night a freeze was forecast with minimum temperature less than 28°F.

**(price before freeze x yield expected before freeze) - (price after freeze x yield expected after freeze).

+revenue change due to protective action less the cost of protection.

++economic gains or losses with protection less the economic gains or losses without protection.

It should be noted that protection cost is a function of the protection decision and the severity of the freeze. It should also be noted that the yield expected after the freeze is a function of both the protective decision and the severity of the freeze. The effect of the grower's protection decision and severity of freeze is thus seen in terms of cost of protection and physical losses (boxes/acre). The grower may be better or worse off, depending upon the combination of the change in price due to the freeze and the effectiveness of grower protective action. This is shown as the revenue gains or losses ($/acre) and may range from a large loss ($712.50/acre when no protection is undertaken and a severe freeze occurs) to a large gain ($100/acre when effective protective action is taken and a severe freeze occurs). The economic gains or losses to the particular grower are thus the revenue gains or losses less the cost of protection.

The value of protective action to the grower for the specific case illustrated in Table 1.1 is the difference between the economic gains or losses with and without protective action for the same level of frost severity. It should be noted that this example did not take into account the likelihood of freeze severity given a specific temperature forecast. This is an important factor which temporizes the numbers illustrated in Table 1.1 and is taken into account in the development of experiment results.

It has been conservatively estimated that as much as $5 million is spent on frost protection measures by the Florida citrus growers on a severe frost night. In light of the continuing increase in diesel and gasoline prices, this nightly cost may rise dramatically in the near future or losses from lack of protection may increase. In the event of tree and fruit damage, the statewide dollar loss may be measured in many millions of dollars, as this past winter has shown. Any possible reduction in both the nightly costs of frost protection and extent of freeze damage will be closely related to the strategy the growers employ once frost has been forecasted. Though many factors influence the grower's initial decision to protect and his nightly strategy, a most important factor is the confidence given to the temperature forecasts. It is felt that the satellite forecast system scheduled for operation by winter 1977 will better assist the individual grower, not only in his initial protection decision, but, more importantly, during the hour-by-hour "wait and watch" period when frequent temperature updates are received.

The Synchronous Meteorological Satellite (SMS/GOES) is currently providing temperature and other meteorological data to ground receiving stations throughout the United States. Before the frost season of 1977-78 begins, the National Weather Service Office in Ruskin, Florida will be prepared to receive SMS temperature observations of peninsular Florida and process this data with the assistance of (1) an image interpreter purchased by NASA and (2) a temperature forecast model currently under development at the University of Florida. The satellite's ability to frequently observe the entire state with 4-nautical-mile spatial resolution and 0.5-degree centigrade temperature resolution should improve both the accuracy and timeliness of NWS frost forecasts.

In order to measure the economic benefits of improved temperature forecasts it is necessary to establish and then compare the nightly costs and losses experienced by growers resulting from (1) using the improved forecasts and (2) using the present forecast system. This methodology implies the establishment of a control group (using present forecasting capability) and a test group (using the SMS/GOES-derived improved forecasts) of representative growers (see Section 3.1). Since the improved forecasts will be freely available to all growers after November 1977, it is not possible to form test and control groups simultaneously in the state of Florida. This situation dictated that the necessary isolation between the citrus growers comprising the control and test groups would have to arise from either geographic or temporal displacement. Geographic separation was quickly rejected due to problems inherent in comparing the California and Florida citrus industries. Thus it was necessary to establish the control group by time displacement, either by using existing historical cost and loss data as kept by growers, or by control group data collection during the 1976-77 season and test group data collection during following frost seasons.

The use of historical data appeared to be possible but highly risky. Numerous discussions with citrus growers in Florida indicated that there was, in general, a lack of the detailed data which was necessary to establish a statistically significant sample of costs and losses. Furthermore, the risk associated with the historical approach was compounded by the impact of fuel price increases over the past three years. Growers who would have fired all their heaters at 26°F, for example, now only fire the cold spots. Therefore, it was finally decided to establish a control group during the 1976-77 season. The same growers who participated during the 1976-77 season could then participate in the 1977-78 season and other future seasons as the test group.

The participants in the experiment are indicated in Figure 1.1. The basic timetable of the experiment is as follows. During the 1976-77 frost season, the National Weather Service provided frost and temperature forecasts to the citrus growers in a business-as-usual fashion. During the 1976-77 frost season, a selected set of citrus growers provided data on actual temperatures, decisions made and actions taken. These growers also provided cost and loss related data. The National Weather Service provided data pertaining to temperature forecasts and actual observed temperatures (in

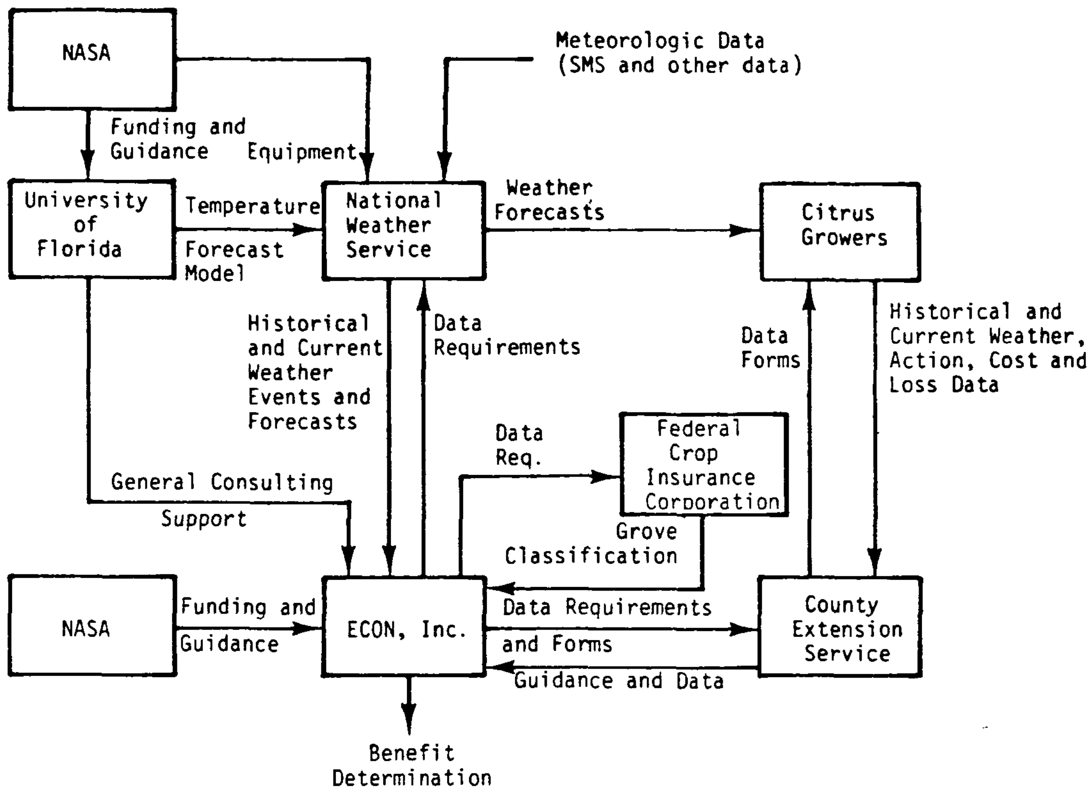


Figure 1.1 Participants in the Florida Economic Experiment

the form of thermographs). These data have been analyzed by ECON and the average cost and loss per event determined for the control group (see Section 4.0).

Current plans call for repeating the above process during the 1977-78 and possibly a following frost season. It is assumed that the SMS data, together with the University of Florida forecasting models, and improved computer and data display equipment, will be used by the National Weather Service starting with the 1977-78 frost season. It is felt that a minimum of two frost seasons of test group experience are required since it is likely that during the first season, growers and forecasters will be learning to adapt their decisions and actions to the improved information. Thus, it is likely that the 1977-78 frost season will be a transient one with the steady-state reached by the 1978-79 frost season. The uncertainty of the occurrence of frost during any particular frost season is another factor which leads to the consideration of more than one frost season for the test group.

The data provided by the test group will, as in the case of the control group, yield average cost and loss per event. As described in following pages, both the control and the test group cost and loss per event data can be extrapolated to the annual cost and loss for the Florida citrus industry for an average frost season (see Section 4.0). The difference between the control group and test group annual costs and losses extrapolated to an average frost season will provide an estimate of the average annual benefits which are a direct result of the improved information. These benefits will include the reduction of citrus grower frost protection costs and the reduction of crop losses that are the result of improved decisions which are due to the improved information. The benefit assessment will not include, because of the limited number of frost seasons and, hence, data samples, those benefits which are the result of better marketing decisions made possible by the improved temperature distribution knowledge provided by the SMS data.

The task of determining economic benefits for the Florida citrus industry is not as easy as it first appears, due to the following major difficulties:

- Accounting for factors which influence the sample grower's frost protection decisions, although these factors are not related to improved temperature forecasts
- Accounting for differences in cold weather severity between the 1976-77 frost season and 1977-78 frost season
- The construction of a representative sample that is not too costly.

These points are discussed in the following paragraphs.

Figure 1.2 illustrates, in a simplified form,* sixteen various events that are of concern to the experimenter in terms of actual weather conditions, NWS frost forecast, grower belief of the NWS forecast and grower actions. The actions which are possible on the part of the citrus grower are classed as protect or no-protect actions. Protective action implies the utilization of heating devices and/or wind machines. No protection implies the lack of utilization of heating devices and/or wind machines. The no-protection events are subdivided so that no-protect situations which arise from either too short notice to take protective action or other constraints (for example, inoperative equipment) are clearly delineated. For each of the events or situations there are costs and losses. The only costs of concern are those associated with frost protection, C_I, and losses which result from inadequate or lack of protection, L_I. N_I represents the number of days out of N that the $I^{\underline{th}}$ event has occurred during the frost season. (Sections 4.2 and 4.3 present the details of the citrus grower cost and loss models). For example, consider event I=13. This represents the situation where frost which was forecasted actually occurred and the grower believed the forecast and protected his grove; protection costs and losses (possibly zero) were incurred which were dependent upon the severity of the frost. For the case I=9, where frost was forecasted but did not occur, (i.e., false alarm)

*The methodology described herein is, for the sake of clarity, a simplification of that actually employed and is presented to convey only the general concept and content of the experiment. The actual detailed procedures differ only slightly and are described in the following sections and appendices.

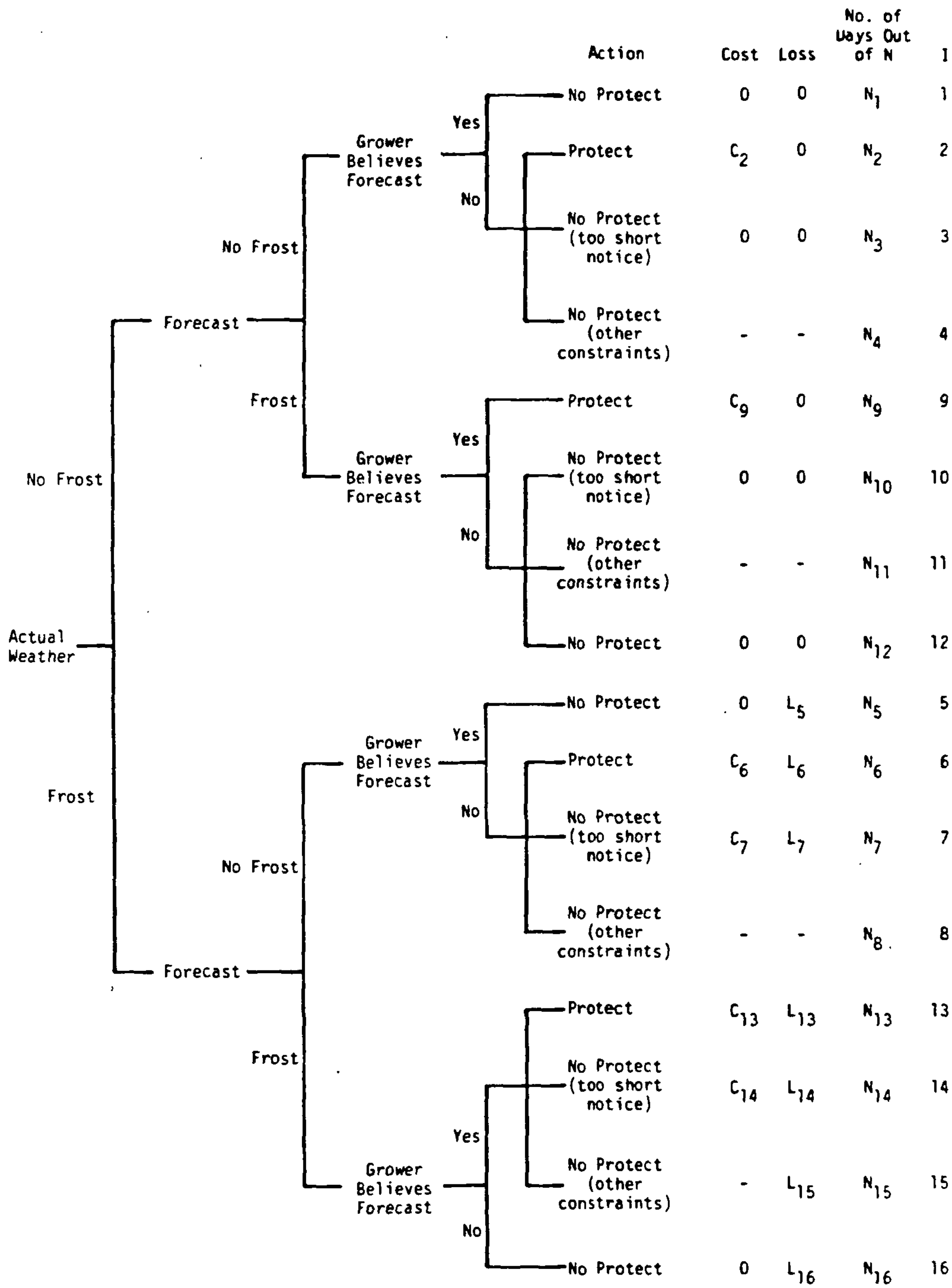


Figure 1.2 Event Descriptions

and the grower believed the forecast, protective action was taken and protection costs incurred but no crop losses occurred.

Note that all of the C, L and N variables have been subscripted by I, the event as illustrated in Figure 1.2. This has been done for the sake of simplification. In general, a more complex subscripting notation is employed of the form:

I = event type

J = citrus grower type

K = citrus grower identification (i.e., grove designation)

M = frost severity index

D = day.

J is an index which represents citrus grower type where geographic, operating practices, and crop differences are taken into account. Thus each participating citrus grower, at the individual grove level, will fall into one of the J types. K is an index which represents the identity of the groves within the J classification. The $K^{\underline{th}}$ grove represents the smallest geographic sector for which data are available and/or the largest sector for which constant weather, decision, cost and loss characteristics exist. The sample growers, indicated by the K subscript, may be classified by type and grouped accordingly.

For the purpose of this analysis, it was necessary to develop a reference frame which could be utilized to compare frost protection and loss data obtained for like events within a frost season and during <u>different</u> frost seasons. For this purpose, the M index is employed and corresponds to the relative damage potential of specific ranges of frost intensity and duration (see Section 3.6). The damage potential, considered separately for fruit and trees, is related to degree-hours per day below a baseline temperature (for example, 28°F). The assumed relationship, as estimated by the University of Florida, is as illustrated in Figure 1.3, where zero (0) implies no damage or loss and ten (10) implies total loss.

Therefore, with the above notation in mind, on any particular day, D, a grower will experience, in general, costs associated with protection, $CST_{I,J,K,M,D}$, and losses, $LOS_{I,J,K,M,D}$, resulting from inadequate or lack of protection when frost occurs. Therefore, the like event costs and losses averaged over a frost season are:

$$EXP_{I,J,K,M} = \frac{1}{N_{I,J,K,M}} \left\{ \sum_{D=1}^{MAXD} CST_{I,J,K,M,D} + \sum_{D=1}^{MAXD} LOS_{I,J,K,M,D} \right\}$$

where $N_{I,J,K,M}$ is the number of days, during the time period consisting of MAXD days, that the event or situation I occurred with "magnitude" characterized by M to the $K^{\underline{th}}$ grove of type J. Note that events associated with I = 4, 8, 11 and 15 are not to be considered in the cost and loss computations. The reason for this is that these events are the result of constraints upon the grower choices of action which have little or nothing to do with the weather forecasts, actual weather and grower believability of the forecasts.

As mentioned previously, the M subscript is a measure of the severity of the frost and is related to the degree-hours of frost. The severity of the frost (in terms of the degree-hour measure) cannot normally be measured in the grove which has undergone protective action since the protective action, as is its purpose, perturbs the temperature that would have occurred if protective action had not been taken. Therefore, it is necessary to obtain

Temp. [°F]	Degree Hours At A Given Temperature											
	1	2	3	4	5	6	7	8	9	10	11	12
28	0/0	0/0	0/0	0/0	0.5/0	0.75/0	1/0	1.25/0	1.5/0	1.75/0	2/0	2/0
27	0/0	1/0	2/0	2/0	3/0	4/0	4.25/0	4.5/0	4.75/0	5/0	5/0	5/0
26	0/0	1/0	2/0	3/0	4/0	4.3/0	4.6/0	5/0	5/0	5/0	5/0	5.5/0
25	1/0	2/0	3/0	4/0	4.5/0	5/0	5.2/0	5.4/0	5.5/0	5.7/0	5.85/0	6/0
24	1.5/0	2.4/1	4/1	4/1	4.5/1	5/1	5.3/1	5.7/1	6/2	6.5/2	7/2	8/2
23	2/1	2.7/1	4/1	4.1/1.2	5/1.5	6/1.75	7/2	7.5/2.2	8/2.4	9/2.6	10/2.8	10/3
22	2.5/1.3	3/1.6	4/1.8	5.5/1.9	7/2	8/2.3	10/2.6	10/2.9	10/3.2	10/3.5	10/3.8	10/4
21	3/2	3.5/2	5/2	6.5/2	8/3	10/3	10/3	10/3	10/3.5	10/4	10/4.5	10/5
20	4/2.5	5/2.75	6/3	8/3.3	10/3.6	10/4	10/4.3	10/4.6	10/5	10/5.6	10/6.3	10/7
19	4.5/3	6/4	7.5/5	9/5.5	10/6	10/6.3	10/6.6	10/7	10/7.5	10/8	10/9	10/10
18	5/4	7/5	9/6.5	10/8	10/9	10/10	10/10	10/10	10/10	10/10	10/10	10/10

Figure 1.3 Preliminary Severity Measure of Frost/Freeze as Estimated by Dr. Gerber and Dr. Bartholic, University of Florida (Note: Upper numbers refer to fruit and lower numbers refer to trees)

temperature profile measurements on control thermometers of the NWS or other nearby locations where temperatures are not perturbed by the protective actions of growers and, thence, to relate these temperature profiles to those which would have occurred in the grove if protective action were not taken. It is this latter temperature which is utilized (together with duration) as a measure of grove frost severity. Estimates were obtained of the relationship between specific control thermometers and the groves in the experiment. Adjustments were made as necessary when data was obtained from grower control thermometers.

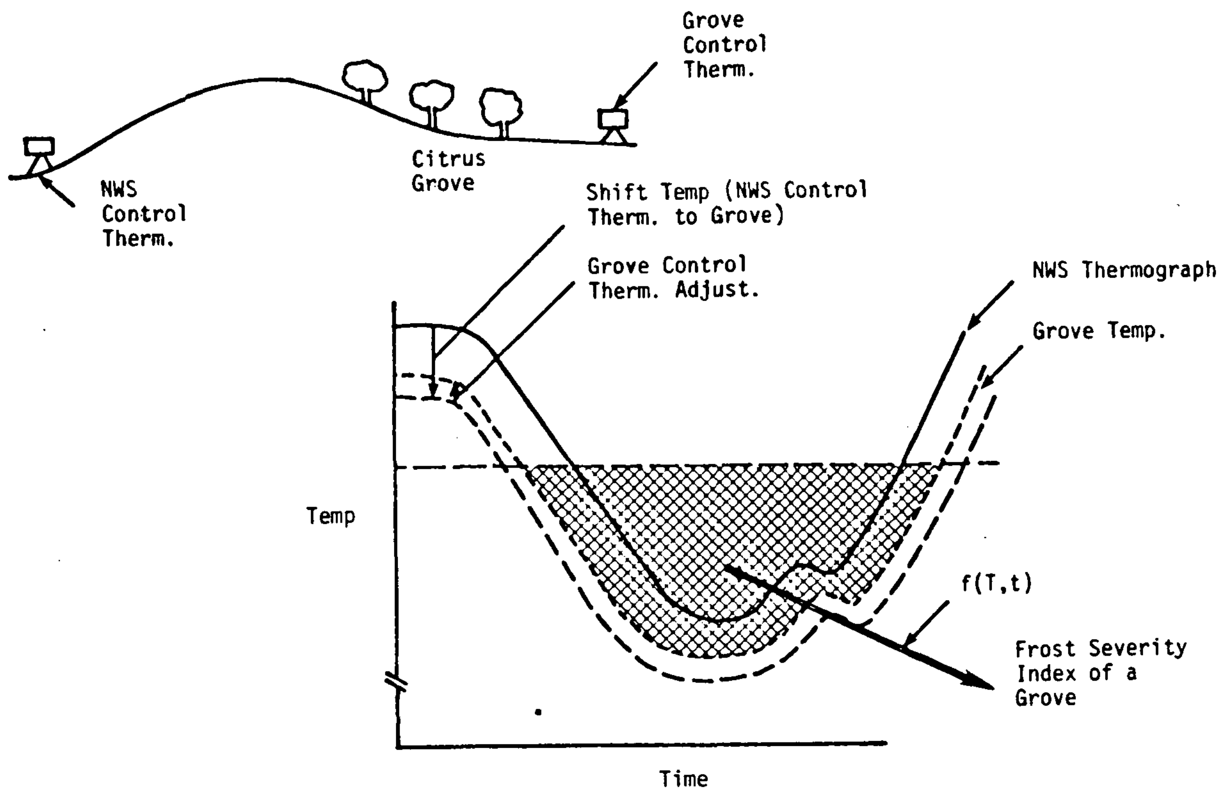


Figure 1.4 Frost Severity Determination

Figure 1.4 illustrates a typical thermograph and the adjustment procedure used for establishing frost severity. (See Section 3.6 for the details of the severity index computation.)

Thus each night of freezing temperatures is characterized by a frost severity index which summarizes its potential impact upon fruit and trees. This characterization is accomplished for each grove along with protection costs and fruit and tree losses. A regression analysis is thence performed (for each fruit type and county) which relates costs and losses to severity of freeze (see Section 4.0). A hypothetical relationship between severity of freeze and economic costs (protection cost and fruit and tree losses) is illustrated in Figure 1.5. Two curves are shown: without SMS and with SMS.

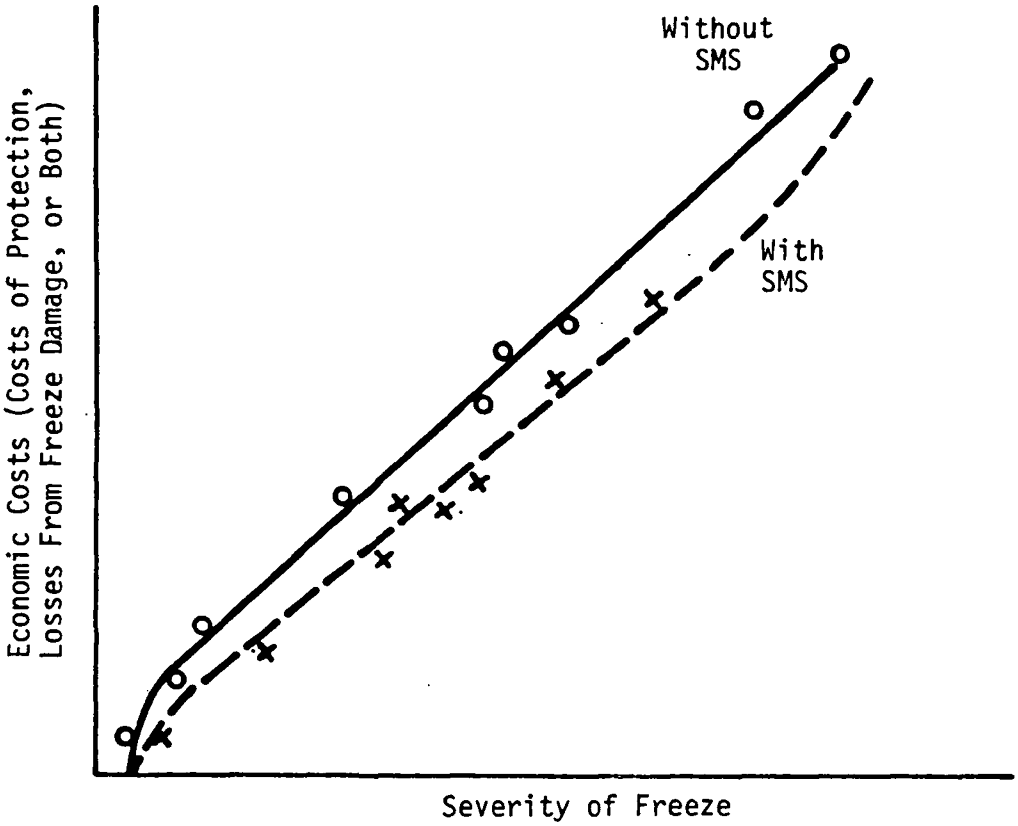


Figure 1.5 Hypothetical Relationship Between Weather Events and Economic Effects With and Without SMS Data

The former implies the control group data using conventional forecasting techniques and the latter implies the test group data using temperature forecasts which incorporate the SMS/GOES data as processed by the University of Florida temperature forecasting models.

In order to establish a measure of the economic benefits which may result from the improved forecasts that are expected to result from the use of the SMS/GOES data and the University of Florida temperature forecasting models, it is necessary to compare the economic costs of the control and test groups as they would have occurred for the same frost season. It should be remembered that the control group data was collected during the 1976-77 frost season and test group data will be collected starting with the 1977-78 frost season. It should also be noted that neither of these frost seasons may be normal or "typical." To ensure that a fair comparison is made of the control and test group results, 30 years of control thermometer temperature data was obtained from the National Weather Service (see Appendix D). This allows 30 frost seasons to be characterized in terms of the severity of freeze index and normal or average frost seasons to be characterized in terms of the number of frost days of different severity levels. This characterization is accomplished at the individual grove level.

Thus the average annual benefits, $\overline{B}$, can be obtained as

$$\overline{B} = \sum_{\substack{M \\ G}} N_{M,G} * [EC_{M,G} - EC'_{M,G}]$$

where $N_{M,G}$ is the number of days of severity M at grove G and EC and EC' represent the economic costs of the control and test group groves, respectively.

To summarize briefly, the economic benefits of improved temperature forecasting capability will be obtained as the result of establishing the relationship between costs and losses and freeze severity (and possibly) other explanatory variables) and, thence, specifying a normal or average frost season in terms of the number of days of different levels of freeze severity. Data have been collected during the 1976-77 frost season which permits the establishment of the cost/loss/freeze severity relationship for the control group. Data will be collected during the 1977-78, and possibly following, frost seasons to establish the cost/loss/freeze severity relationship for the test group. Data have been obtained from the NWS and a normal or average frost season has been characterized in terms of the number of days of different levels of frost severity. Upon completion of test group data collection, the economic benefits of improved temperature forecasting will be obtained.

The overall experiment has been described. The establishment of costs and losses per event is now discussed. Cost and loss per event are obtained from the manipulation of data provided by the citrus growers for each of the groves contained within the experiment sample (see Section 4.0). Grove data is provided on three separate forms: Grove Background Report, Nightly Frost/Freeze Protection Activity Report, and Damage Report. The Grove Background Report, filled out prior to the start of the frost season, provides the following information for each grove: identification and location; citrus variety and rootstock; grove age and percentage resets; grove area, terrain, soil type and influence of large bodies of water; FCIC classification; availability of control thermometer data; month of harvest; average yield for each of the past three seasons; estimate of yield for current season; original intent to produce for fresh or processed market and reasons for choice; wind machines and/or heaters (type, number, type of fuel, average fuel consumption rate).

The Nightly Frost/Freeze Protection Activity Report, filled out only if a fruit frost bulletin by the NWS predicted the lowest temperature to be 28°F or less for the zone within which the grove is located or frost/freeze protection was undertaken (regardless of predicted temperatures) and costs were incurred, provides the following information for each grove: grove identification; date of frost occurrence and/or cost incurrence; specific NWS forecast which influenced action; level of confidence in NWS forecast; labor costs associated with frost/freeze protective action; number and type of wind machines used and time turned on and off; number and type of heaters used and time fired and extinguished; total mileage (trucks and autos) incurred during frost/freeze protective action; minimum temperature recorded on grove control thermometer; observation of damage to fruit and/or freeze not previously reported; if no protective action was taken, reasons why.

The Damage Report, filled out only when damage is observed to fruit and/or trees, provides the following information: grove identification and date; the date of frost/freeze which caused damage; type of damage (fruit and/or tree); manner of marketing fruit before and after damage (fresh or processed); estimated yield prior to and after damage; if there was tree damage, an estimate of the number of years to recover to full production.

The data obtained from these forms, plus pricing data (fuel, fresh fruit and processed fruit), provides the basis for the establishment of cost and loss per event (see Section 3.4). The cost per event consists of three components, namely, (1) labor costs, (2) fuel costs and (3) automobile and truck mileage cost. The loss per event consists of fruit loss and tree loss. The fruit loss is associated with yield in complex ways. The grower who intended to market fresh fruit may, after suffering damage, simply market fruit for processing, at little loss in total yield but with appreciable loss in dollar value. The grower loss per event takes into account both price changes and yield changes.

Economic gains or losses to the grower are dependent upon what has happened in the industry as a whole. Estimates of the change in expected industry production have been obtained from the Florida Crop and Livestock

Reporting Service. From these figures, together with price information and price elasticity, estimates of total industry loss of fresh and processed fruit are derivable and can thence be prorated to individual groves based upon reported yield reductions and market. Tree damage losses are established as the present value of the production losses in future years due to a particular frost event. This utilizes the grower's estimate of the level of tree damage and the number of years before full recovery. In order to translate reduced production estimates into economic losses it is also necessary to forecast average on-tree prices for several years into the future.

Table 1.2 presents an estimate of the grower survey population in terms of the number of growers, total acreage (Lake, Orange and Polk counties) and number of groves. Estimates are also presented for the number of growers who have protected groves, the number of groves which are protected and the protected acreage. Table 1.2 also indicates the number of growers who are participating in the experiment, the number of groves and their total acreage. This represents approximately a 20-percent sample based upon number of protected groves and a 17-percent sample based upon protected acreage. The geographic distribution of the experiment sample population is illustrated in Figure 1.6.

The selection of the sample groves was based upon many factors. The more important factors considered were cooperation of growers and grove managers, geographic location, fruit type, and frost protection measures. The County Extension Agents served as the interface with the growers, explaining the data collection forms and collecting and reviewing the grower data.

Table 1.2 Estimate of Grower Survey Population and Actual Control Group Size			
	Total Acreage	Growers	Groves
Total*	326,000	7,200	8,000 - 9,000
Frost Protected*	51,000	230	1,200 - 1,300
Frost Protected & Control Group Participants	8,616	52	245
*Lake, Orange and Polk Counties			

Typical control group results are illustrated in Figures 1.7 through 1.10 (detailed results are presented in Sections 6.5 and 6.6). Figure 1.7 illustrates the average or mean severity (in terms of the previously described severity of frost index) of frost by date. Two columns are shown for each day; the column on the left indicates the mean severity when considering only those groves for which freezing temperatures (i.e., below 28°F) were experienced, whereas the column on the right indicates the mean severity when considering all groves in the database. The difference in the height of these columns is a measure of the lack of uniformity of the frost.

Figure 1.8 illustrates the percent of sample groves undertaking protective action on each cold night and Figure 1.9 indicates the average per acre cost of protection on each cold night for groves that experienced protection costs and for all groves in the database. The average cost of protection for the 1976-77 crop year varies considerably by county, ranging from a high of $109/acre in Hillsborough to a low of $32/acre in Marion County (see Table 4.5). Because of these large variations, all analyses and extrapolations must be done by citrus variety and county.

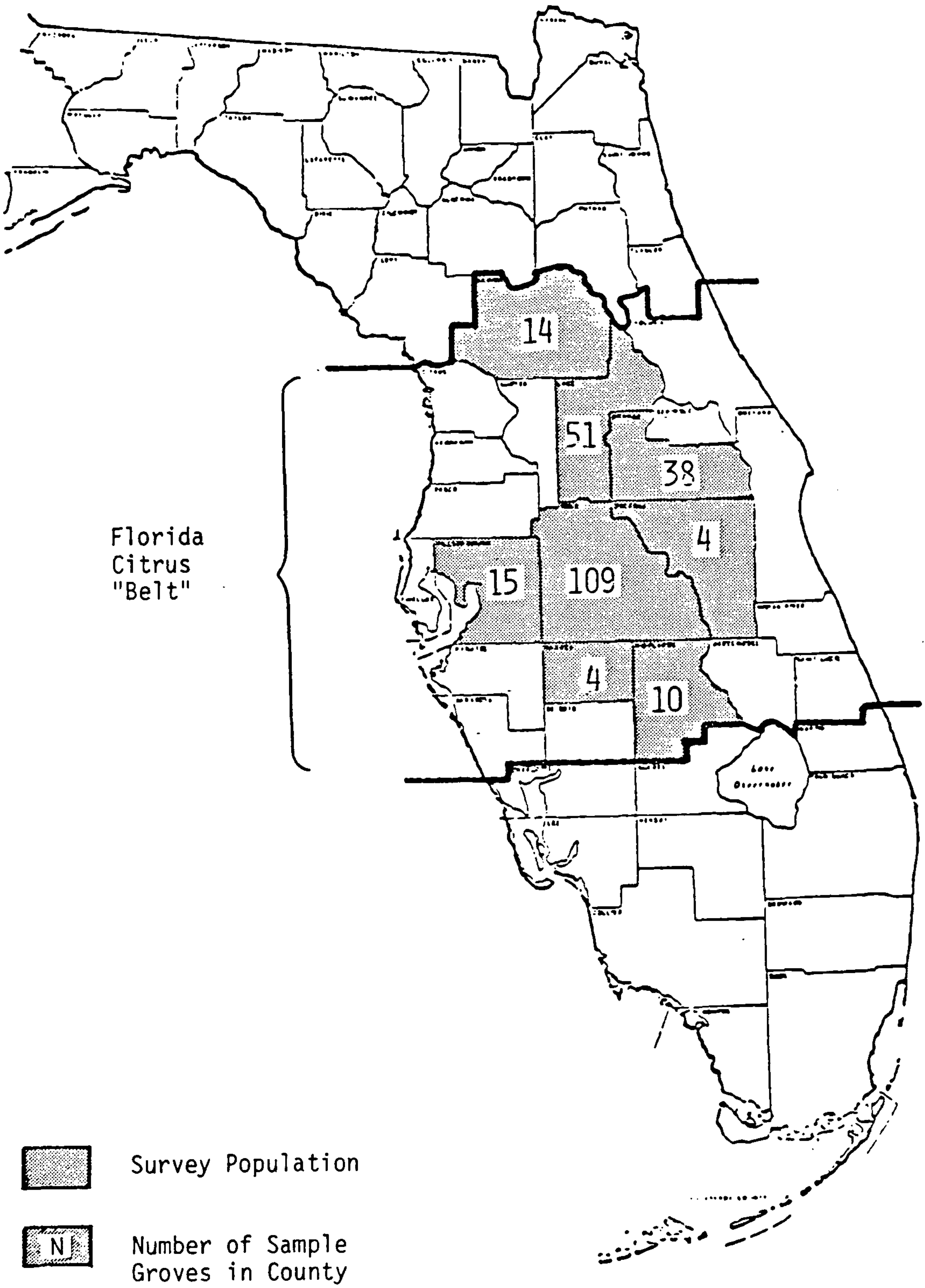


Figure 1.6 Sample Grove Distribution

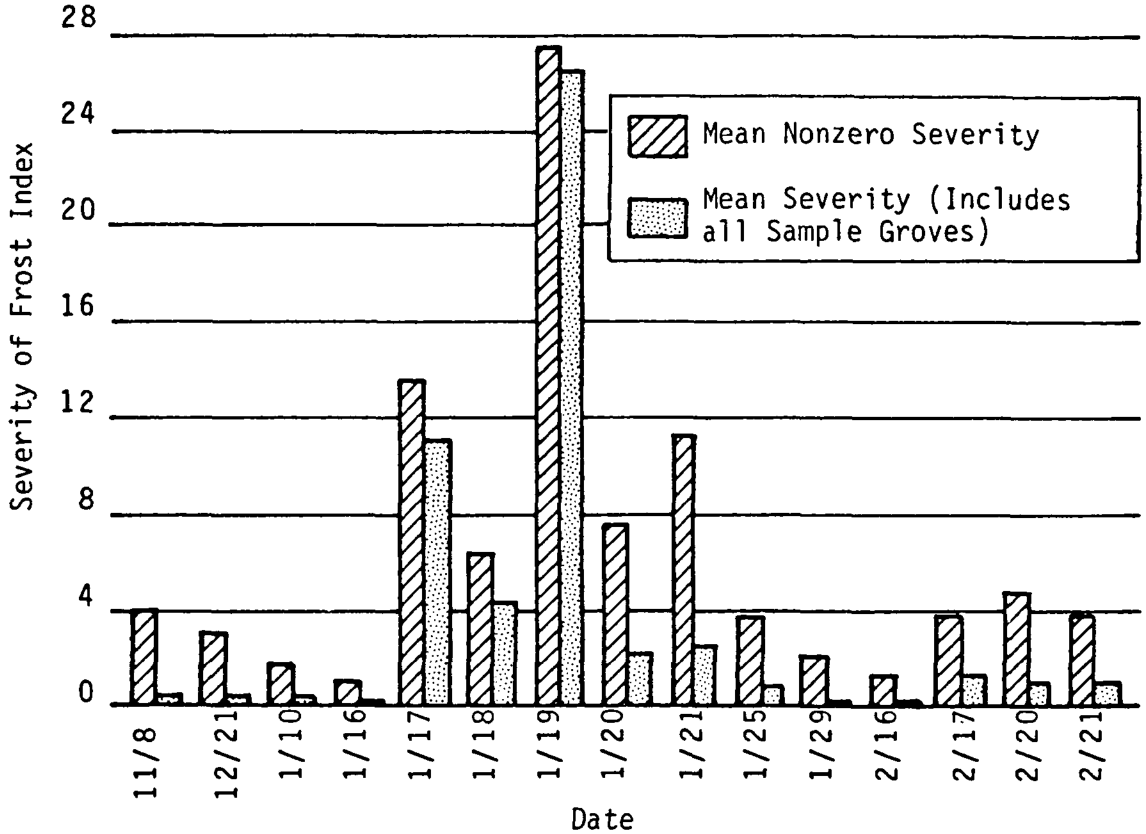


Figure 1.7 Mean Severity of Frost by Date

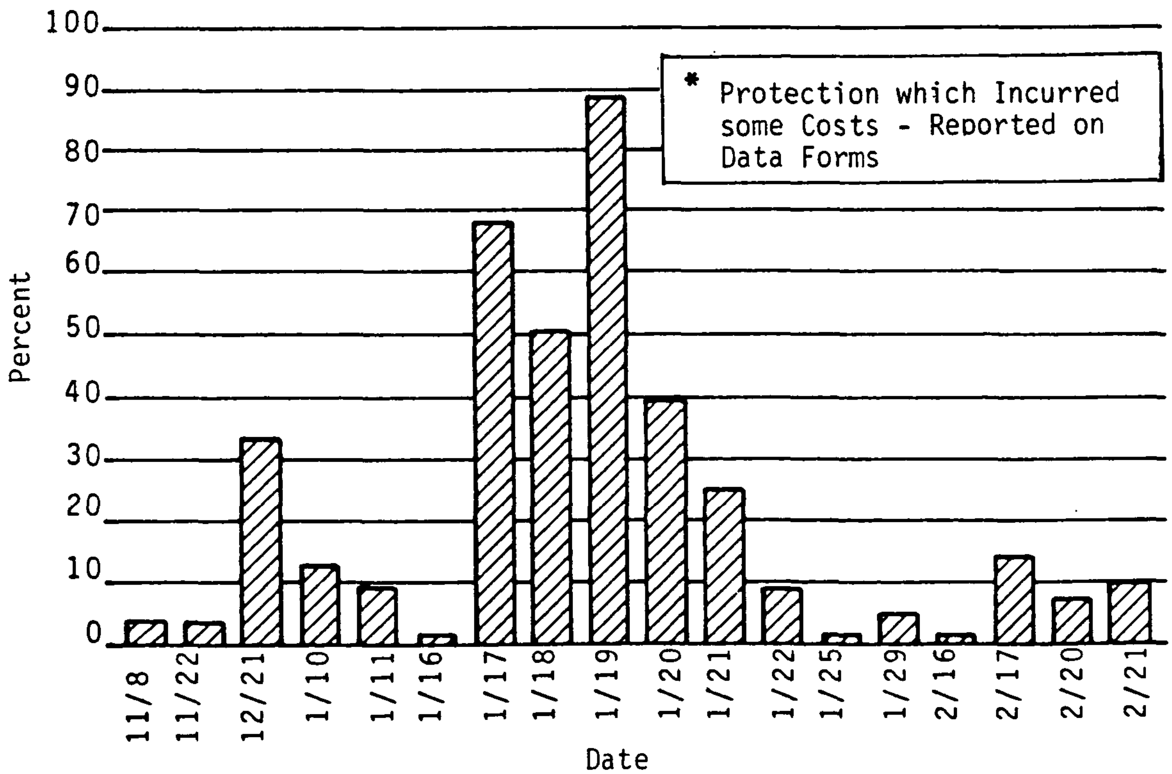


Figure 1.8 Percent of Sample Groves Undertaking Protection*on Each Cold Night

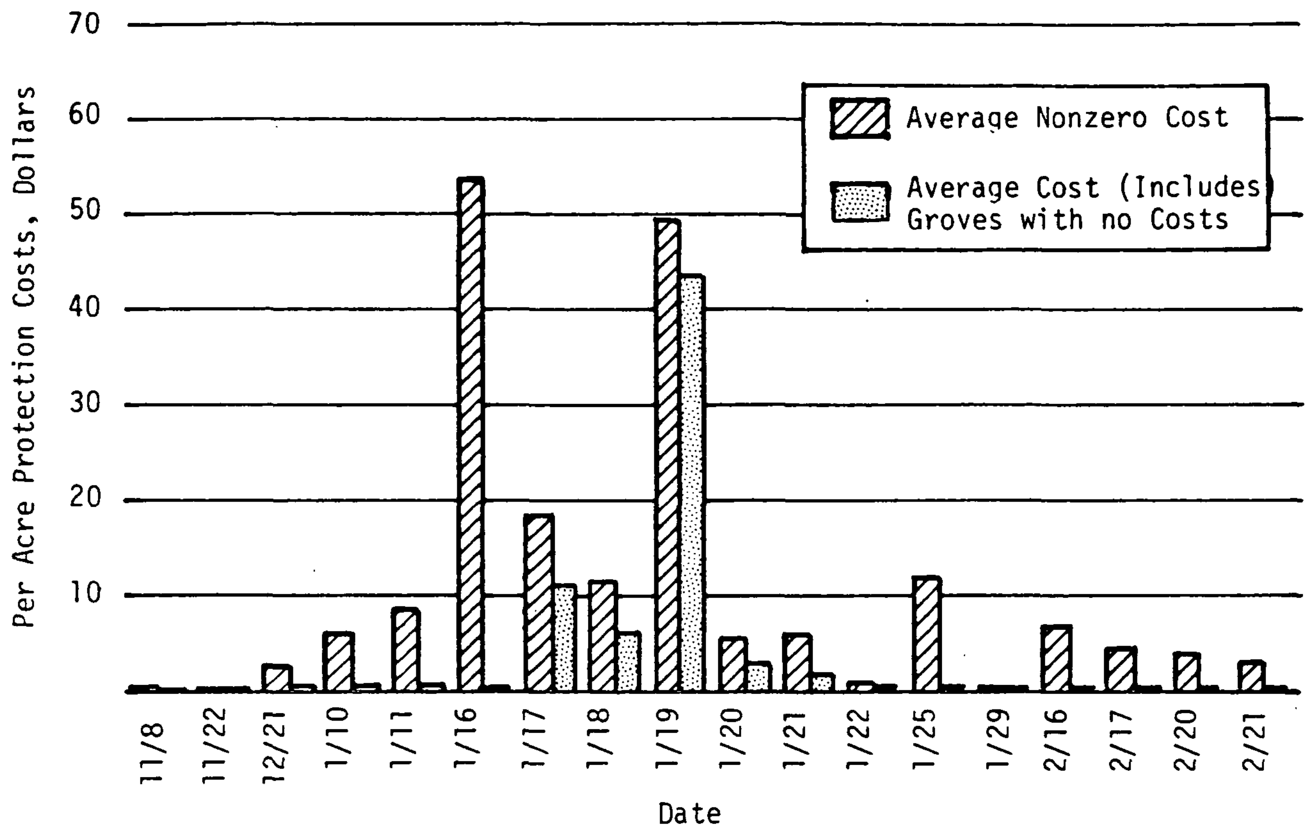


Figure 1.9 Average Per Acre Cost of Protection for Each Cold Night

Figure 1.10 indicates the physical losses for all groves in the control group sample, by frost date. There are two types of losses that can occur due to a freeze. One is a loss of quantity, when fruit is so badly damaged that it drops to the ground or is not worth picking. The second is a loss of quality, when fruit which was originally intended for the fresh market is no longer suitable for fresh sale and must be processed, or when fruit intended for processing loses some of its sugar and juice content so that its yield in pounds-solids declines.

Some growers in the sample experienced total losses of all or part of their fresh or processed fruit. Most were able to save their fruit by diligent protection, but in many cases the damage caused a shift of marketing plans from the fresh sector to the processed one, or a loss in pounds-solids.

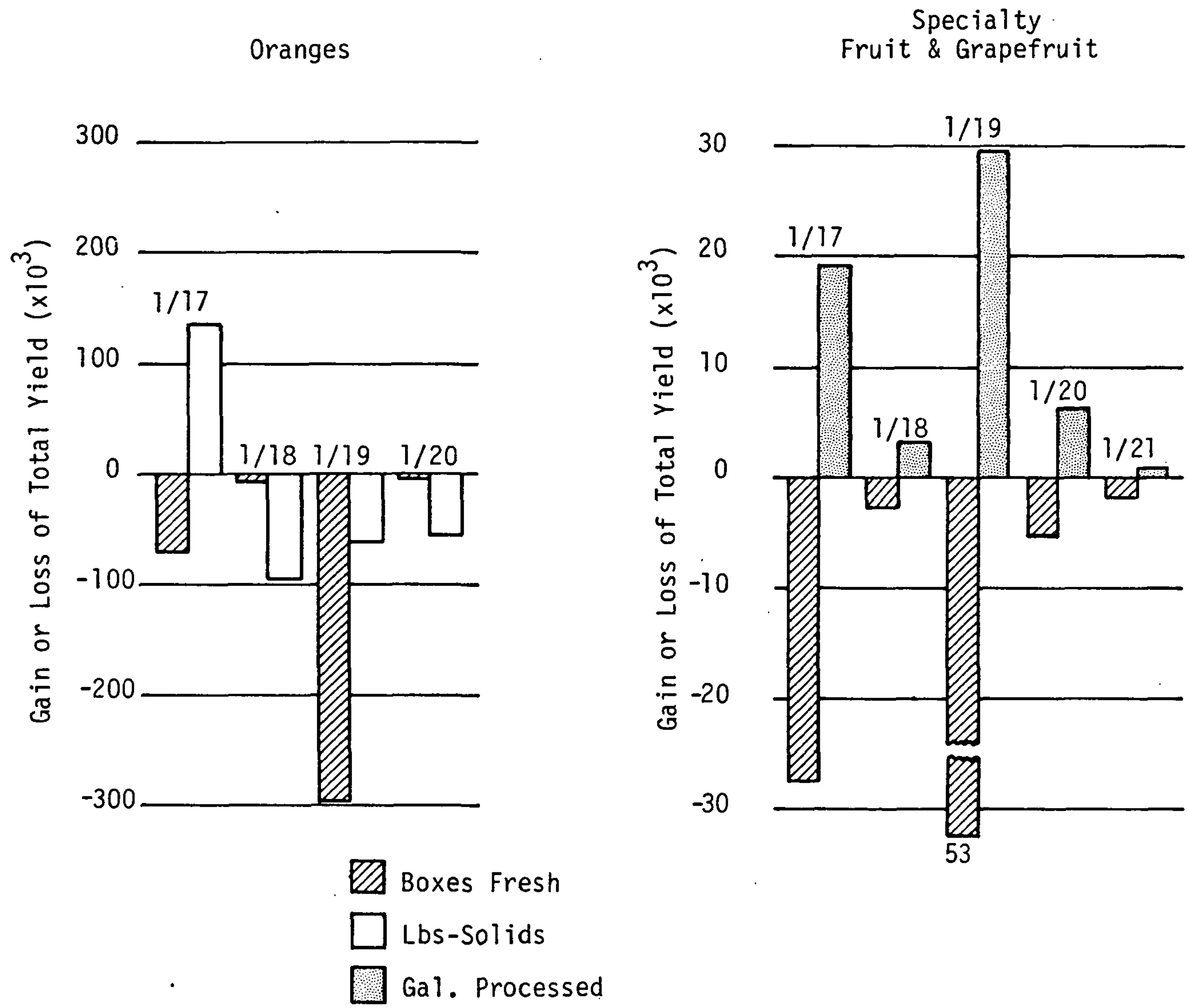


Figure 1.10 Gain or Loss by Night for Groves in Control Group Sample which Suffered Crop Damage

On the average, a large amount of fresh fruit was lost on each of the frost/freeze nights, but due to the shift from fresh to processed, there was a samplewide gain in pounds-solids. Because of some absolute losses, and because of the overall decline in the juice and sugar content in the total crop, these gains do not totally offset the fresh fruit losses.

Figure 1.10 indicates the loss of fruit intended for the fresh fruit market and the gain in fruit for the processed market--the gain is the net of fruit intended for fresh but marketed as processed and the yield reduction of that fruit originally intended as processed.

Regression analyses are underway to relate the developed data on costs and losses to the frost severity index. As of the date of this report, no conclusive results (in the form indicated in Figure 1.5) have been obtained on the cost-loss-severity relationship due, primarily, to the late arrival of damage report data from the growers.

The data presented in the previous tables and figures are based upon information provided by the Florida citrus growers. The basic data were provided by 52 growers covering 245 groves; 2150 Nightly Frost/Freeze Protection reports were provided by the growers. These reports are filed whenever a frost is forecast (i.e., less than 28°F) and/or costs or losses were incurred. Approximately 86 percent of the reports, as per the filing criteria, were submitted by the growers. Two hundred eighty-seven Damage Reports were also filed by the growers. These reports are required whenever damage is observed. Approximately 90 percent of the anticipated damage reports were submitted by the growers.

The economic experiment has been summarized in the previous pages and is discussed in detail in the following pages. Results of the control group data collection and analyses have been summarized in terms of control group costs and losses. At this point in time it is not possible to establish the benefits of improved temperature forecasting to the Florida citrus growers since this must await test group data collection and analysis and the comparison of the control and test group results. Thus, future efforts will be devoted to a repeat of the previously described data collection and analysis but with the improved temperature forecasting capability being available. A comparison of the test group results with the control group results will then be accomplished.

2. FROST/FREEZE FORECASTS AND THE FLORIDA CITRUS INDUSTRY

Frost/freeze forecasts play an important role in the decision process of growers concerned with the protection of their citrus groves from the damaging effects of low temperatures. In order to assess the value of frost forecasts to the Florida citrus industry it is necessary to understand the industry's production values, the relation of citrus producing regions' climate and their geographical distribution, the weather sensitivity of citrus, as well as the role of the National Weather Service in the frost forecasts, and the frost protection methods and decision processes.

This section provides an overview of the Florida citrus industry so that the economic portion of the Florida temperature forecasting experiment can be viewed in the proper perspective.

2.1 Geographical Distribution and Production Value of Citrus Producing Regions

The areas in the United States which are most suitable for citrus production are located predominantly in the subtropical regions of the southeast and southwest (Figure 2.1). These regions have climates which are relatively free from freezing temperature and wind hazards. Florida is the major producing region with almost 75 percent of the total U.S. production. The second largest citrus growing region is southern California. Additional areas having important citrus crop production are located in Texas and Arizona.

The general term "citrus" includes early, midseason and late (valencia) oranges, grapefruits, tangerines, tangelos, temples, lemons and limes. The major citrus products are oranges and grapefruits with the remainder

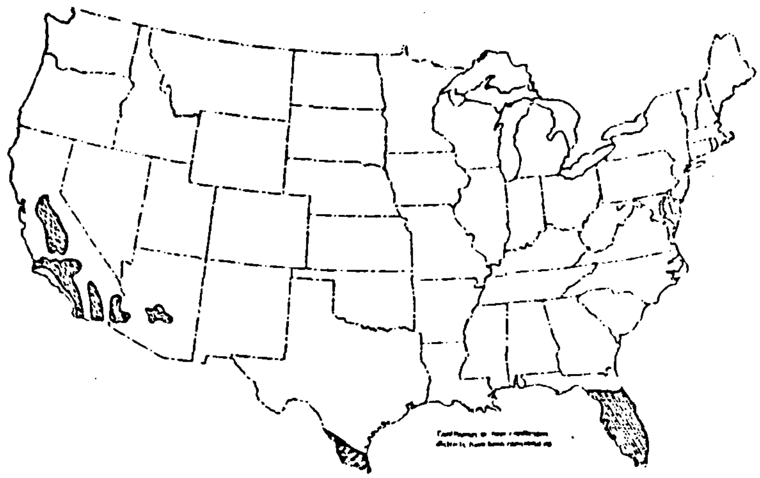


Figure 2.1 Citrus Producing Regions in the U.S.

normally referred to as "specialty fruit." Lemons and limes are grown in the most southern part of Florida where low temperatures rarely occur.

The total U.S. citrus-producing acreage and production is listed by state, for the 1956-1976 time period, in Table 2.1. There was a total of 1,193,600 citrus-producing acres in 1976 (excluding honey tangerines, limes and lemons) of which 796,200 acres (66.7 percent) are in Florida. The detailed geographical distribution of the two main citrus products, oranges and grapefruits, throughout Florida is shown in Figures 2.2 and 2.3, respectively.

The United States is the leading producer of citrus in the world. The total world production of oranges in the year 1975 season was 767.0 million boxes, of which 242.7 million (31.6 percent) were produced in the United States. As far as the grapefruit production is concerned, the United States share is even larger. From the total worldwide crop of

Table 2.1 Principal Citrus Fruits: Bearing Acreage and Production, by States, Crop Years 1956-57 Through 1975-76

Crop Year	Florida		California		Texas		Arizona		United States[2]	
	Bearing Acreage 1,000 Acres	Production[1] 1,000 Tons	Bearing Acreage 1,000 Acres	Production 1,000 Tons	Bearing Acreage 1,000 Acres	Production 1,000 Tons	Bearing Acreage 1,000 Acres	Production 1,000 Tons	Bearing Acreage 1,000 Acres	Production 1,000 Tons
1956-57	536.2	6,025	210.1	2,025	56.7	184	13.6	118	821.1	8,357
1957-58	493.6	5,164	207.2	1,581	59.1	230	13.8	136	777.2	7,120
1958-59	490.6	5,591	202.4	2,219	65.1	271	14.9	96	776.9	8,187
1959-60	508.2	5,581	197.9	1,879	71.1	329	17.3	202	798.0	8,003
1960-61	513.4	5,512	195.3	1,537	76.1	429	18.4	139	806.6	7,629
1961-62	548.1	6,830	190.8	1,438	78.8	211	20.3	182	838.4	8,673
1962-63	497.0	4,773	185.1	1,625	71.0	5	22.3	147	775.4	6,550
1963-64	507.3	3,969	186.5	1,974	62.9	31	24.4	252	781.4	6,226
1964-65	557.1	5,480	181.3	1,802	62.8	120	26.7	231	830.3	7,633
1965-66	598.7	6,242	187.3	2,044	64.8	211	30.3	271	881.1	8,768
1966-67	653.0	8,643	192.8	2,139	68.6	338	37.3	316	951.7	11,436
1967-68	692.4	6,364	201.9	1,406	72.6	193	34.6	367	1,001.5	8,330
1968-69	746.1	8,008	213.5	2,316	80.8	471	34.2	421	1,074.6	11,216
1969-70	817.1	8,308	197.2	2,130	75.9	395	32.2	513	1,122.4	11,346
1970-71	866.7	8,785	203.0	2,118	79.0	683	37.0	349	1,185.7	11,935
1971-72	824.2	8,760	213.1	2,368	80.1	629	40.4	403	1,157.8	12,160
1972-73	820.2	10,124	221.9	2,497	70.0	804	50.8	469	1,162.9	13,894
1973-74	817.3	10,088	269.1	2,285	67.5	709	52.7	330	1,206.6	13,412
1974-75	812.7	10,337	272.7	3,197	64.1	485	55.6	573	1,205.1	14,592
1975-76	796.2	10,943	272.1	2,832	64.1	692	61.2	316	1,193.6	14,783

[1] Does not include lemons, honey tangerines or k-early citrus fruit.

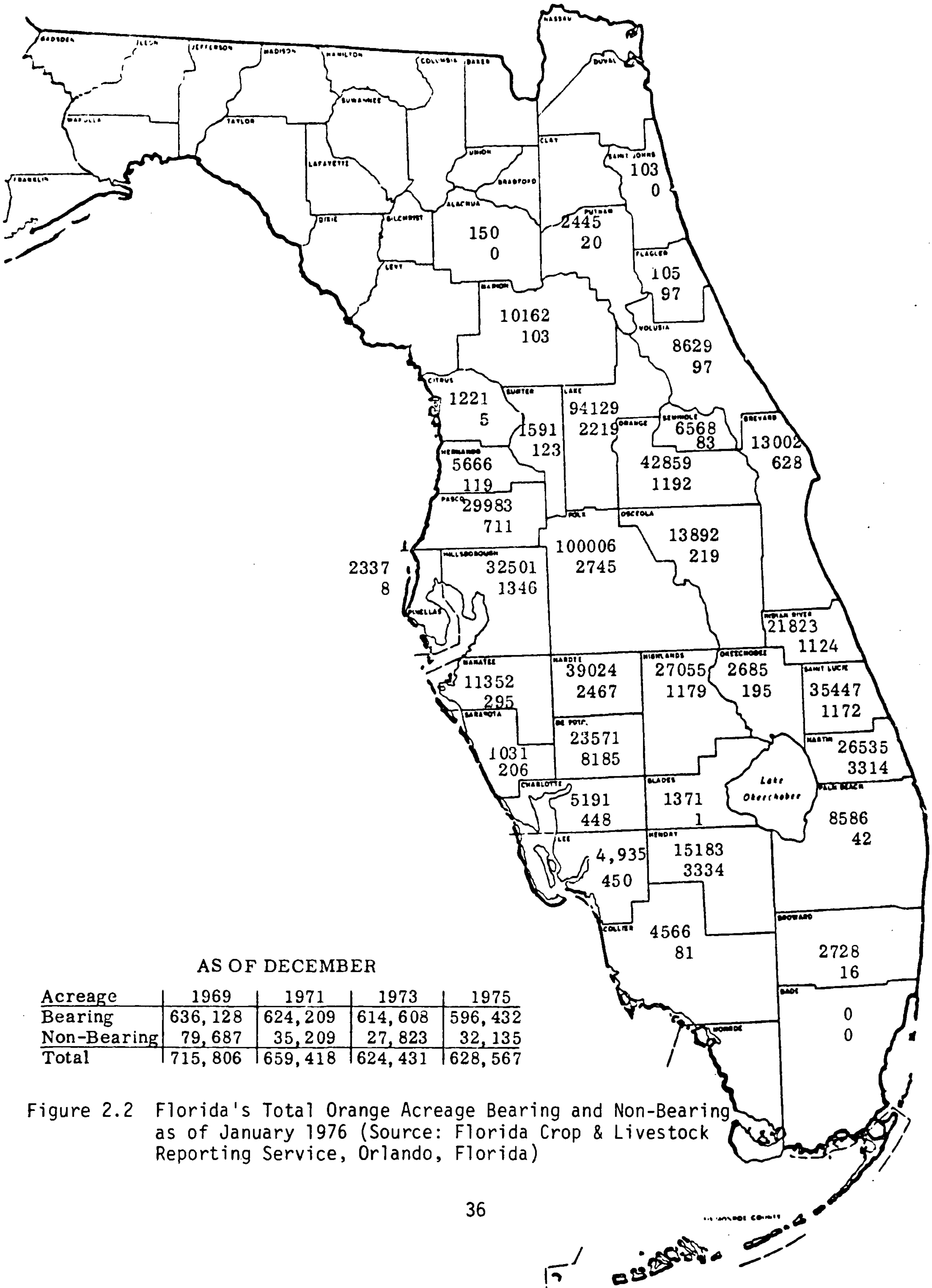
[2] Years before 1965-66 include some data for other states.

Source: Florida Crop & Livestock Reporting Service, Orlando, Florida.

93.8 million boxes, almost 74 percent (69.0 million boxes) were grown in the United States according to the Foreign Agricultural Service of USDA.

As already stated, Florida is the major citrus-producing region in the United States. Florida produced 77.8 percent of the U.S. oranges (8,154,000 tons out of 10,479,000 tons) and 73.3 percent of the U.S. grapefruits (2,088,000 tons out of 2,850,000 tons) in the 1975-76 season as reported by Florida Crop & Livestock Reporting Service.

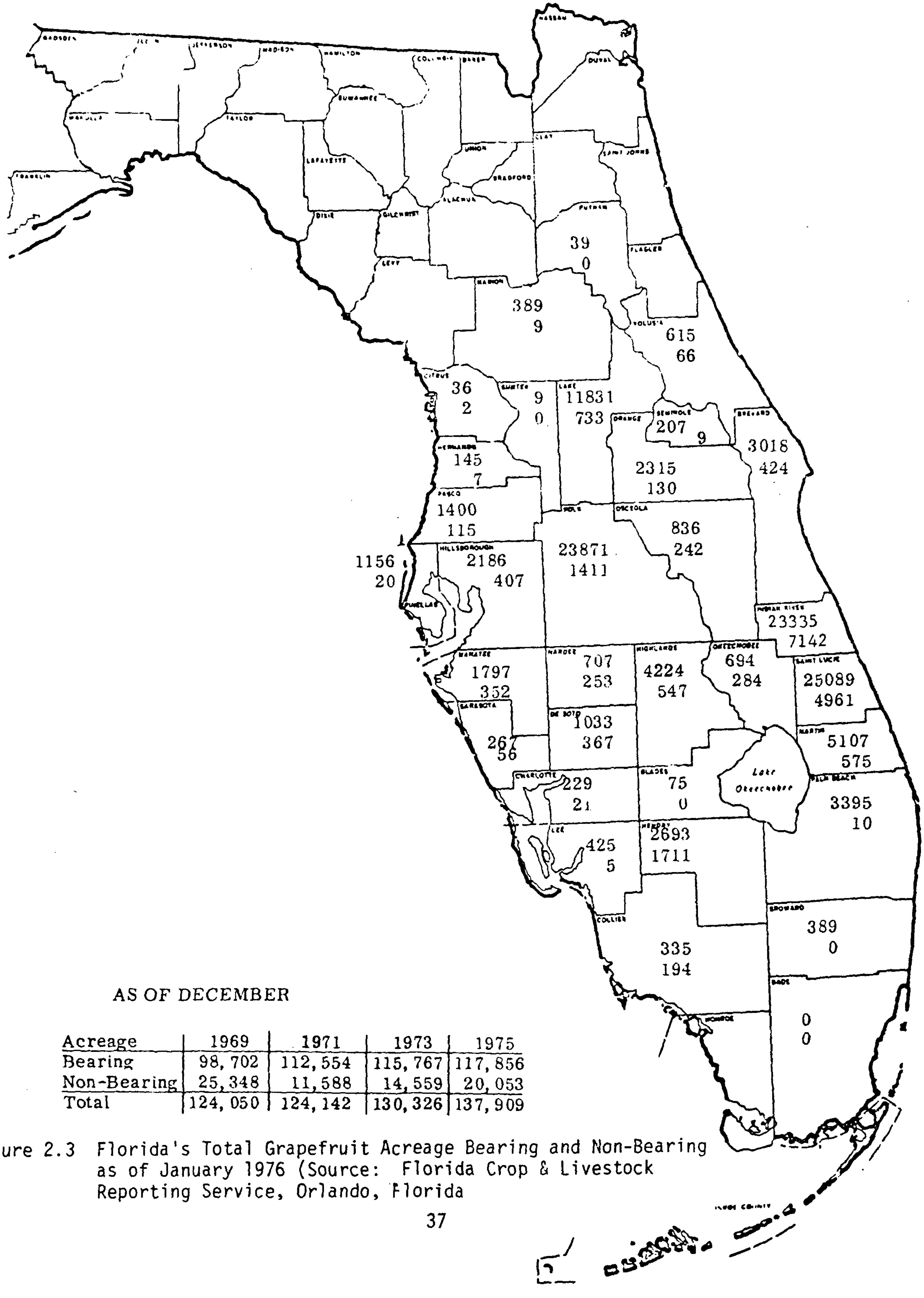
Citrus is harvested from October to July with about half of the total crop being harvested by the end of April. The early and mid-season oranges (about 54.5 percent of all orange production) are picked earlier in the season and the valencia oranges (about 45.5 percent of all



AS OF DECEMBER

Acreage	1969	1971	1973	1975
Bearing	636,128	624,209	614,608	596,432
Non-Bearing	79,687	35,209	27,823	32,135
Total	715,806	659,418	624,431	628,567

Figure 2.2 Florida's Total Orange Acreage Bearing and Non-Bearing as of January 1976 (Source: Florida Crop & Livestock Reporting Service, Orlando, Florida)



AS OF DECEMBER

Acreage	1969	1971	1973	1975
Bearing	98,702	112,554	115,767	117,856
Non-Bearing	25,348	11,588	14,559	20,053
Total	124,050	124,142	130,326	137,909

Figure 2.3 Florida's Total Grapefruit Acreage Bearing and Non-Bearing as of January 1976 (Source: Florida Crop & Livestock Reporting Service, Orlando, Florida

orange production) are picked late in the season. The total Florida production of oranges, grapefruits and specialty fruits (tangerines, honey tangerines, temples and tangelos) for the seasons 1956 through 1976 as well as its utilization, either fresh or processed (including canned, frozen, concentrate, chilled juice, etc.), and average season price per box of citrus are given in Tables 2.2 to 2.4. The estimated values of citrus production, using the given average on-tree price per box, are also presented in these tables and indicate the magnitude of the Florida citrus industry.

Table 2.2 Florida Citrus (All Round Oranges): Bearing Acreage, Yield Per Acre, Production, Utilization, Season Average On-Tree Price Per Box and Value For Crop Years 1956-57 Through 1975-76

Crop Year	Bearing Acreage, 1000 Acres	Yield, 1-3/5 Bu. Boxes/Acre	Utilization of Production			Price Per Box, $	Value of Production, $1000
			Total 1000 Boxes	Fresh 1000 Boxes	Processed 1000 Boxes		
1956-57	374.4	241	90,300	22,616	67,684	1.40	126,678
1957-58	355.6	228	81,000	17,557	63,443	2.14	174,850
1958-59	353.4	235	83,000	15,435	67,565	2.87	238,233
1959-60	370.0	237	87,600	18,890	68,710	1.96	170,057
1960-61	374.1	221	82,700	15,113	67,587	2.98	244,376
1961-62	408.7	266	108,800	19,374	89,426	1.88	203,255
1962-63	370.0	196	72,500	11,427	61,073	2.71	196,116
1963-64	388.0	141	54,900	11,939	42,961	4.44	243,935
1964-65	435.0	189	82,400	14,598	67,802	2.43	200,276
1965-66	472.0	203	95,900	15,382	80,518	1.62	155,625
1966-67	522.0	267	139,500	17,876	121,624	.94	130,526
1967-68	557.6	180	100,500	17,096	83,404	2.07	207,432
1968-69	601.6	216	129,700	13,304	116,396	1.68	218,660
1969-70	636.1	216	137,700	13,263	124,437	1.14	156,876
1970-71	667.1	213	142,300	13,962	128,338	1.46	208,146
1971-72	623.8	220	137,000	11,233	125,767	2.04	280,317
1972-73	619.6	274	169,700	12,233	157,477	1.56	265,361
1973-74	614.5	270	165,800	11,090	154,710	1.47	244,691
1974-75	610.4	284	173,300	13,393	159,907	1.62	280,350
1975-76	596.4	304	181,200	11,730	169,470	2.10	379,692

Source: Florida Crop & Livestock Reporting Service, Orlando, Florida.

Table 2.3 Florida Citrus (All Grapefruit): Bearing Acreage, Yield Per Acre, Production, Utilization, Season Average On-Tree Price Per Box and Value for Crop Years 1956-57 Through 1975-76

Crop Year	Bearing Acreage, 1000 Acres	Yield, 1-3/5 Bu. Boxes/Acres	Utilization of Production			Price Per Box, $	Value of Production, $1000
			Total 1000 Boxes	Fresh 1000 Boxes	Processed 1000 Boxes		
1956-57	112.4	333	37,400	18,347	19,053	.89	33,331
1957-58	95.0	327	31,100	14,704	16,396	.98	30,476
1958-59	94.0	374	35,200	16,639	18,561	1.04	36,552
1959-60	92.3	330	30,500	16,192	14,308	1.05	32,043
1960-61	92.5	342	31,600	15,886	15,714	.96	30,138
1961-62	94.0	370	34,800	17,991	16,809	.67	23,498
1962-63	88.0	341	30,000	14,038	15,962	1.24	37,146
1963-64	83.0	317	26,300	14,719	11,581	2.24	59,147
1964-65	84.0	380	31,900	15,846	16,054	1.47	46,892
1965-66	86.0	406	34,900	15,077	19,823	1.36	47,471
1966-67	87.0	501	43,600	17,281	26,319	.74	32,393
1967-68	87.5	376	32,900	14,702	18,198	2.01	66,317
1968-69	91.2	438	39,900	14,067	25,833	.98	39,011
1969-70	98.7	379	37,400	14,262	23,138	1.70	63,526
1970-71	108.3	396	42,900	14,960	27,940	1.91	81,514
1971-72	112.6	417	47,000	17,039	29,961	2.32	108,991
1972-73	114.6	396	45,400	17,046	28,354	2.08	94,635
1973-74	115.7	416	48,100	18,731	29,369	1.66	79,879
1974-75	115.4	386	44,600	18,797	25,803	1.72	76,367
1975-76	117.9	416	49,100	20,369	28,731	1.38	67,650

Source: Florida Crop & Livestock Reporting Service, Orlando, Florida.

Table 2.4 Florida Citrus (Specialty Fruit): Bearing Acreage, Yield Per Acre, Production, Utilization, Season Average On-Tree Price Per Box and Value For Crop Years 1956-57 Through 1975-76

Crop Year	Bearing Acreage, 1000 Acres	Utilization of Production			Price Per* Box, $	Value of Production, $1000
		Total 1000 Boxes	Fresh 1000 Boxes	Processed 1000 Boxes		
1971-72	69.4	13,700	6,448	7,252	2.24	29,712
1972-73	70.4	12,100	6,443	5,657	2.29	24,764
1973-74	69	13,300	6,343	6,957	2.12	25,341
1974-75	69.3	14,750	7,496	7,254	2.36	30,608
1975-76	65.8	16,450	8,258	8,192	2.49	35,378

*The average season prices of temples, tangerines, honey tangerines and tangelos.

Source: Florida Crop & Livestock Reporting Service.

2.2 Historical Loss Data*

The Florida citrus production is influenced by many factors, such as fruit variety, age of trees, density of planting, topographical location, type of soil, weather conditions and nutritional and cultural practices. Many of these factors are under the control of the growers. Weather, being a collection of various atmospheric conditions such as rainfall, humidity, light intensity, amount of sunshine, temperatures, and atmospheric pressure, cannot be controlled. Of all bioclimatic factors influencing citrus production, freezing temperatures result in the heaviest losses in the citrus-producing regions.

To illustrate the magnitude of the economic impact of a severe freeze on Florida's citrus industry, the damages, to the crop as well as to the citrus-bearing trees, caused by the freeze in the 1962-63 season are considered. The most severe freeze of the century,** prior to the 1976-77 season, caused temperatures to drop to 8°-11°F in Suwannee and Alachua counties and to 25°F as far south as Callier and Palm Beach counties on the mornings of December 13 and 14, 1962. The economic losses were staggering. The total loss was 50 million boxes of citrus** (32 percent of 1961-62 production of 152 million boxes), with an additional 50 million boxes of fruit having to be salvaged as concentrate. Furthermore, the

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*Does not include the unnecessary costs of frost protection (i.e., costs incurred for frost protection when frost was forecast but did not occur.)

**Johnson, W. O., Minimum Temperatures in the Agricultural Areas of Peninsular Florida, Summary of 30 Winter Seasons 1937-67, IFAS Publication No. 9, 1970, University of Florida, Gainesville.

freeze reduced the yield of concentrated juice obtained from the processed fruit. Prior to the freeze, a yield of 1.55 gallons of concentrate per box was estimated for that part of the total orange crop intended to be used for the frozen concentrate orange juice. The actual yield was 1.09 gallons of concentrate per box.* Besides the loss to the crop, the trees sustained damage as well. About 7 to 10 million trees were killed.

Not only was the 1962-63 citrus production very low (106 million boxes) but the next season (1963-64) was also severely affected due to the loss of trees, and production was even lower (92 million boxes) than in the 1962-63 season. It wasn't until 1966-67 that recovery in Florida was sufficient for total citrus production to exceed the level of the 1961-62 season. Citrus production for the United States and Florida is shown in Figure 2.4 for crop years 1950-51 through 1975-76. The effect of frosts and freezes on citrus production can be easily observed.

During the 1976-77 winter season the cold wave of January 17-20 brought temperatures in the low 20s for several hours duration throughout the Florida citrus-producing districts (see Figure 2.5). In some areas the temperature was in the teens and it was snowing in Miami Beach. It was reported by the Crop Reporting Board of USDA in February 1977 that the production prospects for oranges were off by 9 percent and those for grapefruit by 16 percent. In April the orange production was estimated at 192 million boxes, 6 percent above last year's production. However, continued dehydration of freeze-damaged fruit further reduced the yield of frozen concentrated orange juice per box, with the actual yield being 1.07 gallons per box compared

*Florida Citrus Commission, Two Days in December, A Report on the Florida Freeze of 1962, Lakeland, Florida.

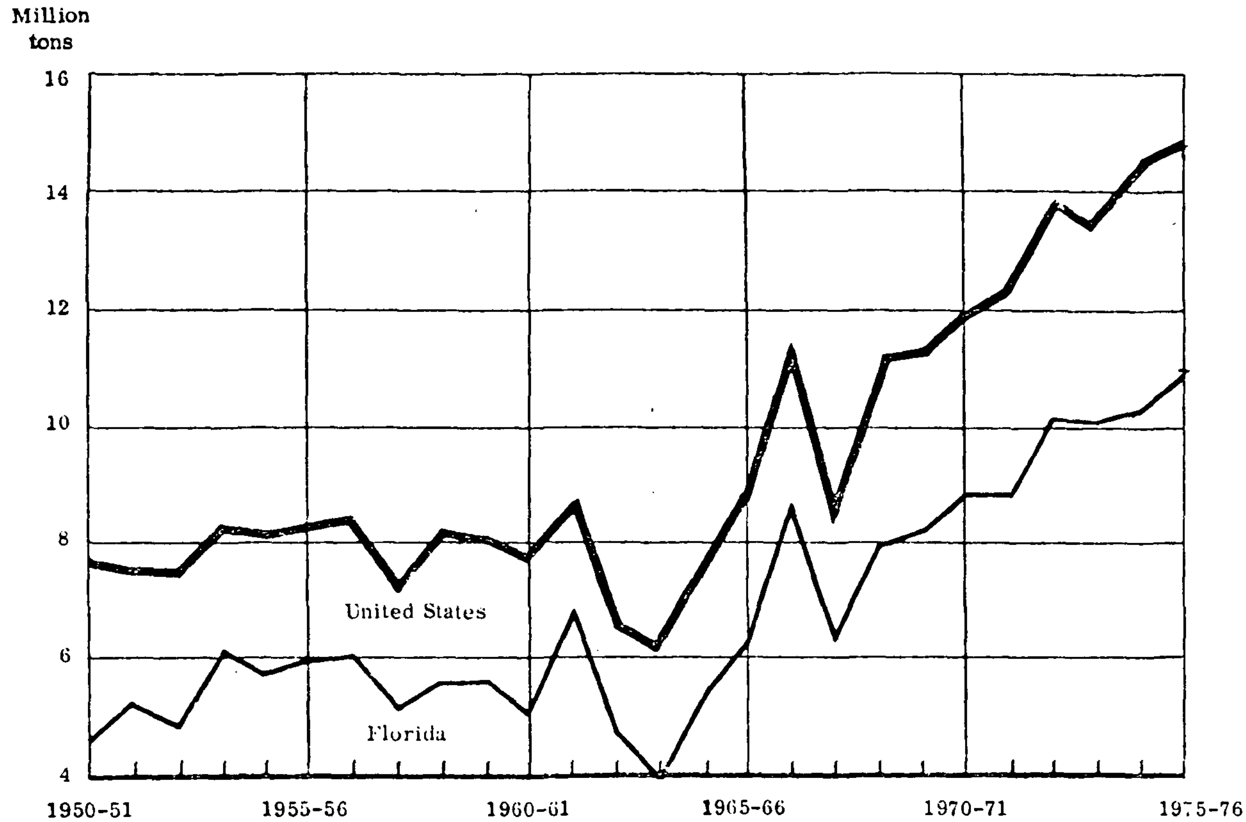


Figure 2.4 Principal Citrus Fruits: Production for United States and Florida, crop years 1950-51 through 1975-76.

with the January 1 prefreeze projection of 1.29 gallons per box (which was also the average of 1975-76 crop year). The April estimate of total grapefruit was for approximately the same yield as that of the previous year. The total physical losses, as of the end of harvesting season were 33.81 million boxes of citrus, not including lemons and limes; of this, 15.93 million boxes of fresh fruit and 17.88 million boxes of fruit for processing were lost.

Table 2.5 summarizes the freezes which have occurred since 1939, indicating the estimate of the citrus crop (oranges and grapefruits only) and and the final production achieved in each season. The original USDA estimates of citrus production (by variety) are compared with the actual production in Table 2.6 The influence of freezing temperatures during the winter season on citrus crop production is readily apparent.

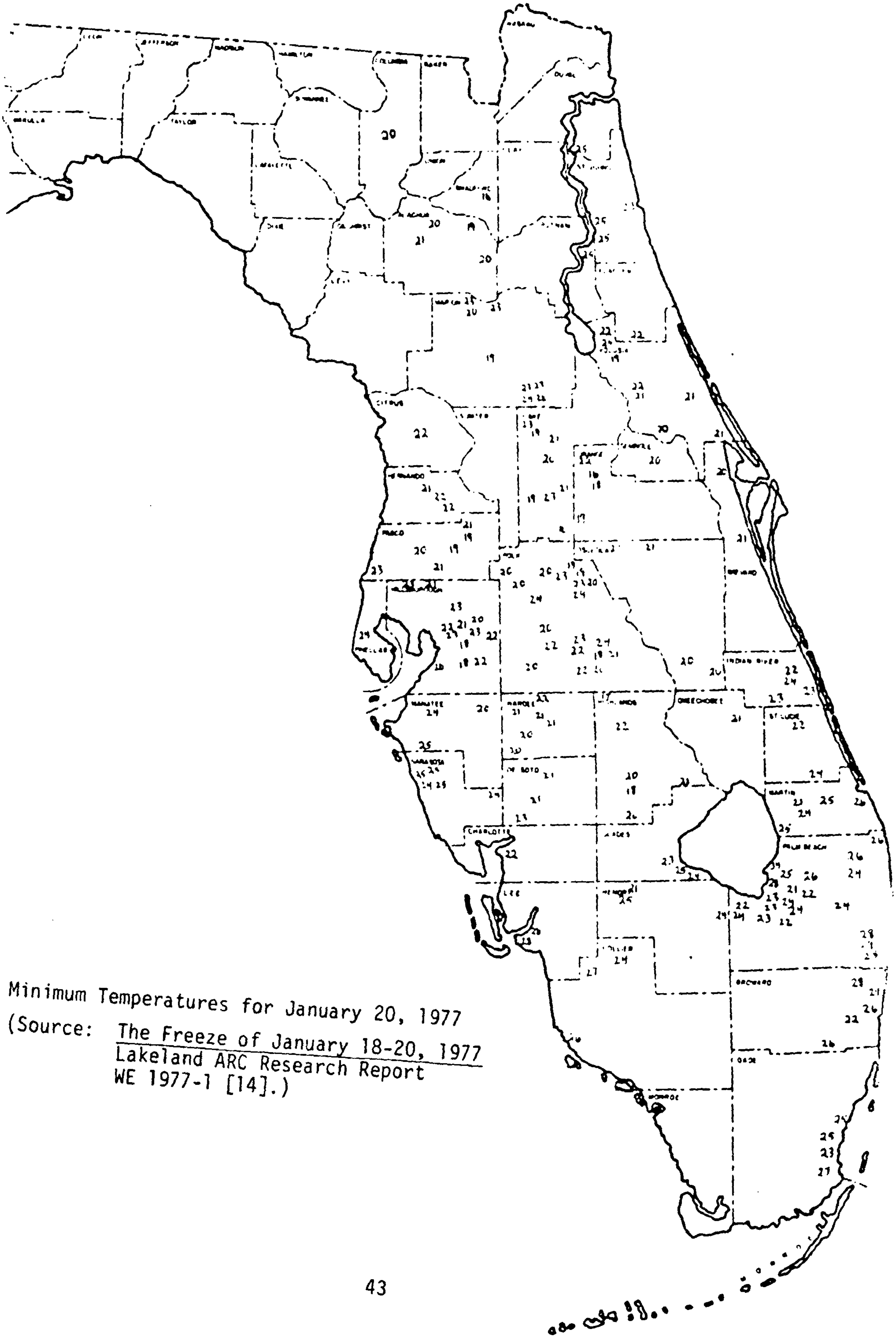


Figure 2.5 Minimum Temperatures for January 20, 1977
(Source: The Freeze of January 18-20, 1977
Lakeland ARC Research Report
WE 1977-1 [14].)

Table 2.5 Historical Freezes Which Influenced Citrus Crops, 1939-40 Through 1973-74 Seasons.

Seasons	Description of Freeze	Monthly Production Estimate[a] (10^6 boxes)	Final Production (10^6 boxes)
1939-40	During the dates of January 27, 28 and 29 temperatures of 15° and lower covered the upper one-third of the state. Temperatures in the low 20's covered the remainder of the state.	na[b] na	26[c] 16[d]
1946-47	On February 6 temperatures were in the low 20's in the North and in several pockets throughout the State. Temperatures in the mid 20's covered the remainder of the state except along the southern coast.	na na	54 29
1957-58	Freezing temperatures occurred on December 12 and 13 in the northern and central areas of the state. On February 4 and 5 temperatures in the mid 20's covered the entire state.	102 36	82 31
1962-63	A "big" freeze in all areas of the state during the period December 11-15 produced the "greatest citrus loss in history." Below normal temperatures occurred during each month of the winter season.	120 38	74 30
1969-70	Temperatures of 28° and lower occurred January 7-11 which damaged fruit in the northern and central districts. Temperatures of short duration in the mid 20's occurred in the northern and central districts on February 4 and caused minor damage. Loss of fruit due to the freeze was minimum, but juice yield was reduced.	140 37	143 37
1970-71	Freezing temperatures and heavy frost occurred on November 25 in all agricultural areas except the lower east coast. Heavy fruit and wood loss occurred in Hillsborough County on January 20 and 21 as severe freeze in the upper teens covered all areas except the lower east coast.	175 49	147 43
1976-77	One of the major freezes of the century occurred January 16-21. Snow fell in Miami for the first time in recorded weather history. Minimum temperatures in the teens were noted on the morning of January 18 with durations of 26°F and below for 6 to 12 hours. Very heavy frost was seen in the Everglades that night. Even colder air was on its way southward from Canada. On the next day, January 19, high temperatures were only in the 30s in northern and central Florida, and 40s in southern Florida, the lowest maximum temperatures ever recorded. On the night of January 19-20, temperatures remained in the 20s thoughout all of Florida for many hours. 98 percent of oranges surveyed by F.C.&L.R.S. on January 20 had ice, with 48 percent showing hard ice to the center of the fruit.	217 58	184 52

[a]Refers to the monthly estimate of the Florida Crop and Livestock Reporting Service which preceeded the first freeze of the season, providing the freeze occurred prior to the 10th of the month. For example, if a freeze occurred prior to January 10, the December estimate is listed. If the freeze occurred after January 10, the January estimate is listed.

[b]Not available.

[c]Oranges

[d]Grapefruit

Source: Florida Canners Association, Florida Citrus Mutual and Florida Crop and Livestock Reporting Service.

Table 2.6 Original Government Estimates For Seasons 1968-69 Through 1974-75 As Compared With Season Total Production (in thousand of boxes) 1/

	ORANGES				GRAPEFRUIT			
	*Early & Midseason		Valencias		Seeded		Seedless	
Season	Orginal Estimate	Actual Production	Original Estimate	Actual Production	Original Estimate	Actual Production	Original Estimate	Actual Production
1968-69	73,000	74,200	56,000	60,000	13,000	12,200	29,000	27,700
Over & Under	-1,200		-4,000		+ 800		+1,300	
	Comment:	Some freeze damage in northern and central area. Rainfall plentiful during season except April & May. No hurricane damage						
1969-70	87,000	78,100	62,000	64,800	10,000	9,500	27,900	27,000
Over & Under	+8,900		-2,800		+ 500		+ 900	
	Comment:	Severe cold January 7,8,9,10,11. Some damage in northern and central districts. Rainfall for season adequate to some excess during winter, dry during April and March.						
1970-71	100,500	87,100	74,000	60,200	15,000	11,800	34,000	31,100
Over & Under	+13,400		+13,800		+3,200		+2,900	
	Comment:	Severe cold Nov. 25, Jan. 20-21, Feb. 8. Freeze damage severe in many areas. Near drought conditions over central & southern areas during most of the year.						
1971-72	73,000	74,100	64,000	68,200	10,000	10,900	33,000	36,100
Over & Under	-1,100		-4,200		- 900		-3,100	
	Comment:	Warmest winter on record. No freeze damage, no hurricanes. Rainfall was spotty.						
1972-73	92,000	90,000	82,000	79,700	11,000	10,200	34,000	35,200
Over & Under	+2,000		+2,300		+ 800		-1,200	
	Comment:	No freeze, no hurricanes. Rainfall ample from June to date.						
1973-74	93,000	92,100	72,000	73,700	10,500	10,000	37,500	38,100
Over & Under	+1,100		-1,700		+ 500		- 600	
	Comment:	No major cold weather, severe dry weather, January through May. No hurricanes through August. More than ample rainfall June, July and August.						
1974-75	102,500	101,900	77,000	76,700	9,500	7,200	35,500	37,400
Over & Under	+ 600		+ 300		+2,300		+1,900	
	Comment:	Generally mild winter, severe drought first five weeks, no hurricanes. Ample rainfall during June, July and August.						
1975-76	103,500	104,300	74,000	82,400	9,000	7,800	41,000	41,300
	- 800		-8,400		+1,200		- 300	
	Comment:	No hurricanes. No major cold weather. From extremely dry first of season to ample rainfall rest of season from June to date.						

*Temples included.

Source: Florida Citrus Mutual, Annual Statistical Report, 1974-75 Season
1/ 90 lb. oranges, 85 lb. grapefruit.

The value of production of oranges lost due to frosts and/or freezes is illustrated as follows: It was estimated by the USDA (Table 2.6) that the total production of oranges would be 174.5 million boxes during the 1970-71 season. The actual production was only 147.3 million boxes. The loss of 27.2 million boxes of oranges can be attributed primarily to the rather severe freezes in that season. Although the increase in prices for undamaged citrus fruit after the freeze offsets the lost revenue due to freeze damage, the magnitude of losses indicates the importance of frost protection for the citrus industry.

There are additional losses in citrus production due to ice, rain, hail and hurricanes, but all these are minor compared to losses caused by freezing temperatures.

2.3 Weather Sensitivity of Citrus

There are basically two types of frosts; the advective freeze and the radiational frost. An advective freeze occurs when a mass of cold, dry air having thickness of 500 to 5,000 feet is transported from the polar regions by winds having velocity exceeding 5 mph. A cold front of dense air displaces a warmer air mass very rapidly as it moves southward. The temperature falls rather uniformly throughout the night (Figure 2.6) during the advective freeze on low grounds as well as high grounds. Pockets of warmer air remain in valleys (Figure 2.7).

A radiational frost occurs when air, soil and plants are cooled to freezing temperatures through loss of heat by radiation. The thickness of the cold air mass is between 30 to 200 feet and moves slowly with wind velocity under 3 mph. The surfaces of plants and earth exhibit a heat loss at a greater rate than the surrounding layer of air which is cooled

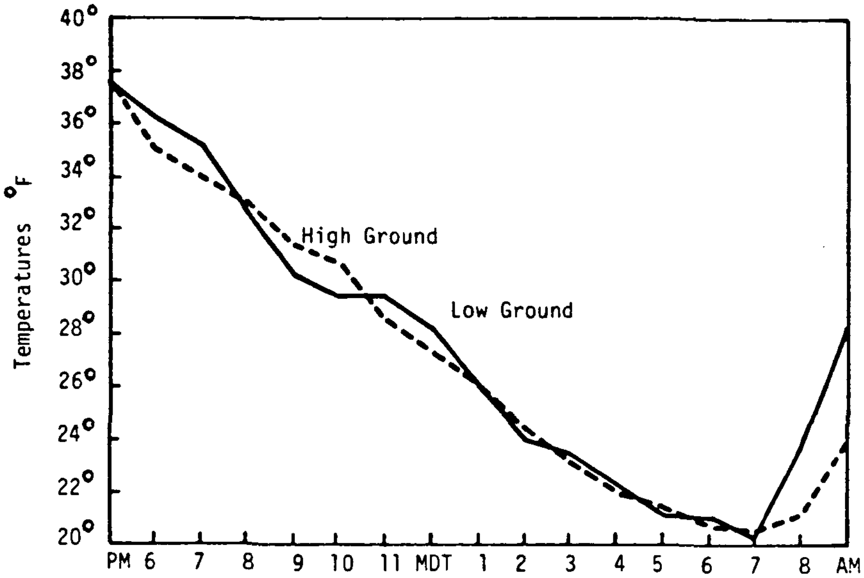


Figure 2.6 Typical Temperature Progression for Advective Freeze Indicating Little Difference in Temperatures on High and Low Ground Locations on a Windy Night (Source: Johnson, W. O., Minimum Temperatures in the Agricultural Areas of Peninsular Florida, Summary of 30 Winter Seasons 1937-67, IFAS Publication No. 9, University of Florida)

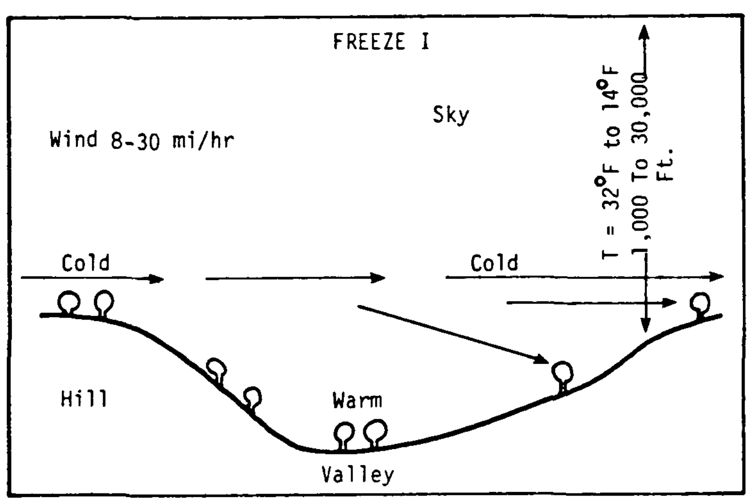


Figure 2.7 Diagram Showing Micrometeorology of a Freeze in a Hilly Country. In flat country, micrometeorology is similar to hilltop on left. (Source: Reuther, W., Editor, The Citrus Industry, Vol. III, University of California, Chapter 10)

by this radiation and, through thermal conduction, cools the subsequent layers of the atmosphere. This process results in a temperature inversion, when air temperature increases with the increasing height above the ground. Also, as a consequence of the thermal inversion during radiational frosts, there are higher temperatures on high grounds and lower temperatures on lower grounds (Figures 2.8 and 2.9). The cooled air is heavier than the dry air and flows down due to gravitational forces into lower elevations. If there are depressions in the sloping terrains, very cold frostpockets are formed.

An elevation difference of as little as 4 to 5 feet above a surrounding area can cause an increase of from 2° to 5°F on cold, clear and calm nights. If there is an air flow of the warmer air in a layer 10 to 40 feet above the tree tops, the rising colder air (due to the inversion) mixes with the warm air of upper layers and the resulting turbulence is often sufficient to prevent the development of radiation frosts.

A relatively high atmospheric moisture results in formation of small crystals on plants and soil, so called hoarfrost or white frost, when soil and plants are cooled to the dew point temperature.* A low atmospheric moisture, when dew point is lower than the soil and plant surface temperatures, results in black frost since the air is too dry to form crystals. Radiational frosts are characterized by calm air, clear skies and low atmospheric water vapor content.

The very damaging freeze-frost combinations occur when cold, freezing winds are replaced by calm periods of radiational frost. A typical Florida

*The dew point temperature is the temperature at which the moisture in the air begins to condense onto leaf surfaces.

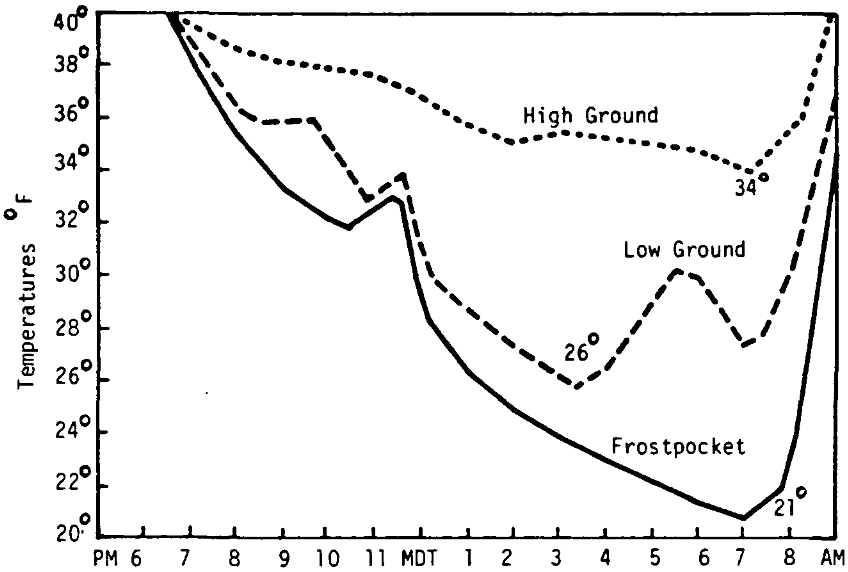


Figure 2.8 Typical Temperature Progression for Radiational Freeze Indicating Considerable Difference in Temperatures with Elevation. Night--clear skies with long periods of calm. (Source: Johnson, W. O., Minimum Temperatures in the Agricultural Areas of Peninsular Florida, Summary of 30 Winter Seasons 1937-67, IFAS Publication No. 9, 1970, University of Florida)

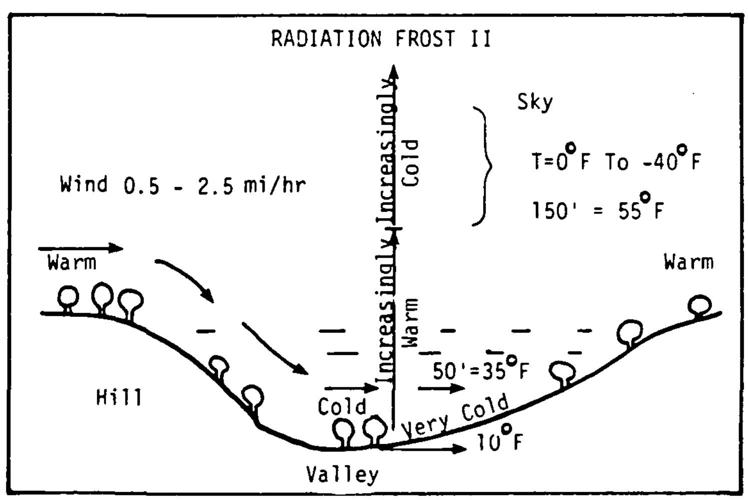


Figure 2.9 Diagram Showing the Micrometeorology for a Radiation Frost in Hilly Country. A radiation frost may develop alone or as the second stage (calm) of an advection freeze. In the latter case, the hilltop trees enter the second stage very cold, while the valley trees enter the calm night somewhat warmer. (Source: Reuther, W., Editor, The Citrus Industry, Vol. III, University of California, Chapter 10)

freeze may last two days. The first night is usually a cold windy advective freeze but rarely a seriously damaging one. Usually there is a little warming of the air or trees during the second day as cold air continues to move south. During the second night the wind usually falls soon after sunset and the stratifying air may reach dangerously low temperatures rather soon, especially in low areas. This is when the greatest damage to fruit and trees is done. On the third day the wind usually shifts and begins to replace the cold air with warmer air from the ocean.

The most severe damage results when an early winter freeze is followed by a period of warm weather sufficient to initiate new growth, which in turn is followed by a second freeze in the same winter. The trees are much more susceptible to freezing temperatures because of the new growth and are then killed to the ground.

The movement of a mass of cold polar air into subtropical regions, associated with an advective freeze, results in very low air temperature--between 8°F and 28°F. The probability of occurrence of these temperatures is small in December, increases throughout January and decreases from the middle of February. The records show that several severe freeze-frost combinations occurred in late November and milder radiational frosts as late as April.

The January 1977 freeze, the worst in Florida in 15 years, followed the pattern of freeze-frost combination. The first wave of cold air entered the peninsula during the night of January 16/17 with temperatures in the upper 20s to lower 20s in central Florida. Moderate winds prevented any frost during that night but temperatures dropped to the low 20s with durations up to six hours and moderate frosts developed during the night of January 17/18. Then the massive cold wave of an advective freeze with strong winds brought along snowfalls as far south as West Palm Beach. The temperatures stayed low during the day of January 19 and as the high front moved eastward out of the peninsula, winds diminished and temperatures dropped below 28°F early in the evening. The whole peninsula experienced very low temperatures, from low 20s in the north-central region (in the teens in some areas) to mid 20s in the southern region, with durations of up to 14 hours below freezing level. The most damage to the citrus crop was reported as occurring during the night of January 19/20.

2.4 The Role of the National Weather Service

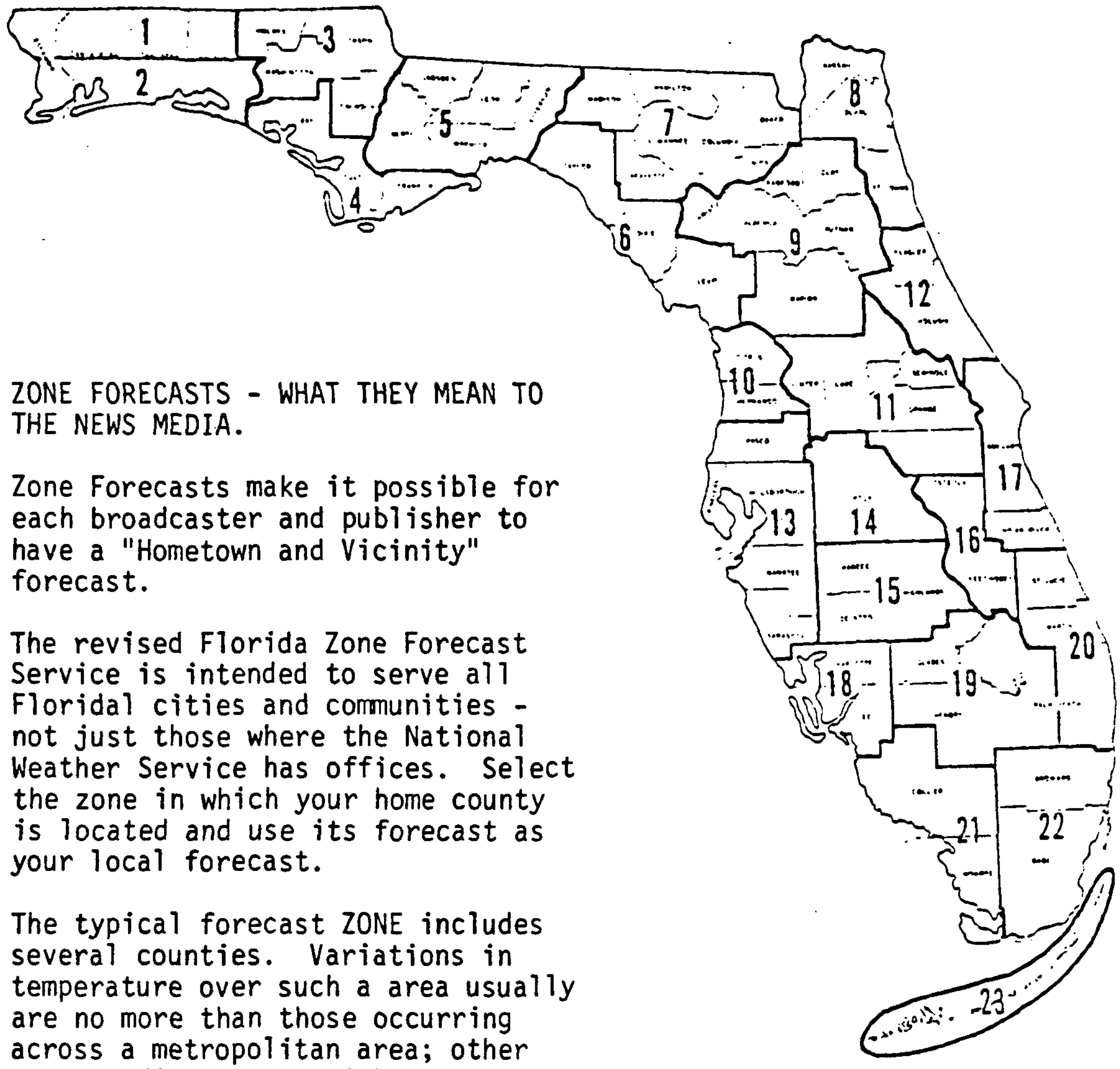
2.4.1 Frost Warning System in Florida

The vulnerability of the citrus crop to the effects of freezing temperatures and the impact of an accurate and timely weather forecast have been recognized for a long time. The Federal-State Agricultural Weather Service was established in the citrus belt of Florida, with headquarters in Lakeland, in 1935 and later extended to cover the whole peninsula. The forecast bulletins issued twice a day during the frost season (from November 1 through March 31) provide the growers with an estimate of the geographic distribution of the anticipated minimum temperatures.

The weather forecasting function of the Federal-State Agricultural Service was incorporated into the National Weather Service, with Florida headquarters in Ruskin. The forecast zones are shown in Figure 2.10.

The minimum temperature forecast, accompanied by an outlook for the next one to three nights, and forecasts of clouds and winds are the

FLORIDA FORECAST ZONES
(Revised October 1, 1972)



ZONE FORECASTS - WHAT THEY MEAN TO THE NEWS MEDIA.

Zone Forecasts make it possible for each broadcaster and publisher to have a "Hometown and Vicinity" forecast.

The revised Florida Zone Forecast Service is intended to serve all Floridal cities and communities - not just those where the National Weather Service has offices. Select the zone in which your home county is located and use its forecast as your local forecast.

The typical forecast ZONE includes several counties. Variations in temperature over such a area usually are no more than those occurring across a metropolitan area; other weather differences within a zone are usually little different. The Zones shown in the map on this page are revised as of October 1, 1972 to better meet the needs of the using public.

Figure 2.10 Map Showing Florida Forecast Zones as Used by the National Weather Service (Source: National Weather Service, Southern Region Headquarters, Fort Worth, Texas) main function of NWS Agricultural Weather Service. The other functions* are:

a. To offer an advisory service of how to prevent damage from frost and/or freezes

b. To provide temperature durations for key stations throughout the growing areas (these are available immediately following nights of frost damage)

c. To compile annual reports on the general character of each season with respect to crop-weather relationship, tabulations of minimum temperatures from stations within the forecast area for selected nights, durations of temperatures below 32°F from all survey stations and and comparative data and observations.

d. To study temperature and crop relationships, researching the meteorological relationship with respect to methods and equipment for frost protection.

2.4.2 Frequency and Dissemination of Frost Forecasts

Currently the official weather forecast by the National Weather Service (NWS) is made four times a day, at 6:00 a.m., 10:15 a.m., 4:15 p.m. and 10:15 p.m. The early morning forecast at 6:00 a.m. is a temperature outlook for the next 24 hours for the entire state. No detailed meteorological data are forecast.

The 10:15 a.m. forecast is the next important forecast of the day. The weather prediction is based on the data obtained from the meteorological soundings, the readings of government thermometers throughout the state (about 200 thermometers), and the additional data obtained from the weather stations, such as the heat flux from the earth and radiational losses. The forecast begins with a preamble, for the whole of peninsular Florida, which

*Operations of the National Weather Service, U.S. Department of Commerce, NOAA, NWS, Silver Springs, Maryland, 1974.

gives qualitative indications about temperature, the minimum temperature and its approximate time of occurrence, wind direction and wind speed, and finally information on any possible temperature inversion. The preamble is followed by detailed temperature forecasts expressed as a 4°F interval for each forecast zone.

The 4:15 p.m. forecast is an update of the 10:15 a.m. forecast, based upon the additional temperature readings of the government thermometers. There is no input from the meteorological soundings (they are launched only twice a day). This forecast rarely deviates from the 10:15 a.m. forecast. Typical 10:15 a.m. and 4:15 p.m. forecasts are presented in Figures 2.11 and 2.12, respectively.

Finally, the 10:15 p.m. forecast is an update of the 4:15 p.m. forecast and includes changes in weather problems that may occur. Normally, if the 4:15 p.m. forecasted temperatures are above 28°F, the 10:15 p.m. forecast is not given.

There are several means of forecast dissemination, such as teletype, public radio and telephone. Typically, a grower receives the official NWS forecast on his own teletype, which costs him approximately $100/month for the teletype line. The official NWS forecast is rebroadcast by public radio stations and also disseminated via radio by 24-hour continuous weather broadcasts, updated every six hours, with taped messages repeated every 4 to 6 minutes. Many growers have special receivers which enable them to listen to this VHF-FM radio broadcast at frequencies of 162.55 MHz and 162.40 MHz.

MANN
ZCZC
FXUSS RWRB 281515

PENINSULAR FLORIDA FARM AREA MINIMUM TEMPERATURE FORECAST
ISSUED AT 10:15 AM EST WEDNESDAY JAN 23 1975
NATIONAL WEATHER SERVICE TAMPA BAY AREA RUSKIN FLORIDA

FOR TONIGHT FROST AND FREEZE WARNING ALL ZONES
CLEAR AND COLD ALL ZONES. TEMPERATURES WILL DROP STEADILY DURING THE NIGHT
WITH LOWEST TEMPERATURES NEAR SUNRISE. WINDS LIGHT AND VARIABLE
WITH PERIODS OF CALM AFTER MIDNIGHT.

LOWEST TEMPERATURES

ZONES 6 7 8 22 TO 26 FROST

ZONE 9 24 TO 28 FROST

ZONES 10 11 12 13 14 15 16-28 TO 32 POCKETS AND COLDER LOCATIONS
26 TO 23 WITH FROST.

ZONE 17 32 TO 36 SCATTERED FROST

ZONES 18 19 21 34 TO 40 PATCHY FROST PACKLANDS.

OUTLOOK FOR THURSDAY NIGHT...NOT AS COLD. CHANCE OF FROST
AGAIN CENTRAL AND NORTH PORTION.

Figure 2.11 Typical 10:15 a.m. Forecast

FAUSB RWRB 28211

PENINSULAR FLORIDA FARM AREA MINIMUM TEMPERATURE FORECAST
ISSUED AT 4:15 PM EST WEDNESDAY JANUARY 28 1976
NATIONAL WEATHER SERVICE TAMPA BAY AREA RUSKIN FLORIDA

FROST AND FREEZE WARNINGS

TONIGHT...CLEAR AND COLD ALL ZONES. TEMPERATURES FALLING STEADILY
DURING THE NIGHT WITH LOWEST TEMPERATURES TO OCCUR NEAR SUNRISE.
LIGHT AND VARIABLE WINDS WITH PERIODS OF CALM AFTER MIDNIGHT.

LOWEST TEMPERATURES

ZONES 6 7	20 TO 24 FROST
ZONES 8 9	24 TO 28 FROST
ZONES 10 11 12	26 TO 30 WITH 24 TO 26 COLD POCKETS AND MUCKLANDS. FROST
ZONES 13 14 15 16	28 TO 32 WITH 26 TO 28 COLD POCKETS AND MUCKLANDS. FROST
ZONE 17	32 TO 36 SCATTERED FROST
ZONES 18 19 21	33 TO 37 SCATTERED FROST
ZONES 20 22	35 TO 40 PATCHY FROST

TEMPERATURE OUTLOOK...NOT AS COLD. CHANCE OF SCATTERED FROST
NORTHERN ZONES FRIDAY MORNING.

Figure 2.12 Typical 4:15 p.m. Forecast

2.4.3 Informal Non-NWS Forecasts

Besides these public means of dissemination, the growers can obtain the latest forecast by calling the unlisted telephone number of the NWS Office at Ruskin or the Federal-State Agricultural Weather Service at Lakeland and listening to the recorded official NWS forecast. This is especially beneficial to smaller growers who cannot afford to have the teletype service. The growers also communicate extensively among themselves and with the county extension agents and exchange information about temperatures obtained from their thermometers. There are no official (by NWS) temperature readings of government thermometers after dark, only the unofficial data provided by the growers. Importantly though, meteorologists of the Federal-State Agricultural Weather Service give an informal "localized" forecast, which is based on the above unofficial data and information from NWS, for growers' particular regions, by phone. Besides the temperature range, they also provide the probabilities with which these temperatures will occur. This type of constant communication usually lasts until 1:00 a.m. on a cold night. By that time the growers have decided whether to initiate a frost protection action or have assumed that the temperature will not become low enough to cause any damage.

2.4.4 The Improved Weather Forecast

It is anticipated that, starting with the 1977-78 frost season, the utilization of satellite-measured temperature data will result in improved accuracy of weather forecasts and knowledge of actual temperature distributions across the state of Florida. It is expected that this, in turn, will have a direct impact on improving frost protection decisions, with reduced protection costs and crop losses, and will lead to improved marketing strategies. Currently, weather forecast accuracy is dependent, to a large extent, upon the forecaster's experience and knowledge of local conditions. To a large extent, the satellite data, together with computer forecasting models, will help to remove the human factor from weather forecasting and will, therefore, make the forecast independent of the forecaster's capability.

At present, all data available to a meteorologist are in discrete sets, whether from meteorological sounding or temperature readings from ground stations. Approximate temperature maps are then generated. These are combined in the forecaster's mind, based purely on his experience, into a more or less continuous picture in time and space, reflecting also all other factors playing an important role in this highly subjective weather forecast. It requires a number of years of experience to master all of the intricate peculiarities in topography and other factors in order to make effective and accurate forecasts. Unfortunately, many of the experienced meteorologists are retiring from NWS and the younger forecasters do not, in some cases, have the necessary experience.

The remotely measured temperature data by the SMS/GOES satellite will be available to the NWS forecasters starting with the 1977-78 winter season. The temperature data will be transmitted to the NWS office in Ruskin and processed with an image interpreter. Increased frequency of data interpretation (temperatures could be remotely measured every 30 minutes) will provide a continuous map of meteorological events in time as well in space, and thus could be a decisive step in minimizing the subjectivity of weather forecasts.

Another important improvement in the NWS weather forecast capability will be the use of the temperature forecast model which can use the satellite-measured temperature data. This model has been developed by the University of Florida. These new methods used in weather forecasting will thus enable the NWS to improve its frost warning system and make it more independent of forecasters' skills.

One of the first results of this improved database for forecasting will be the narrowing of the forecasted temperature range from 4°F to 2°F.* This narrower range of temperatures would be extremely helpful during "wait and watch" nights when the forecasted temperature is in a borderline region, and the growers must decide either to take a protective measure or not to take one.

It is assumed that the 1977-78 winter season will be a transient one, with NWS forecasters at Ruskin learning to use the new systems. During these frost seasons data will be gathered for the test group, control group data having been gathered during the 1976-77 frost season.

2.5 Frost Protection Methods

The research in the areas of environmental physiology** indicates that there is a dynamic energy exchange between the plant's tissues and its environment which, together with other factors such as air temperature, wind velocity, relative humidity, soil moisture and fertility, regulates the process of growth and development as well as the conditions during frosts and freezes. The decision to use or not to use a particular frost

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*Private communication with Mr. James Georg, NWS.

**Reuther, W., editor, The Citrus Industry, Vol. III, University of California.

protection method is influenced by these factors and additional natural features in and around a grove. These are: local topography and possibility of thermal inversion, windflow paths, type and chemical state of soil, temperature of the water used for irrigation or sprinkling, temperature of the ground, availability of cover crops and windbreaks, proximity of large bodies of water and other citrus orchards, and dormancy status of trees (dormant trees are less susceptible to frost damage).*

The heat stored in soil is released during the cold nights. The amount of heat radiated from moist sandy soil is greater than from other types of soil because sandy soils have greater heat capacity and thermal conductivity, and they do not cool the surrounding layer of air extensively.

The proximity of lakes and reservoirs to orchards is most beneficial during advective freeze nights. Much of the heat stored in these large bodies of water during the warm period, because of water's large heat capacity and thermal conductivity, is then picked up by the air in passing over the water surface and is recovered by leeward trees in the grove.

All the terrestrial heat from the trees, soil and water is absorbed by clouds, if it is cloudy, and almost three-quarters is radiated back to earth. As a result of this fact, a radiation frost does not normally develop when the air is calm and there are clouds or fog, even if the temperature is low enough to cause frost when the sky is clear.

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*Cooper, W. C., R. H. Young, and F. M. Turrell, Microclimate and Physiology of Citrus: Their Relation to Cold Protection, _Agri. Sci. Rev._, 2(1):38-50, 1964.

The most common protective system of a citrus grove against freezing temperatures consists of a combination of the two principal methods of frost protection: using heaters to generate heat, and using wind machines to create turbulence which redistributes heat in and above the orchard.

Heaters have proved to be the most efficient in the heating of citrus orchards. Oil heaters are very effective in combating long advective freezes. Most heaters currently in use have a capacity to burn all night (up to 6 hours) without refueling, are relatively easy to light under all weather conditions and satisfy environmental standards (do not produce excessive smoke). Return stack, jumbo cone and lazy flames are the most commonly used heaters in Florida.

Heat released from heaters by burning fuel is in convective and radiational forms. Convective heat, in the form of hot gases and heated air, is distributed throughout the grove by movement of the air. Radiational heat is released from the flame and heater stacks. Trees close to heaters are warmed by radiant heat rather than by convective heat. A heater is more effective with the increasing percentage of radiational heat it can produce.

The effect of heaters is greatly reduced by radiational losses of heat directly to the sky from the top of a grove and by light hot air, warmed by convectional heat, being blown away by the wind. The total losses from an unprotected citrus grove on cold calm nights range from 0.9 to 1.8 million BTU/acre/hour.* Because of the above stated losses, the

*Gerber, J. F. and J. D. Martsolf, Protecting Citrus from Cold Damage, AESUF, Circular 287, 1966.

total heating system should provide 3 to 5 million BTU/acre/hour to adequately protect an orchard.

There are several other factors which influence the effectiveness of cold protection by heaters, the most important of which is wind. Since the hot air is blown away by wind, protection is greatly reduced on windy nights. Windbreaks reduce the velocity of wind and increase heating efficiency. Border areas of an orchard require additional heaters for good protection because of an inflow of cold air. The heat distribution throughout a grove should be as uniform as possible. The effect of wind is reduced for larger groves since the trees tend to reduce the wind speed. Size of trees also plays an important role. Large trees resist the wind and their canopies are also large and therefore intercept more radiant heat.

Refueling of heaters represents a problem during advective freezes of long duration (a heater can hold up to 9 gallons of fuel). Normally, insufficient laborers are available to distribute the fuel. Some growers, therefore, use more heaters than necessary so they have enough fuel for two nights. A system with permanent oil supply pipes eliminates this problem but requires a large capital expenditure and is therefore used primarily in nurseries.

As stated earlier, a wind machine redistributes the heat in the layers of air by producing enough turbulence to break up the temperature inversion of the air and mixing its warm and cold components. This mixture is then transported across the orchard and the cold air is pushed out until a pressure equilibrium is set up between the mixture in the orchard and cold dense air outside the orchard. One wind machine (30 brake horsepower-bhp) can protect 3.5 to 6 acres. Several wind machines operating together provide greater temperature response per machine than one. Large machines (90 bhp and more, using two propellers) also provide greater protection in low spots.

The efficiency of wind machines depends on the thrust and reach of propellers in relation to the power source. The thrust and reach decreases with decreasing temperatures as air density increases and viscosity decreases. The wind machine's reach on a very cold night is about 50 percent of the reach on a warm day. Wind machines offer advantages in cold protection because they minimize labor requirements, require less refueling and less fuel storage than heaters, are permanently located in the grove, have a low operational cost per acre, and do not produce smoke and air pollution. These advantages must be weighed against the disadvantages of rather high capital costs and the failure of the wind machine to provide adequate cold protection under all conditions.

Additional protection may be provided by a combination of wind machines and heaters. The heaters not only give added protection at lower temperatures, but also increase the effectiveness of wind machines.

There are other methods of cold protection, such as utilizing the proximity of lakes and reservoirs, creating windbreaks, providing proper air drainage, and also irrigation, sprinkling, chemical spraying, insulation of trees, and manmade fog. To a large extent, these methods are either not available or not used, for economic reasons, in commercial citrus production. A comparison of major grove-heating systems is presented in Table 2.7.

Overhead water sprinkling as a frost protection measure has several advantages. The sprinkler system can be started and stopped easily, the

Table 2.7 A Comparison of the Important Grove-Heating Systems

System	Radiant Heat	Effectiveness: With Low Ceiling	Effectiveness: With High Ceiling	Effectiveness: As Border Heater	Air Pollution	Efficiency (BTU/Degree Temp.Rise)	Costs: Fixed Capital	Costs: Fuel	Costs: Labor
Lard pail*	Poor	Good	Poor	Good	Poor	Poor	Good	Fair	Fair
Lazy Flame	Fair	Good	Poor	Fair	Fair	Poor	Fair	Good	Fair
Jumbo cone	Good	Excellent	Fair	Poor	Good	Fair	Poor	Good	Fair
Return stack (gas or oil)	Good	Excellent	Fair	Poor	Good	Fair	Poor	Good	Fair
Pipeline	Fair	Excellent	Poor	Good	Fair	Fair	Poor	Good	Good
Wax candles	Poor	Good	Poor	Good	Poor	Fair	Excellent	Poor	Poor
Wind machines	Poor	Excellent	Poor	Poor	Excellent	Excellent	Poor	Excellent	Excellent
Wind machines and heaters	Fair	Excellent	Good	Good	Good	Excellent	Poor	Excellent	Good
Petroleum coke bricks	Excellent	Excellent	Excellent	Excellent	Good	Excellent	Excellent	Poor	Fair
Heaters and petroleum coke bricks	Good	Excellent	Excellent	Excellent	Good	Good	Fair	Good	Fair
Wind machines and petroleum coke bricks	Fair	Excellent	Good	Excellent	Good	Excellent	Poor	Excellent	Good

* Not acceptable where smoke controls exist.
Source: Albrecht (1967), The Citrus Industry Vol. III, W. Reutber, editor, University of California

labor cost is minimized and the sprinklers are used for regular irrigation. The system must be capable of supplying enough water so there is a continuous supply of heat obtained from freezing of water drops. It is, however, not efficient against severe freezes.

Recently the new micro-jet nozzles have become very popular since they do not freeze in very cold temperatures and provide a very fine spray of water which absorbs the cold air and thus effectively protects the trees.

2.6 Frost Protection Decision Process

2.6.1 Factors Influencing Grower's Decision to Protect

The decision of a grower to initiate protective action against freezing temperatures, assuming that they are forecasted for a coming night, depends upon a number of factors which have to be considered simultaneously. Besides meteorological factors such as current and forecasted temperature and its duration, wind velocity, humidity and cloud movement, protection decisions take into account such factors as the grove topography, variety of citrus grown and its use as fresh or processed product, market prices, previous crop damage, the grower's feeling on acceptable risk.

The geographical location, topology, the local microclimate and other factors influence the need for and the selection of frost protection technology. Wind machines and heaters could be used independently as well as in combination. The use and function of both wind machines and heaters have already been described. The combined use of both of these methods is the most effective when the temperatures are low, and/or inversions are very weak. The heaters provide additional heat which is then mixed throughout the grove by wind machines. Fewer heaters per acre are needed (approximately 15 to 25) in this combined system.

The exact level of freezing temperatures and their durations seem to be critical as far as the damages to the fruit and trees are concerned. It was reported* that leaf temperatures of 20°F and colder kill 100 percent of mature leaf tissue, while temperatures in the range of 20° to 21°F can be expected to kill between 50 to 70 percent. A 22°F reading was found to kill only 5 percent, and temperatures in the range of 23° to 24°F killed only 1 percent. Commercial growers tend to consider a hard freeze (one resulting in fruit loss and/or tree damage) to be characterized by temperatures equal to or less than 26°F for four or more hours (see Table 2.8). Therefore, as protection measures, wind machines are normally started when air temperature drops to 32°F and a duration of two or more hours at this or lower temperature is forecasted, and the air mixing started several degrees before critical temperatures, damaging to fruit

Table 2.8 Freezing Point for Citrus (°F)

Degrees of at least two hours duration		Degrees of at least two hours duration	
Small green oranges	28.5	Tender growth	27.0
Green oranges and grapefruit	27.5	Dark green growth	24.0
Half ripe orgs. & grapefruit	27.5	Buttons	24.0
Full ripe orgs. & grapefruit	27.0	Open bloom	30.0
Tangerines	29.5		

Source: The National Weather Service Office of State Climatology, Lakeland, Florida.

*Hendershott, C. H., The Responses of Orange Trees and Fruits to Freezing Temperatures, American Society for Horticultural Science Proceedings, Vol. 80 (1962), pp. 247-254.

and leaves, are reached. The heaters are normally lit when the temperature readings are 26°F. As it was stated above, these temperatures are typical and actual decision points vary greatly among the growers.

Some varieties of citrus are more sensitive than others to freezing temperatures and therefore require greater protection. Another important consideration linked to citrus variety is the date of fruit maturity. Some varieties mature during the winter months and, as a result, could be harvested immediately after a damaging frost. On the other hand, if the spring-harvested varieties are damaged, the losses are more severe.

Finally, the intended final use of the crop, whether it be for fresh fruit or processed concentrate, greatly influences long-term protection methods. Certain varieties of citrus, such as honey tangerines or temple oranges, are much more valuable as fresh fruit and, therefore, it is desirable to protect this valuable crop because of the substantial difference in market price between the fresh fruit and processed product.

In addition to these influences, the grower in the short run is always aware of fresh fruit spot prices, concentrate futures prices, his current debt situation and the price of fuel. These factors could be said to influence the grower's feelings on acceptable risk. What is unknown or at best uncertain to the grower during the crucial nightly decision making is the weather. In order to illustrate the interplay between what is known to the grower, that is location, variety, final use, acceptable risk and the weather, an example of the decisions faced on a hypothetical frost night is presented in the following section.

2.6.2 An Example of Decision Strategy During a Hypothetical Frost Night

10:15 a.m.: NWS forecast for 24-28°F in grower's area. Negligible wind velocity, typical radiational night, grower alerts foremen to possibility of frost. Foremen check condition of wind machines, amount of fuel, ordering more if necessary. High school students hearing forecast begin calling to offer services, but grower tells them to wait until 7:00 p.m. for decision.

4:15 p.m.: NWS forecast confirms 10:15 a.m. forecast.

6:00-7:00 p.m.: Grower makes first major decision on whether to just keep the foremen around for running the wind machines or hire the labor crew for the night to fire heaters. Grower decides to have full complement and tells students to arrive at 10:00 p.m.

10:15 p.m.: NWS forecast is lowered slightly to 23-27°F in most areas, possible 21°F in cold spots. Temperature at 32° in cold spots. Our grower is "risk adverse," that is, high quality tangerines for high grade fresh fruit, and consequently he orders the wind machines started in low-lying areas. He frets about the high cost of the diesel fuel, but is assured by the thought of a higher market price if frost causes damage statewide.

11:00 p.m.: Temperature at 32°F in most groves, 27°F in the "coldspots." Grower, on receiving telephone temperature reports from key groves, orders all wind machines started. Though 32°F will do no damage, he realizes that the wind machines have a greater efficiency in air mixture if started at 32°F or above. What bothers him is his uncertainty over the duration of the temperature. For example, even if it drops below 26°F for an hour, he will suffer no damage. He finishes the hour by receiving a report that a cloud bank is moving towards his area, which would raise his temperatures. He wonders if he has wasted fuel by starting the machines so early.

12:00 Midnight: Cloud bank hasn't materialized. Temperature falls to 26°F in cold spots, but there is still a rumor of cloud movement. Grower is uncertain over temperature duration. Being uncertain, he orders laborers to fire one-half of the heaters and turn off the wind machines in the cold spots. The remaining heaters are not used yet for two reasons: (1) if the temperature stays at 26°F or above only half would be needed anyway, (2) knowing that the heaters are good for only six hours of burning time, they are saved for the off-chance of an extended frost (usually the second night).

1:00 a.m.: Cold spot temperatures have been raised to 30°F by heaters, other groves at 32°F. So far so good.

2:00 a.m.: Cloud bank passes over briefly, temperatures rise and then rapidly fall. Grower was faced with uncertainty on whether to shut off heaters but decided to play it safe and leave heaters on.

3:00 a.m.: Temperatures falling rapidly in cold spots, at 24°F in some locations. Most groves holding at 30°F. Grower orders all heaters lit in colder groves. Since this is a radiational frost, he only has to protect until just after sunrise, and therefore he will have enough fuel for the remainder of the night. However, if this were an advective freeze (i.e., the blowing cold front), relative grove elevation would make little difference, and protection would have to be extended even after sunrise. At 3:00 a.m. and 24°F in this situation, the grower would probably decide to sacrifice the fruit to save his trees. He would keep the heaters lit until grove temperature reached 26°F, turn them off, let the temperature fall to 24°F again and then relight, continuing this until the danger was over. Though these temperatures and durations would damage the fruit, the repeated breaks in duration 24-26°F would save his trees and furthermore save fuel, so that he could go until the late morning hours. A grower will always sacrifice the fruit to save the trees, since a damaged tree takes several years before it returns to normal production. It must be noted that the dormancy state of the tree plays a crucial role here. If the trees were in the "green flush" stage (i.e., not dormant), a temperature of even 27°F might have damaged them.

3:30 a.m.: Temperature up to 29°F in cold spots, 30°F in most groves.

3:30-7:00 a.m.: Air temperatures remain fairly constant, as do grove temperatures. Grower continues with wind machines in higher elevations, heaters in cold spots. Turns off wind machines and extinguishes heaters at 7:00 a.m.

8:00 a.m.: Laborers sent home. Orders forman to assess fruit damage.

The frost protection process, that is, the major decisions pertaining to the protection of fruit and trees, together with all information and major factors influencing there decisions, is illustrated in Figure 2.13, which shows as the input the NWS broadcasts and the readings of grove thermometers. Decisions are based on these inputs and other factors such as availability of frost protection technology (wind machines and/or heaters) and risk adverseness of growers, as was described in previous paragraphs. Due to the complexity of the whole problem, only the decisions due to the major factors during the frost protection process are shown (Figure 2.13).

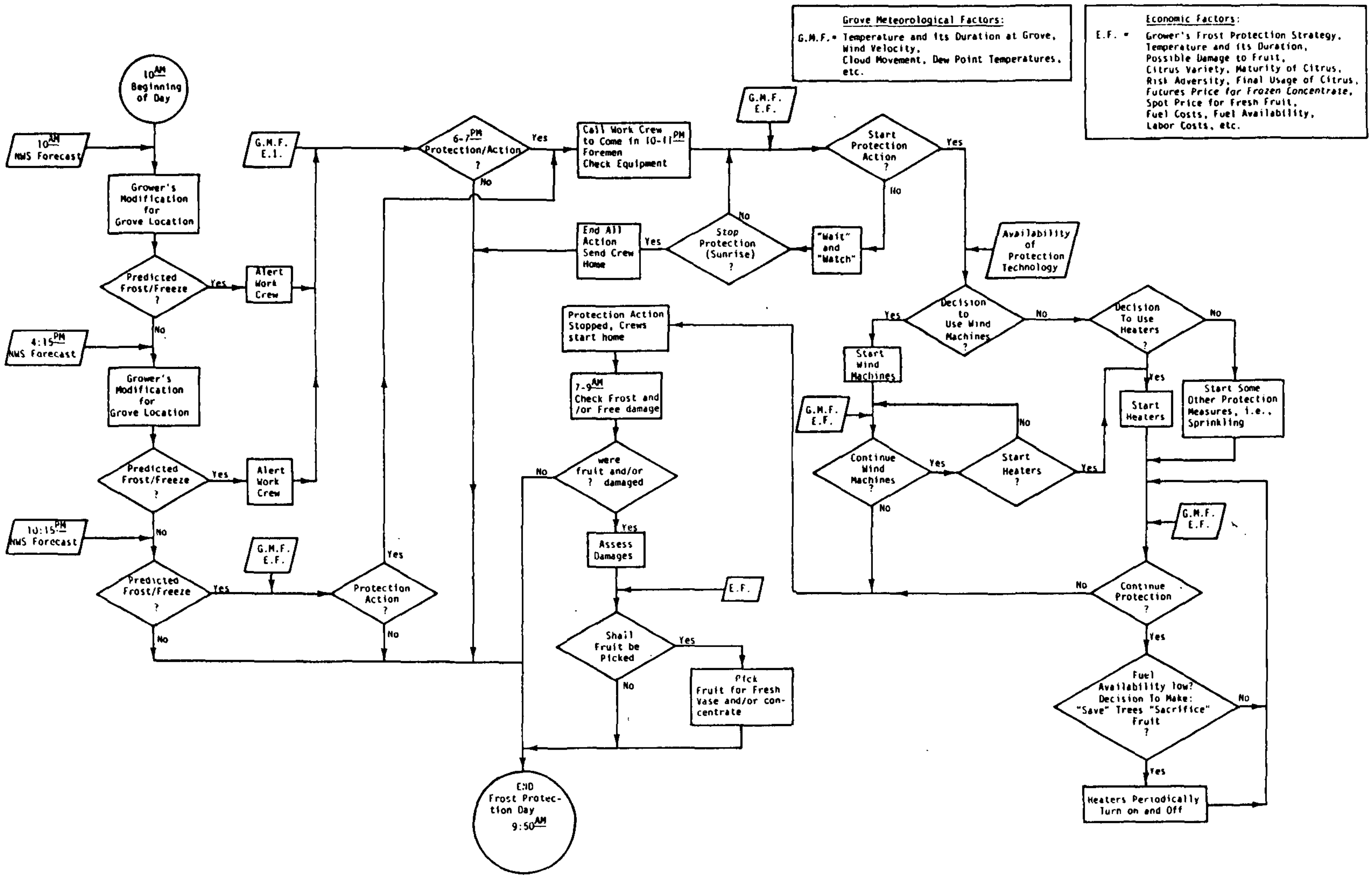

Figure 2.13 A Flowchart of a Typical Frost Protection Strategy During a Hypothetical Frost Event

2.7 Measuring the Value of Improved Temperature Forecasting

During the 1976/77 frost season, Florida citrus growers received minimum temperature forecasts and frost/freeze warnings from the National Weather Service in the routine manner established over many years. That is to say, although SMS/GOES was already in orbit, the NWS agricultural forecasters did not make use of the satellite data* in preparing their forecasts, nor did they use the University of Florida minimum temperature model. The data collection for the experiment commenced on December 1, 1976 as described in Section 3. Individual citrus growers in the experimental sample were asked to record details of their costs of protection and their losses associated with each frost or freeze that occurred from December 1, 1976 to March 31, 1977. The NWS provided a complete record of all agricultural temperature forecasts and readings of the NWS control thermometers scattered throughout the survey area. The latter are in the form of continuous thermographs.

During the 1977/78 frost season the National Weather Service at Ruskin will have the equipment to receive on-line color images, and the University of Florida minimum temperature model will be implemented on a minicomputer at Ruskin. It is anticipated that these new technological factors will improve the minimum temperature forecasts on clear cold nights (radiational freeze) in two ways: (1) the SMS/GOES spatial resolution of 4 n.mi. is considerably finer than the resolution available in previous methods, (2) the frequency of updates of objective temperature data can be increased from two to three times a day to hourly.

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*There were, in fact, occasions when the NWS at Ruskin received black and white images from NASA/KSC during the 1976/77 season.

The same experimental sample of citrus growers will participate in the experiment again in the 1977/78 frost season. They will provide the same cost and loss records (see Section 3 for details) as they provided in the 1976/77 season. The National Weather Service will again provide a complete record of all agricultural temperature forecasts for the frost season and the NWS control thermometer readings for those thermometers in the survey area. This data will be analyzed in the same way for both seasons in order to obtain a measure of the economic costs and losses associated with frost/freeze for each season. By subtracting the economic costs and losses for 1977/78 from those for 1976/77, a measure of the economic benefits of improved temperature forecasting will be derived. Figure 2.14 illustrates the basic concept of the economic evaluation.

There are a number of difficulties with the methodology described above. The most obvious is the impact on the difference in costs and losses of the difference in weather itself, regardless of forecast accuracy. Another difficulty arises in relation to changes in cold protection strategies due to a combination of changing market factors, the changing price of fuel for orchard heaters and the evolving state of the art with regard to the technology of protection.* The planned benefits analysis will attempt to deal with the effects of these factors, which are not explicitly a result of the design of the experiment.

The economic costs and losses in each season will be normalized to allow for the specific effects of that season's weather events. First, the observed costs and losses for each weather event in the sample groves will

*Newer, more effective protection devices may also cost more.

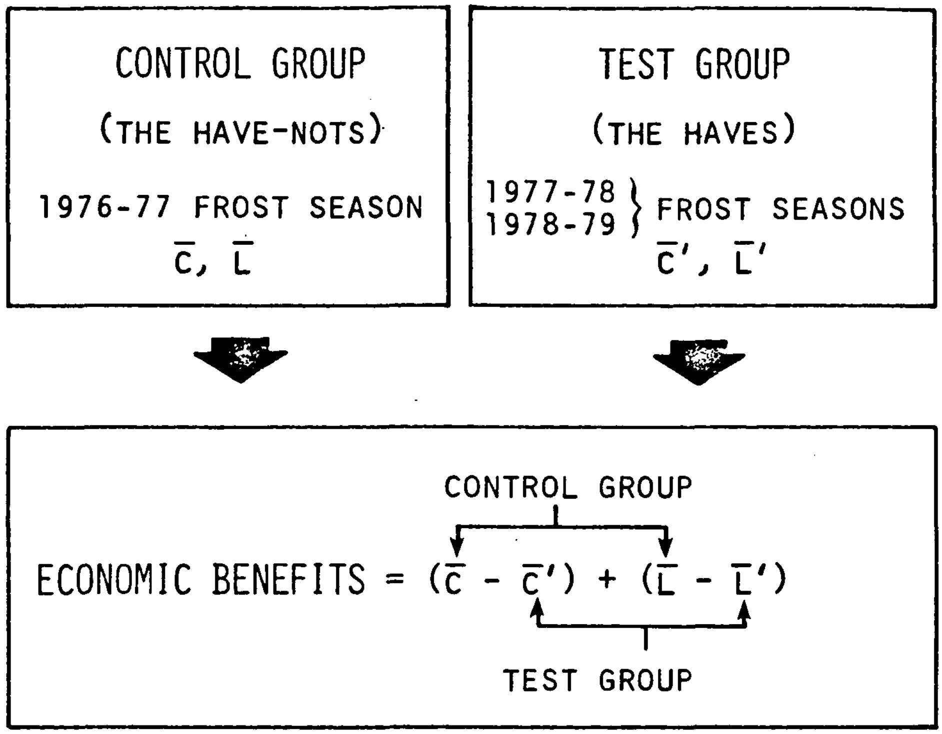

Figure 2.14 Basic Concept

be related to the measure of weather severity developed in this study from grove and NWS temperature records. A statistical regression relationship will be estimated for each season, as illustrated in Figure 2.15. Results of the statistical analysis for 1976/77 are reported in Section 4.7. Second, using the NOAA minimum temperature records for the years 1937-67, a typical pattern of weather events within a Florida frost season will be developed. Finally, economic costs and losses will be normalized to the typical pattern. The same procedure will be followed with the test group in 1978. As a result, the economic benefits of improved temperature forecasting will be normalized for the typical pattern of weather events.

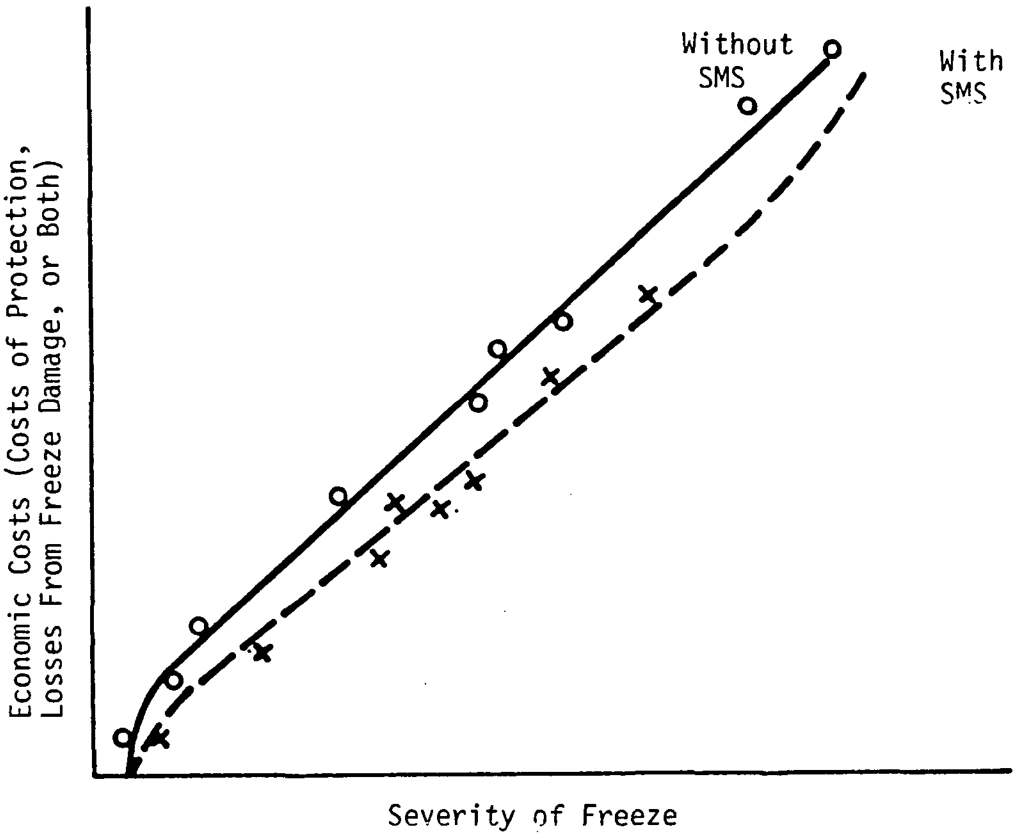

Figure 2.15 Hypothetical Relationship Between Weather Events and Economic Effects With and Without SMS

The remaining difficulties will be handled by scaling the sample results to the total protected citrus production. The scaling factors will have to be adjusted to reflect changes in the cost per unit of cold protection between the 1976/77 frost season and the 1977/78 season. While the details of this adjustment remain to be fully worked out, it is clear that minor fluctuations in the price of factors in the application of cold protection should be ignored; only major trends and shifts should be included in the scaling. One trend which appears to be on-going is the reduction in protection activity in general due to the high price of fuel relative to the price of citrus fruit. This will not show up in the estimates of protected acreage, which are made based on capability rather than intention. Thus, it will be necessary to estimate this trend by another method such as purchases of fuel and/or sales of replacement equipment for protection.

3. THE DESIGN OF THE EXPERIMENT

In order to demonstrate the economic benefits associated with improved meteorological information, it is necessary to measure a set of variables from which all costs and losses that accrue to the users of the information can be determined in terms of the quality of the information. To correctly compare the measured costs and losses which result from the utilization of improved information in the grower decision process, it is also necessary to measure other variables, such as grove temperature as a function of time (from which a measure of frost severity can be established), to establish the susceptibility of groves to freezing temperature damages, and to determine the specifics of frost forecasts. The following paragraphs describe the design of the experiment with specification of measurement procedures for all necessary variables.

3.1 Experiment Concept: Control and Test Groups

The Synchronous Meteorological Satellite (SMS/GOES) currently in orbit is furnishing temperature and other data to ground receiving stations. The National Weather Service is receiving much of this data at Ruskin, Florida and utilizing computer and display equipment which was installed at Ruskin in November 1977, together with temperature forecast models developed at the University of Florida. Thus, actual temperature distributions of 4n.mi. spatial resolution and 0.5° centigrade temperature resolution can be observed hourly across the state of Florida and incorporated into the University of Florida forecast models. These forecasts can then be utilized, in conjunction with other data available to the National Weather Service, in the determination of the meteorological forecasts provided by the National Weather Service to the citrus growers.

It is anticipated that the citrus growers will, as they have in the past, utilize the temperature forecasts in their planning and decisions pertaining to frost protection. As has been discussed previously, SMS/GOES temperature data may result in improved temperature forecasts, which may in turn result in both reduced citrus crop protection costs and reduced citrus crop losses.

The economic portion of the experiment was designed to measure the economic benefits which result from improved frost forecasting as well as the benefits associated with reduced citrus crop protection costs and reduced crop losses due to frost/freeze damage. The experiment, because of the very limited number of frost seasons which can realistically be considered (i.e., the sampling problem), is not being planned to provide experimental verification data of the economic benefits from improved marketing decisions which may result from better knowledge of actual temperature distributions throughout the state of Florida.

It should be noted that the objective of the Florida ASVT is actually twofold, namely, (a) to demonstrate the impact of satellite-derived data upon the accuracy and timeliness of frost forecasts to Florida citrus growers, and (b) to measure the resulting economic benefits. The experiment concepts to be discussed in the following pages are concerned only with the measurement of the economic and related (i.e., fuel conservation) benefits.

In order to measure the economic benefits of improved information (i.e., the SMS/GOES temperature data), it is necessary to establish and then compare the costs and losses which would result with and without the improved information. This implies establishing two separate groups, namely, a test group (the "haves") and a control group (the "have-nots").

Since the National Weather Service does not at this time contemplate changing the information distribution network, and since current agricultural temperature forecasts are available to all citrus growers, it is not possible to establish control and test groups simultaneously in the state of Florida. This implies that the necessary isolation between the citrus growers comprising the control and test groups must be established through geographic and/or time displacement. Since geographic displacement within the state of Florida is not possible, it is theoretically possible to establish a control group outside of Florida. Serious doubt as to the credibility of a control group outside of Florida has been raised by representatives of the Florida citrus growers, the NWS, the USDA County Extension Agents and the University of Florida. Since it was deemed important to develop credible results, the idea of a control group outside the state of Florida has been ruled out. Thus, it is necessary to establish the control group by time displacement.

It was therefore decided to establish a control group consisting of a number of growers during the 1976-77 frost season. The same growers which participate as the control group could also participate in the test group during the 1977-78 and other future frost seasons. The Florida citrus crop frost forecasting experiment plan is predicated upon this approach.

The basic concept of the experiment is as follows. During the 1976-77 frost season, the National Weather Service provided frost and temperature forecasts and measurements to the citrus growers in a business-as-usual fashion--that is, without the benefit of SMS/GOES temperature data, without the University of Florida forecasting models and without the computers and display equipment required to operate on the SMS/GOES data with the University of Florida models. During the 1976-77 frost season, a selected set of citrus growers provided data on actual temperatures, decisions made and actions taken. These growers provided cost- and loss-related data. The National Weather Service provided data pertaining to temperature forecasts and actual observed temperatures. This data was analyzed by ECON, and the average cost and loss per event determined for the control group.

The same processes, as performed during the 1976-77 frost season, will be repeated during the 1977-78, 1978-79 and possibly following frost seasons. It is assumed that the SMS/GOES data, together with the University of Florida forecasting models, and improved computer and data display equipment, which are being used by the National Weather Servic, starting with the 1977-78 frost season, will continue to be used in the future. It is felt that a minimum of two frost seasons of test group experience are required since it is likely that during the first season, growers and forecasters will be learning to adapt their decisions and actions to the improved information. Thus, it is likely that the 1977-78 frost season will be a transient one with the steady-state reached by the 1978-79 frost season.

The data provided by the test group will, as in the case of the control group, yield average cost and loss per event. As described in following pages, both the control group and the test group cost-and-loss-per-event data can be extrapolated to the annual cost and loss for the Florida citrus industry for an average frost season. The difference between control group and test group annual costs and losses extrapolated to an average frost season will provide an estimate of the average annual benefits which are a direct result of the improved information. These benefits will include the reduction of citrus grower frost protection costs and the reduction of crop losses, which are the result of the improved information. The benefit assessment will not include, because of the limited number of frost seasons (and hence data samples), those benefits which are the result of better marketing decisions made possible by the improved temperature distribution knowledge provided by the SMS/GOES data.

3.2 Methodology

3.2.1 Segmentation

The sample of Florida citrus groves falls into several major classes or segments. For each grove in the experiment sample, a citrus variety is identified* at the beginning of the data collection. The varieties are:

- Early and midseason oranges
- Late (valencia) oranges
- Seeded grapefruit
- Seedless grapefruit
- Tangelos or temples
- Tangerines.

Lemons and limes were excluded because they are not usually grown commercially in areas of the state which experience regular winter frosts, being too sensitive to cold weather.

The groves can also be segmented according to type of cold protection. There are major differences in cost and effectiveness of different methods of cold protection. For example, oil heaters cost more (per acre) to run

*Occasionally more than one variety grows in a single grove, but this is rare.

than wind machines and are more effective in protecting the grove, particularly against an advective freeze. For calm, clear nights, the combination of heating and wind machines may be recommended, and so forth. In this experiment, the major types of cold protection are distinguished as follows:

- Heaters (return stack, jumbo, lazy flame)
- Wind machines (single and double)
- Overhead sprinklers (with or without microjet nozzles)
- Central systems for heating groves
- Irrigation
- Fog machines.

The differences in costs of protection and losses from freeze damage can be analyzed by type of protection because of the segmentation.

Citrus groves may differ in respect to the microclimate due to geographic location, elevation, the proximity of windbreaks and of large bodies of water. Predicting the effect of these factors on minimum temperatures in the grove on cold nights is very difficult. Nevertheless, observations on the spatial distribution of temperature for a night of frost or freeze permit segmentation of the experimental citrus groves according to observed severity of frost/freeze. An index of severity is developed in Section 3.6. For each weather event, the groves can be segmented by the level of severity. Costs of protection and losses from frost/freeze damage can be analyzed according to the degree of severity observed.

3.2.2 The Sampling Plan

The distribution of the protected acreage throughout the citrus region is very important in determining the target population, the survey population, and finally, the sampling frame. The target population is considered to be the total citrus-producing acreage which is protected against the freezing temperatures. However, the protection of citrus is less important in the southern areas of peninsular Florida, and only acreage allocated for the specific fruit and nurseries is protected. Also, the citrus-bearing acreage in the northern areas of the peninsula, even if it is almost all protected, represents only a small fraction of the total protected acreage. Therefore, it seems reasonable to exclude the citrus-bearing protected acreage in the southern and northern areas of the peninsula from the data-gathering portion of the experiment. The survey population is therefore defined as the citrus-bearing acreage which is protected against the possibility of freezing temperatures, and is geographically located in the central region of the peninsula of Florida. It is this population from which cooperative growers were selected for participation in the control and test groups. The survey population is estimated as comprising approximately 95 percent of the target population.

In order to estimate both the number of growers included in the target population and the number of growers who might participate in the economic experiment, ECON contacted two USDA multicounty extension agents in 1976. These extension agents* assist citrus growers in the prime protected producing areas of Polk, Lake, Orange and other east coast counties. Table 3.1 shows their estimates of total acreage, number of growers, number of groves in their jurisdiction. The protected acres within this region represent more than 75 percent of the total protected acreage in Florida.

*John Jackson and Tom Oswalt.

Table 3.1 Estimate of Grower Survey Population and Sample Size Based on Data from the Major Frost-Affected Citrus-Producing Areas*

	Total Acreage	Growers	Groves**
Total	326,000	7,200	8,000-9,000
Frost Protected	51,000	230	1,200-1,300
Frost Protected and Probable Participants	20,000	55	400-600

*Based on Lake, Orange and Polk Counties and parts of other counties on east coast; estimation done in April, 1976.

**Assumes average grove size of 40 acres

The survey population may be divided for sampling purposes into sampling units. For the case at hand, the sampling unit is the citrus-producing grove which is protected against the effects of frost and/or freeze. A grove containing a minimum of 50 citrus-bearing trees is considered to be the smallest unit. This is consistent with the Florida Department of Agriculture's Commercial Citrus Inventory published biennially.* Groves vary in size; the large groves may contain several thousand acres of trees and the effect of the size should be included in an evaluation of the sampling.

There are two basic types of sampling frames, namely, the area frame sampling and the list frame sampling. These sampling frames, and their

*Commercial Citrus Inventory, Florida Department of Agriculture, Florida Crop and Livestock Reporting Service, Orlando, Florida.

combination, the multiframe sampling, are currently used in the collection of data for agricultural statistics.

In area frame sampling, the frame consists of an aggregation of characteristics concerned with agriculture associated with these sample segments using three different concepts: the closed segment, the open segment, and the weighted segment. The closed segment includes all agriculture that is inside the segment boundaries and excludes all that is not. In the open segment all activities of farms with headquarters located inside the segment are associated with the segment even if some activities are outside the segment boundaries. In the weighted segment, all agriculture associated with a farm is attributed to the segment in proportion to the fraction of the farm acreage that is inside the segment.

A list frame is a list of identified elements from the sampled population. For the particular case under consideration, lists of names and addresses of growers and grove managers will be used in collection of information. The cost of data collection from the list frame is relatively low. The indexing of various characteristics used for efficient stratified sample designs can be easily developed and incorporated in the list frame. The list frame, however, is almost never "complete" because the units of the frame (i.e., groves), are continually changing. Therefore, only nonprobability sampling is used with a list frame.

This disadvantage is removed in multiple-frame sampling where more than one frame is used. For agricultural statistical purposes this implies the use of both a list frame and an area frame. This method is very effective for specialized types of crops, such as citrus, which are not correlated with land alone. For the citrus experiment, some of the main characteristics pertinent to the sampling, such as frost protection technology, variety of citrus, use of crop, micrometeorological factors and the cost associated with the frost/freeze protection, are not associated with land. Therefore, most of the data for population can be collected more efficiently through the list frame. The area frame complements the list frame and thus allows the application of probability surveys.

A variety of list sources is available for the development of the list frame to be used in the experiment. The following organizations maintain statistical records which are available for use:

- Florida Department of Agriculture and Consumer Services
- Florida Crop and Livestock Reporting Service
- Agricultural Stabilization and Conservation Service
- State Farm Census
- Assessor's records
- State Government records maintained for inspection and controls
- Records of Florida Cooperative Extension Service, University of Florida, Institute of Food and Agricultural Science
- Citrus grower's records.

One of the most important sources for the construction of the list frame is the Florida Cooperative Extension Service, whose records are periodically updated by the county extension agents. They have an intimate knowledge of almost all citrus groves in their districts (one or more counties) and maintain a constant communication with citrus growers. Their help was especially valuable in determining the location and distribution of protected groves, the availability of cooperative growers who were willing to supply information on their costs of protection and losses from freeze damage, and the relationship of these groves to the target population.

In designing the sampling plan for the economics portion of the experiment, the overriding concern was the availability of cooperative citrus growers with protected acreage in central Florida. The flow of timely and accurate information from these growers was essential to the success of the experiment. Random sampling thus was excluded as a possibility since the response rate from randomly selected citrus growers was judged too low by University of Florida fruit scientists and ten county extension agents. It was decided to use a nonprobability sample based on the list frame existing in the county extension service records. For this purpose a guideline was prepared indicating the number and type of groves desired in each county (of the eight-county area in central Florida) and the county extension agents were asked to submit lists of growers and groves which would be used for the experiment. ECON interviewed a number of growers who agreed to participate, but most of the selection process was in the hands of the extension agents. The resulting sample (Table 3.2) included the majority of growers who (a) have protection capability, (b) are willing to divulge their cost and loss information.

3.2.3 Expansion From Sample to Industry

The results in terms of the costs and losses experienced by the citrus growers for the sample groves, within a frost season, represent the basic economic data for the experimental sample. From these results, it is possible to infer the economic impact of the frosts and freezes on the part of the citrus industry which employs cold protection, by "expanding"

Table 3.2 Sample Groves by County	
County	Number of Sample Groves
Polk	109
Lake	51
Orange	38
Hillsborough	15
Marion	14
Highlands	10
Hardee	4
Osceola	4

all the sample results. The factors of expansion are derived as follows. Let C_{IJK}, L_{IJK} and A_{IJK} be costs per acre, losses per acre and acreage for county I, fruit type J within sample unit (grove) K. Most groves are homogeneous as to fruit type, and of course lie within one county. Also, let

CP_I = total protected citrus acreage in county I

CT_{IJ} = total citrus acreage of fruit type J in County I

CT_I = total citrus acreage in county I $= \sum_J CT_{IJ}$

First, the total protected acreage in county I of fruit type J is estimated as follows:

$$\hat{A}_{IJ} = CT_{IJ} * CP_I/CT_I$$

Then the protection costs per acre and freeze losses per acre can be estimated for each county and fruit type as follows:

$$\hat{C}_{IJ} = \sum_k A_{IJK} * C_{IJK}/\sum_k A_{IJK}$$

$$\hat{L}_{IJ} = \sum_k A_{IJK} * L_{IJK}/\sum_k A_{IJK}$$

Finally, the expansion is completed by calculating the total protection cost and freeze loss (for protected acreage):

$$\hat{C} = \sum_{I} \sum_{J} \hat{C}_{IJ} * \hat{A}_{IJ}$$

$$\hat{L} \quad \sum_{I} \sum_{J} \hat{L}_{IJ} * \hat{A}_{IJ}$$

In actual practice, the exogenous industry statistics on protected acreage by county and fruit type are difficult to obtain, and some approximations are necessary. These are described in Section 4.6 of this report.

3.2.4 <u>Normalization of Costs and Losses to Standard Weather Pattern</u>

The results for the 1976/77 season may differ from the results for the 1977/78 season due to differences in the weather itself. This is not the same as the economic effect of improved temperature forecasting. Clearly, it is essential to base the comparison of economic costs and losses between the two frost seasons on a standard weather pattern; in other words, to normalize the results for weather differences.

The National Weather Service in Florida has provided ECON with a computer tape which contains temperature profiles of the years 1937 to 1967 for all nights from November 1 to April 1 on which the observed temperature fell below 32°F. These profiles were recorded at 72 NWS thermometers in the citrus-growing region of Florida. Analysis of this weather data allows calculation of the standard weather pattern. Details of the procedures are provided in Appendix D.

For both the control group (1976/77) and the test group (1977/78), a statistical relationship between costs and losses will be estimated, on the one hand, and the severity of frost/freeze, on the other hand. The equation for this relationship can be written formally as:

$$C_{IJKM} = \beta^{(0)}_{IJ} + \beta^{(1)}_{IJ} S_{IJKM} + \beta^{(2)}_{IJ} S^2_{IJKM} + \varepsilon_{IJKM}, \text{ and}$$

$$L_{IJKM} = \alpha^{(0)}_{IJ} + \alpha^{(1)}_{IJ} S_{IJKM} + \alpha^{(2)}_{IJ} S^2_{IJKM} + \eta_{IJKM}$$

where I and J are indices referring to the segmentation of the analysis, K indexes the groves, M indexes weather events and S is the severity of frost/freeze. The ε_{IJKM} and η_{IJKM} terms are disturbances (errors). Once the coefficients (α's and β's) of these equations have been estimated by regression, the standard weather pattern obtained from the 30-year temperature profiles can be used to generate normalized costs, $\overline{C}_{IJKM}$, and losses, $\overline{L}_{IJKM}$, by introducing $\overline{S}_{IJKM}$, the standard severities, into the equations, assuming zero errors. An alternative procedure is to compute hypothetical costs and losses for each grove and each cold night in the 30-year data, effectively simulating the 30 years of frost in the sample groves. Then an average cost and loss can be computed for each grove and each calendar date. This latter method appears to be computationally simple, but the actual choice of method will be made after completion of the regressions and the preliminary analysis of the 30-year data.

3.3 The Sample of Citrus Growers

The major citrus-producing area in Florida is located in the central region of the state, around the sandy ridge extending north-south within the interior of the peninsula. The results of the biennial survey by the Florida Crop and Livestock Reporting Service (Figures 2.2 and 2.3) show that, of Florida's 706,200 total citrus-bearing acreage, almost 51 percent (406,000 acres) is located in Marion, Lake, Orange, Polk, Hillsborough, Osceola, Hardee and Highlands counties, which are all located in the central part of the state. The Indian River producing region along the east coast has more favorable climatic conditions and generally does not require citrus protection.

A survey by the Florida Citrus Mutual in 1974 estimated that a total of 105,745 acres utilize heaters for frost protection (Table 3.3) and that 78,019 of these acres (73.8%) are in the above listed counties. No survey was performed to estimate the acreage protected by wind machines and other frost/freeze protection methods, but it is reasonable to assume that the protected citrus acreage in the seven counties of the central part of the state represents more than 75 percent* of all Florida's acreage protected against frost and/or freeze.

The distribution of the protected acreage throughout the citrus region is very important in determining the target population, the survey population, and finally, the sampling frame. The target population is considered to be the total citrus-producing acreage that is protected against the possibility of freezing temperatures. However, the protection of citrus is less important in southern areas of peninsular Florida and only acreage allocated for special fruit (limes, lemons, etc.) and nurseries is protected. Also, the citrus-bearing acreage in the northern areas of the peninsula, even if almost all protected, represents only a small fraction of the total protected acreage. Therefore, it is reasonable to exclude the citrus-bearing protected acreage in the southern and northern areas of the peninsula from the data-gathering portion of the experiment, and to define the survey population as the citrus-bearing acreage which <u>is</u> protected against the possibility of freezing temperatures and is geographically located in the central region

*This percentage would be higher for the protection technology which is more capital intensive (such as wind machines).

Table 3.3 Estimated Citrus Acreage Protected by Heaters

County		Total Acres	Estimated Heated Acres
Polk		150,122	30,000
Volusia		12,324	7,300
Brevard		20,160	2,000
Hendry		22,447	--
Dade		4,531	680
Seminole		12,067	200
Manatee		18,943	4,546
Hardee		50,716	3,042
Lake - Orange		208,757	8,350
Hillsborough		59,727	23,293
Marion		13,988	7,134
Osceola		19,051	4,500
Highlands		38,803	6,200
Pasco		42,331	4,000
	TOTAL	673,967	101,245
Broward		5,030	--
Indian River		51,815	--
Martin		41,385	--
Palm Beach		17,566	--
St. Lucie		75,397	--
Charlotte		6,734	--
Collier		5,052	--
Desoto		25,478	500
Glades		1,572	--
Lee		7,439	--
Okeechobee		3,597	--
Pinellas		5,825	250
Sarasota		1,612	50
	TOTAL	248,502	800
Putnam		4,709	1,400
Sumter		2,379	500
Citrus		2,222	500
Hernando		9,150	1,300
	TOTAL	18,460	3,700
	GRAND TOTALS	940,929	105,745

SOURCE: Florida Citrus Mutual, 1974.

of the Florida peninsula. Figure 3.1 shows the survey population and its relation to the total citrus acreage. It is this population from which growers were selected for participation in the control and test groups. The survey population is estimated as comprising approximately 95 percent of the target population.

Several methods are used for the collection of data for agricultural statistics.* The method which is most effective for the data collection associated with specialized types of crops such as citrus, which are not correlated with land alone, is "list frame sampling." Once the list frame is established, the specific elements can be selected for inclusion as part of the control and/or test groups taking into account their specific characteristics.

The development of the list frame (list of all participants) used in the experiment was primarily based upon the records of the Florida Cooperative Extension Service, which are periodically updated by the county extension agents. The agents have an intimate knowledge of almost all citrus groves in their districts (one or more counties) and maintain a constant communication with citrus growers. Their help was instrumental in the construction of a list and selection of all growers (and groves) who participated in the experiment. A key element in the selection of growers for participation in the experiment was the county extension agent assessment of the probable grower cooperativeness in providing data and filling out forms over extended periods of time. The cooperation of growers, grove managers and caretakers

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*Scope and Methods of the Statistical Reporting Service, U.S. Department of Agriculture, Miscellaneous Publication No. 1308, Washington, D.C., 1975.

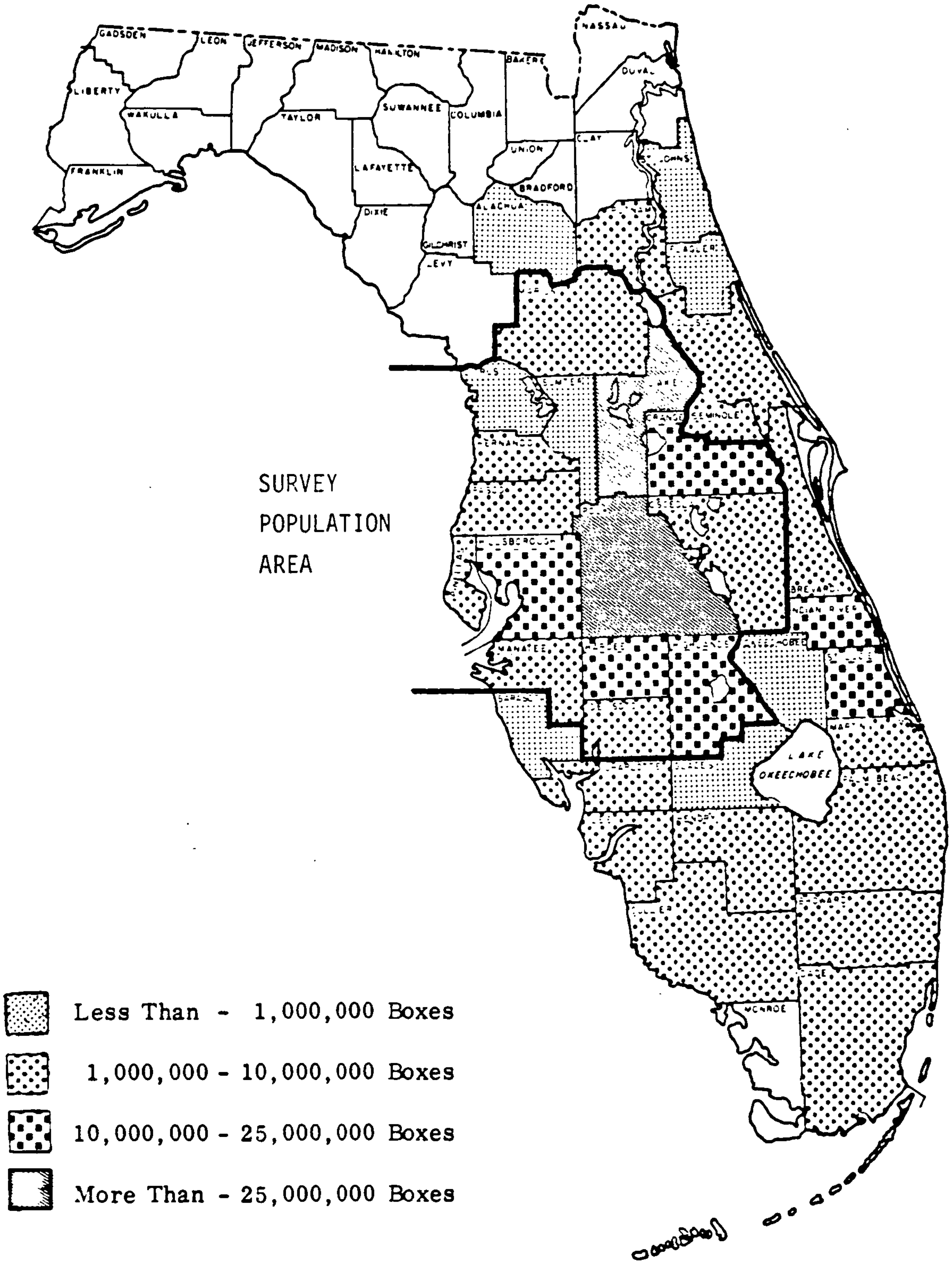

Figure 3.1 Relation of Survey Population (Protected Citrus Acreage) to Total Citrus Acreage in Terms of Citrus Production (1974-75)

is most important in the effort to obtain as complete a list of all measured characteristics as possible. The complete and timely return of questionnaires and cooperation during interviews is necessary for the successful collection of data.

3.4 Grower Data Collection

Grower data collection is concerned with obtaining information about the sample grove characteristics, their past history and present and future status, and frost protection decisions, actions, costs and losses. The most effective way of obtaining this information is to obtain it directly from the people who in the past and the present take care of the groves which are part of the experiment. They are called "growers" even if they do not own the groves and are only the managers or caretakers of the groves.

In general, data can be collected by interviewing the experiment participants or by obtaining written responses of participants to prearranged questions in a questionnaire. Although both interviews and questionnaires rely heavily upon the validity of verbal reports, there are important differences between these two methods.

In an interview, because the interviewer and the person interviewed are in direct contact when the questions are asked and answered, there is great flexibility in eliciting information. The interview surveys typically attain higher response rates than surveys using the written answers of the respondents (participating growers in our case). The presence of an interviewer generally decreases the number of "don't know" and "no" answers. Interviewers also clarify questions which may be confusing to the respondent and thereby obtain relevant responses. Finally, the interviewer can observe as well as ask questions and his observations sometimes provide answers to the questions which would have remained unanswered on a questionnaire. However, the cost associated with the interview survey is often prohibitive.

The questionnaire survey is a much less expensive procedure. The questionnaires are usually mailed or handed to respondents with a minimum of explanation and the answered forms are then returned by mail. They can be administered to a large number of individuals simultaneously, while an interview survey calls for questioning each individual separately. With a given amount of funds it is then possible to obtain a much larger sample with a questionnaire survey than by personally interviewing each respondent.

A data form questionnaire has an impersonal character since the wording and the order of questions, the instructions about the meaning of questions and how to fill out the forms in general, are all standardized. This standardization ensures some degree of uniformity and helps in the subsequent evaluation of responses. On the other hand, a question with standard wording may have different meanings for different people or might be incomprehensible to some respondents. Carefully written instructions and assistance to the subjects during the administration of the questionnaire help to solve this problem.

Another advantage of questionnaires is their anonymity. The respondents may feel freer to express views they fear might be disapproved of otherwise or get them into trouble. Finally, it is characteristic of the questionnaires that they place less pressure on the subject for immediate response. Having been given an ample time to answer the questions in a written form, a respondent can consider them more carefully. However, this advantage brings along a disadvantage in delayed response from some subjects and also demands a personal effort on the part of the subjects to return the answered questionnaires.

The questionnaire technique was extensively employed during the data collection for this experiment. It was, however, supplemented by interviews in order to clarify some questions, increase the rate of response in general, and increase the reliability of results.

The citrus growers who participated in the control group but did not respond by mailing their completed forms were contacted by the county extension agents who administered their regions. The agents interviewed the growers either in person or via telephone. Additional interviewing of some growers was also done by ECON employees, especially in the districts where a large number of participating growers represented an excessive work load for the agents. It is not possible to measure exactly the increase in responses due to this additional effort of interviewing the growers, but it could be said with certainty that the combination of both survey techniques, mailed questionnaires and personal interviewing, has contributed greatly to the overall high rate of response.

3.4.1 Design of Questionnaires

In general, questionnaires are designed to obtain information by asking questions about what a respondent knows, believes or expects, feels or wants, intends or does or has done, and about his explanation or reasons for any of the preceding. The questions are not in an arbitrary order. The order of questions, the number of questions about the same subject, and their grouping in "batteries" is very carefully planned. The order of questions is important so that they do not affect each other nor offend or make the respondents adopt a defensive attitude towards the inquiry.* The questions which might affect the answers to other questions are dispersed in the questionnaire. The most general questions are normally asked first and the more specialized ones are asked at the end of a group of questions about the same subject.** The first questions are easy ones, sometimes only of little relevance to the investigation, and also have as a purpose "relaxing" the respondent and gaining his confidence. When certain delicate questions must be asked, they are generally put at the end of the questionnaire or at the end of a "battery" of questions on any particular subject; by this time the respondent is in a trusting frame of mind and there is more chance of obtaining a reply. Even if the respondent takes offense, answers to the preceding questions will not be distorted.

The total number of questions must not be too great, to avoid tiring the respondent, resulting in the last questions being answered less accurately. Questions on a variety of subjects are usually grouped together. The questions on the same subject help to limit the errors and the answers can be compared and checked; the analysis is thus given an additional depth.

The questionnaire survey measures a variety of variables. These variables are then categorized using several measurement techniques referred to as "nominal," "ordinal," "interval" and "ratio" scales.*** The nominal scale merely distinguishes the categories that comprise a given

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*Duverger, M., An Introduction to the Social Sciences, F. A. Praeger, New York, 1964.

**This arrangement of questions is called "the funnel technique."

***Babbie, E. R., Survey Research Methods, Wadsworth Publishing Co., Inc., Belmont, California, 1973.

variable. For example,* region of the county, grove location, and type of protective technology are nominal variables. The categories comprising a nominal variable are mutually exclusive, but they bear no other relationship to one another.

The ordinal scale reflects a rank-order among the categories comprising a variable. The question: "On a scale of one to ten, how much confidence do you have in the NWS forecast?" (question four in the Nightly Frost/Freeze Protection Activity Report) would be an example of a measurement on an ordinal scale.

The interval scale also utilizes numbers to describe conditions. The numbers have, however, definite meanings such as measurements of temperatures on the Fahrenheit scale. The ratio scale is similar to the interval scale and has the additional characteristic of true zero. For example, the age of citrus trees is measured on the ratio scale.

The form of questions has a great influence on the response to them. The text of questions should be as simple as possible, the language used should be familiar and easily comprehensible to all respondents. The questionnaire items should be clear and unambiguous. A lack of understanding between the researchers and respondents could arise either when the respondents have given little or no attention to the topic of an investigation and the researchers who formulate questions are deeply involved in it, or the researchers have only a superficial understanding of the topic and fail to specify the intent of their questions sufficiently. During this experiment this problem was minimized by pretesting the questionnaires

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*Variables from the questionnaires designed in the experiment are used as examples.

whenever possible, and by frequent consultations with the experts in the citrus industry.

The questionnaires contain two basic forms of questions: open-end and closed-end questions. In the case of open-end questions, the respondent is asked to provide his own answer to the question and is provided with a space to write his answer. This type of question represents a problem during processing of answers because of the need for additional coding and also because there is a danger that the answers might be essentially irrelevant to the topic of the investigation.

In the case of closed-end questions, the respondent is asked to select his answer from among a provided list. The closed-end questions provide a greater uniformity of responses and are more easily processed. The response categories provided should be exhaustive and they should include all possible responses that might be expected. Also, the answer categories should be mutually exclusive--the respondent should not feel compelled to select more than one. Multiple answers, which are sometimes desirable, create difficulties in processing, which can be overcome by careful coding of the results.

During the experiment with the Florida citrus growers, a thorough study of the theoretical considerations and general guidelines of questionnaire design was made. In order to gather all necessary information for the evaluation of economic benefits due to the improved temperature forecasts, three different types of questionnaires or reports were designed and utilized: (a) Grove Background Report, (b) Nightly Frost/Freeze Protection Acitvity Report, and (c) Damage Report. All three reports have a different character and were designed to provide a specific type of information. In order to enable the growers to easily distinguish the three different types of reports, they were printed on colored paper. Green paper was used for Grove Background Reports (these forms were then called "green forms"), white paper was used for the Nightly Frost/Freeze Protection Activity Reports ("white forms") and, finally, pink paper was used for the Damage Reports ("pink forms"). These are illustrated in Figures 3.2 to 3.4 Instructions on how to complete the questionnaires were given separately for each type of questionnaire and were printed on paper of a corresponding color (i.e., "green forms" instructions on green paper, etc.). This distinction of forms by their color proved to be very convenient during the administration of the questionnaire survey.

The following sections briefly describe the three different reports which were used during the data collection for the experiment with Florida citrus growers.

3.4.2 Grove Background Report* (Refer to Figure 3.2)

The Grove Background Report is designed to gather general information concerning the groves selected for the experiment. The information provided by this report is assumed to be invariant during the Florida winter season (from December to March). This report is completed prior to the start of the frost season.

The format of the report is such that a short introductory statement at the top informs the respondent that the questions are to be answered only once at the beginning of the frost/freeze protection season. A box is provided in the right hand corner of the green form for an identification number which is uniquely assigned to every grove in the sample. The number

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*Examples of filled out reports and the corresponding instructions (as given to the citrus growers) are presented in Appendices E and A, respectively.

has two parts: the first part identifies the county in which the grove is located and corresponds to a part of the automobile license tag numbers of that county; the second part is the serial number in the list of all groves which are administered by that county extension agent.

The questions in the Grove Background Report are arranged into five content subsections, each labeled by an underlined heading. The first subsection groups together twelve questions concerning the description and characteristics of the grove. To avoid confusion, the definition of a "grove" is given in the instructions for this report (a need for this definition was discovered during a pretesting of the questionnaire). A "grove" is defined as a land area (a) with citrus of the same variety, (b) planted mostly at the same time, (c) having a uniform degree of frost/freeze protection and (d) subject to the same management and agricultural practices.

Each grove usually has its own name or number which is used by the grower. This name is filled out as the reponse to the first question and is used as a cross-reference during the evaluation of collected data. The second question is concerned with the grove's geographical location. The State of Florida is divided into townships, ranges and sections and these three parameters help to identify the location of a grove. This information is necessary to obtain the FCIC classification for the grove, which is needed for scaling purposes. The following two questions are of a closed-end type and a grower is asked to select the variety of citrus grown in the grove and the type of rootstock from the lists provided.

Citrus trees reach their full productivity when they are about seven years old. Therefore, the fifth and sixth questions are concerned with the age of trees as well as percentage of all trees which are resets (new trees

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GROVE BACKGROUND REPORT

I.D. No. ________

This section records some specific information about one of the groves selected for this study. Most of this information will not change from December to March. Please be as specific as possible in answering these questions.

DESCRIPTION AND CHARACTERISTICS OF THE GROVE

1. Your own grove identification: ____________

2. Grove location: ________ / ________ / ________
   Section / Township / Range

3. Variety of Citrus grown in this grove:

   CIRCLE ONE NUMBER

   1 Early Oranges
   2 Midseason Oranges
   3 Late (Valencia) Oranges
   4 Temples
   5 Tangelos —
   6 Tangerines & Honey Tangerines
   7 Seedy Grapefruit
   8 White Seedless Grapefruit
   9 Red-Pink Seedless Grapefruit
   10 Some other variety; PLEASE SPECIFY: ________

4. Type of rootstock: CIRCLE ONE NUMBER
   1 Rough Lemon
   2 Sour Orange
   3 Cleopatra Mandarin
   4 Trifoliate Orange
   5 Carrizo Citrange
   6 Other

5. Year grove was planted: ____________

6. Percentage of all trees that are resets less that 7 years of age or skips: ________ percent

7. Grove area (If possible be as specific as tenths of an acre of actual citrus bearing tree acres.): ________ acres

8. Grove terrain: CIRCLE ONE NUMBER
   1 High Ground
   2 Low Ground
   3 Other; PLEASE DESCRIBE ________

9. Grove soil type: CIRCLE ONE NUMBER
   1 Ridge
   2 Flatwoods
   3 Other; PLEASE DESCRIBE ________

10. Are there any large bodies of water which may influence your grove? 1 Yes 2 No

11. Is there a control thermometer associated with this grove which is outside of the protected area? 1 Yes 2 No

12. If you know the Federal Crop Insurance Corporation classification of this grove would you please write it down? ________

If you have any questions, call your county extension agent.

GROVE STATUS

13. Month of expected harvest: CIRCLE ONE NUMBER
    1 January
    2 February
    3 March
    4 April
    5 May
    6 June
    7 July
    8 August
    9 September
    10 October
    11 November
    12 December

14. Average yield in this grove in the
    1973-74 season: ________ boxes per grove
    1974-75 season: ________ boxes per grove
    1975-76 season: ________ boxes per grove

15. Estimate of yield for the 1976-77 season: ________ boxes per grove

16. Grove has experienced frost/freeze damage in the past three years which has reduced the grove's productivity or damaged the trees:
    1 Yes → When did this damage occur? Month:________ Year________
    2 No Month:________ Year________
    Month:________ Year________

17. Did this damage prompt any additional frost/freeze protection measures for this grove? 1 Yes 2 No

MARKETING PLANS

18. At this time, do you intend to produce the citrus from this grove for fresh or processed market? CIRCLE ONE NUMBER
    1 Fresh
    2 Processed
    3 Don't know

19. What are the primary reasons you plan to market this fruit in this manner? CIRCLE AS MANY AS APPLY
    1 Variety or quality of fruit
    2 Expected market price
    3 Anticipated costs of freeze/frost protection
    4 Other; PLEASE EXPLAIN: ________

PLEASE CONTINUE ON NEXT PAGE

Figure 3.2 Grove Background Report

FROST/FREEZE PROTECTION MEASURES

20. Wind machines used in this grove? 1 Yes
2 No...GO TO QUESTION 22

21. Wind machine data for this grove:

Type of Machines	Number of Machines	Type of Fuel	Average Fuel Consumption Rate*

*diesel........gallons/hour
gasoline......gallons/hour
electricity...kilowatts/hour
propane.......pounds/hour

22. Heaters used in this grove? 1 Yes
2 No...GO TO QUESTION 26

23. Heater data for this grove:

Type of Heaters	Number of Heaters	Type of Fuel	Average Fuel Consumtion Rate*

*diesel fuel...gallons/hour
propane.......pounds/hour

24. Storage capacity and fuel on hand:

Type of Fuel	Storage Capacity	Fuel on Hand
diesel	gal.	gal.
propane	lbs.	lbs.
other		

25. Average price of fuel on hand: diesel fuel ______ ¢/gallons
propane ______ ¢/pound
other ______

26. Other frost/freeze protection methods used in this grove?

1 Yes → What kind? 1 Permanent Oil Heating System
2 Sprinklers
3 Flood Irrigation
4 Other; PLEASE DESCRIBE: ______

OTHER INFORMATION

27. What other information can you provide that would be helpful in understanding the management of this particular grove?

PLEASE DESCRIBE ______

replanted in place of older trees which have died) less than seven years of age and thus not in full production. Question seven is concerned with the citrus-bearing area, excluding such things as empty spaces, roads, and non-producing trees. Questions eight through ten are concerned with factors such as grove terrain, grove soil type and the presence of large bodies of water which influence a grove's micrometeorology and hence affect frost/freeze protection measures. Again, this information is helpful when comparing and scaling results. A control thermometer located outside of the protected area is important in establishing the temperature profile of a grove which would exist if the protective action were not taken. Therefore, question eleven is designed to determine if control thermometer data may be forthcoming. The last question in this subsection is a rather sensitive one* and therefore it was put at the end so the answer to it would not adversely influence answers to other questions. It concerns the Federal Crop Insurance rating of a grove, which is needed for the classification of groves according to their susceptibility to frost/freeze damage.

The second subset of questions concerns the past and present status of the grove: the month of expected harvest, average yields per acre for the past three years and the estimated yield for the 1976-77 season. The response to question sixteen identifies damage sustained by a grove in the past three years and any additional frost/freeze protection measures this damage may have prompted (question seventeen). Both questions are typical contingency questions** since they are relevant only to a subset of the

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*The rate of response to this question was very low. Information was eventually obtained directly from the Federal Crop Insurance Corporation.

**Babbie, E. R., Survey Research Methods, Wadsworth Publishing Co., Inc., Belmont, California, 1973.

growers. The second part of question sixteen and question seventeen are contingent upon the "yes" answer to the first part and are answered only by growers who suffered fruit and/or tree damage.

The next subsection of this report deals with the marketing plans a grower may have for the citrus produced in this grove, and the primary reasons for the plans. Finally, the questions contained in the last subsection concern the frost/freeze technology used in the grove protection. Wind machines and/or heaters of various types, using several different fuels and having different rates of fuel consumption, might be employed. Information on fuel storage capacity and the price of fuel on hand sheds light on the grower's decision-making process, since the amount of fuel and its price plays a role in the decision to protect. The final two questions are concerned with other frost/freeze protection methods which are used for the grove and any other information which the grower thinks would be helpful in understanding the management of this particular grove.

3.4.3 Nightly Frost/Freeze Activity Report (Refer to Figure 3.3)

The response to this report is crucial in measuring the cost of frost/freeze protection, the severity of frosts/freezes and, in general, determining the actions growers took on cold nights when frost/freeze protective action was, or was thought to be, necessary.

An introductory paragraph at the top of the form provides the grower with the set of conditions under which the form is to be filled out. A Nightly Frost/Freeze Activity Report is to be filled out for each grove for each day that a fruit frost bulletin by NWS on that day predicted the lowest

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NIGHTLY FROST/FREEZE PROTECTION ACTIVITY REPORT

Please limit your answer to one grove only (see the instruction sheet for the definition of a "grove" as used in this report). Please answer the following questions only if a fruit frost bulletin by NWS predicted the lowest temperatures to be 28°F or less for the zone in which this grove is located or you had taken any frost/freeze protection during which you incurred costs regardless of predicted temperatures.

1. Your own grove name: ____________ grove I.D. number: ________

2. Date of frost/freeze . . . . Month: ________ Day: ________

3. Which of the NWS forecasts influenced you to initiate some form of frost/freeze protection? . . . .
   CIRCLE ONE NUMBER
   1 10:15 a.m.
   2 4:15 p.m.
   3 10:15 p.m.

4. On a scale of one to ten, how much confidence do you have in the NWS forecast identified in Question 3?
   CIRCLE ONE NUMBER
   no confidence 1 2 3 4 5 6 7 8 9 10 absolute confidence

5. On this night, did you take any action which incurred costs (including calling in laborers, paying someone extra to check the equipment, starting wind machines, firing heaters, etc.)?
   1 Yes
   2 No...GO TO QUESTION 12

6. Labor costs associated with this night's frost/freeze protective action, prorated to this grove:
   1 Total direct wages of laborers called in . . . .$ ________
   2 Extra direct wages of other personnel to supervise, to monitor weather, check or operate equipment, etc. $ ________

7. Wind machines:

	Number of Machines	Fuel Type	Fuel Consumption Rate*	Time (hours and minutes)	
				On	Off
Group 1					
Group 2					
Group 3					

*gasoline......gallons/hour
diesel........gallons/hour
propane.......pounds/hour
electricity...kilowatts/hour

8. Heaters:

	Number of Heaters	Fuel Type	Fuel Consumption Rate*	Time (hours and minutes)	
				Fired	Extinguished
Group 1					
Group 2					
Group 3					
Group 4					
Group 5					
Group 6					

*diesel........gallons/hour
propane.......pounds/hour

9. Operating costs of any other used frost/freeze protection method: $ ________

10. Total approximate mileage incurred during frost/freeze protection travel, prorated to this grove: . . . Trucks: ________ miles
    Automobile ________ miles

11. Minimum temperature recorded on the control thermometer for this grove: . . . . ________ °F

12. Was there observed any damage to fruit and/or trees not previously reported? . . . . .
    1 Yes...DO NOT FORGET TO FILL OUT A DAMAGE REPORT
    2 No

13. If you took no action which incurred costs what were the reasons for not taking it?
    1 Weather conditions did not seem to warrant it
    2 Market conditions
    3 Anticipated protection costs too high
    4 Frost previously damaged
    5 Started too late—not enough time
    6 Took limited action. No additional expense incurred (alerting laborers, having checked equipment at no additional cost, etc.)
    7 Other reason; PLEASE EXPLAIN ________

If you have any questions, call your county extension agent.

Figure 3.3 Nightly Frost/Freeze Protection Activity Report

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temperature to be 28°F or less* for the zone in which the particular grove is located, or, if frost/freeze protection measures were undertaken regardless of predicted temperatures. The answers are limited to one grove on one form. A detailed set of instructions accompanies this report.

Responses to the first two questions provide the identification of a grove for which the answers are provided and a date of frost or freeze. Both the names of groves used by growers and the identification number of the grove used in the experiment are required. Answers to questions three and four provide information pertaining to which of the NWS forecasts influenced the grower decision to initiate some kind of protective action and the degree of confidence the grower had in the NWS forecasts.

It should be noted that even if the NWS forecast predicts a cold night, a grower who takes into account the microclimatological conditions may decide not to take any protective measure. The response to question five indicates if a grower had taken any action associated with frost/freeze protection which incurred costs such as (a) calling in laborers (seasonal or high school students) and paying them wages even if they did not perform any work and were later sent home, (b) asking some members of a permanent staff to perform activities associated with frost/freeze protection (such as monitoring the weather, checking and preparing the equipment, operating the wind machines, etc.) for which they were paid beyond and above their regular wages.

---

*An exception was made for growers in Marion County, for whom the trigger temperature was set to be 27°F. The county is located in the southern part of Zone 9 (Figure 2.10). The NWS forecasts are always the same for Zones 8 and 9 and as a result the forecasted lowest temperatures for Marion County are a few degrees lower than the actual measured ones.

Questions six to eleven are contingent upon the "yes" answer to question five. The answers to these questions provide information about labor and fuel costs incurred in the course of undertaking frost/freeze protection measures. Since actual protection costs may be incurred jointly for more than one grove, all costs have to be prorated to the one grove for which the nightly report is prepared. For example, one labor crew may fire and extinguish heaters in several groves of various sizes. Each one of these groves may be protected by a different number of heaters requiring different amounts of time for their firing and extinguishing.

The two basic technologies used for frost/freeze protection are wind machines and heaters. Questions seven and eight are concerned with number of wind machines and/or heaters utilized, types of fuel used, fuel consumption rates, and time they were turned on and off. Since both wind machines and heaters of different types may be employed for different lengths of time for the protection of one grove, a concept of a "group" of machines or heaters is used. A group of heaters consists of all heaters of the same type, having the same rate of fuel consumption, and which are turned on and off at the same time. For example, a grove is heated by 40 heaters, 20 are fired at 1 a.m. and the remainder are fired at 2 a.m. All heaters are extinguished at 6 a.m. There are, therefore, two different groups of 20 heaters each. It may take some time to turn on and off wind machines or heaters of the same group. It is assumed that turning them on is done in the same sequence as turning them off and therefore all devices (of the same group) are in operation approximately the same time. The recorded times on the nightly report are those times at which the first machine or heater in a group was turned on and off, respectively.

The response to the ninth question provides the operating costs associated with other protection methods which could be used (such as overhead sprinkling, flood irrigation, burning of wood, etc.). Another cost is associated with the usage of cars and trucks in transporting personnel and equipment between groves, homes and offices. The response to question ten provides data on mileage incurred as a result of protection measures.

As discussed previously, it is necessary to establish the temperature profile in a grove that would have occurred if protection measures were not undertaken. This is necessary in order to establish the level of frost severity in the grove. This is achieved by adjusting NWS control thermometer data. A final adjustment can be made if the grower has a local control thermometer which records minimum observed temperature. The response to question eleven provides this minimum recorded temperature.

The next question concerns the damage which may have been observed after a cold night. Since there is a separate damage report, the question only calls for the grower's attention to this fact, and reminds him to fill out a damage report if he observed any damage to fruit and/or trees.

Finally, if there was no cost-incurring action taken on the part of a grower but the NWS forecast indicated that frost was forecast for the zone within which the grove is located, the grower is asked to circle as many reasons as applicable for not protecting the grove that night. A list of possible answers is provided in the last question.

3.4.4 <u>Damage Report</u> (Refer to Figure 3.4)

The responses to the questions posed in this report provide a basis for the evaluation of losses suffered by the growers during the frost/freeze nights either to the fruit, or the trees, or both fruit and trees.

The short introduction instructs a grower to answer following questions if damage was observed to fruit and/or trees and to limit his answers for one grove to one Damage Report. The response to the first question identifies the grove: both the name used by a grower and the identification number used in the experiment are required. The next two questions ask for the date on which a grower fills out the report and the date (or dates) of nights which caused the damage. It should be noted that the Damage Report may be completed long after the observation of damage since the extent of the damage may not be measurable until harvesting.

If damage is to fruit only, responses to questions four to eight are required; if damage is to trees only, then responses to questions ten and eleven are required. The response to question four determines if there was any damage to fruit, and questions five through eight are contingent upon a "yes" answer to question four. The marketing plans before the damage, after the damage, and changes in marketing plans are determined from the responses to questions five and six, while the yield of citrus (in boxes per acre for fresh fruit, and pounds-solids per acre for processed fruit) are obtained from the responses to questions seven and eight.

In the case of tree damage, the "yes" answer to question nine leads to questions concerning the severity (in the form of the expectation of when the grove will return to full production) and extent of damage (questions ten and eleven). Other grower comments may be made in the space provided in question twelve.

3.4.5 Data Collection Results

Previous sections described the general activity of various participants in the experiment. The collection of frost and freeze protection

Econ INCORPORATED
NINE HUNDRED STATE ROAD
PRINCETON, NEW JERSEY 08540
609 924 8778

DAMAGE REPORT

Please answer the following questions when you observed damage to your fruit and/or trees. Please limit the answers for one grove to one page.

1. Your own grove identification: ______________________ and grove I.D. number: ________
2. Today's date . . . . Month: ________ Day: ________
3. On what night (or nights) was the damage done? . . . . Month: ________ Day(s): ________
4. In this grove, was there any damage to the fruit? . . . . 1 Yes
   2 No...GO TO QUESTION 9
5. How did you intend to market the fruit before the damage? . . . . 1 Fresh
   2 Processed
6. How do you intend to market the fruit now? . . . . 1 Fresh
   2 Processed
7. How would you estimate the yield before the damage? . . . . ________ boxes per acre
   or ________ lbs-solids per acre
8. How would you estimate the yield after the damage? . . . . ________ boxes per acre
   or ________ lbs-solids per acre
9. Was there any damage to the trees? . . . . 1 Yes
   2 No...GO TO QUESTION 12
10. If there was damage to the trees, in how many years do you expect full production from this grove? . . . . ________ years
11. What is the approximate percentage of the grove which was damaged? . . . . ________ percent
12. Would you wish to make any other comment? PLEASE DESCRIBE . . . . ______________________

____

____

If you have any questions, call your county extension agent. ______________________

Figure 3.4 Damage Report

data was administered by ECON with the active cooperation of the county extension agents. The agents, who maintain constant communication with citrus growers, played a major role in the entire data collection process. This included the selection of participating growers, the distribution of the questionnaires, the collection of completed forms, review of data provided on the forms, and the return of the collected forms to ECON for data processing.

Fifty-two growers managed the 245 groves which were involved in the economic experiment and made up the control group. Some growers managed only one grove involved in the experiment; other growers (mainly the large cooperatives) managed more than ten groves (maximum was 18 groves). The specific breakdown of groves by county is illustrated in Figure 1.6. Each grower was given, at the beginning of the winter season, a three-ring binder containing an introductory page, instructions on how to fill out the Grove Background Reports, Nightly Frost/Freeze Protection Reports and Damage Reports, and an ample supply of all three forms (samples of this material are found in Appendix A). At the same time, each grower was sent a letter explaining the purpose and scope of the experiment (see Appendix A).

All participating growers were supplied with stamped, addressed envelopes. The growers, after they filled out the questionnaires, mailed them to their county extension agents. The agents were also supplied with stamped, addressed envelopes, and after they gathered all completed background reports or nightly reports for the time period during which there was a frost or freeze, they sent all the forms to ECON for monitoring and checking of received forms for the completeness, and for futher processing.

The mailed-in questionnaire procedure that was used during the experiment had a main advantage in reduced cost. However, it had several disadvantages, mainly a lower rate of response then would have been possible if all the forms were delivered and collected personally; and secondly, some of the questions, which were initially poorly understood, remained unanswered.

These disadvantages were circumvented by using several alternate procedures. First, the agents remained in constant communication with the growers and were able to help them to better understand some of the more complicated questions. Secondly, the two agents whose counties had the largest number of sample groves, namely, Polk and the combined Lake-Orange, received assistance from ECON field representatives. This help was very important, especially after the January freeze, when in a short period of time a large number of Frost/Freeze Activity Reports had to be collected, recorded and sent out for processing.

The Grove Background Reports were distributed to all the participating growers at the beginning of December, together with instructions on how to complete the forms. The growers were asked to answer all questions and send the completed forms to their agents as soon as possible. It would have been preferable to collect all Grove Background Reports before the first frost or freeze. This was not, however, the case. A large percentage of Grove Background Reports were filled out in December, but a majority of them were returned in January and some even in February.

Since the background reports were essential for a grove to be included in the sample, all groves which were initially selected, but whose background reports were not received, were dropped from the experiment. There were only 10 groves out of 255 which were dropped for various reasons, resulting in the final 245 sample groves. Some growers who initially wanted to participate decided later against the participation; some growers had to withdraw for reasons beyond their control.

The growers were asked to fill out the Nightly Frost/Freeze Protection Activity Reports the day after the frost and/or freeze. Very few growers responded in that manner and the majority of them filled out the forms at a later date when their daily activities allowed them to do so. It should be noted that the accuracy of reports suffered very little, perhaps not at all, since most growers kept rather accurate informal records.

Table 3.4 summarizes the received activity reports and indicates the very high response level. The final response was 2,142 reports received out of 2,495 expected, or approximately 86 percent.*

Damage to fruit and/or trees can be observed after a frost or freeze. Fruit damage can be assessed the following day and, in the case of freshly packed fruit, evaluated in about a week. In the case of processed fruit, the damage to fruit is reflected in the loss of juice, which can be accurately evaluated at the time of delivery of fruit for processing.

Initially, the Damage Reports were supposed to be filled out relatively soon after the frost or freeze event that caused the damage. However, it

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*Actually, approximately 300 additional reports were received when they were not anticipated indicating the incurrence of costs on nights when frost was not forecast but was anticipated by the growers.

Table 3.4 Summary of Grower Reports

County	Background Reports		Grove Acreage (Received)	Nightly Activity Reports (Received)																		Damage Reports (Received)
	Planned	Received		11/8	11/22	12/21	1/10	1/11	1/16	1/17	1/18	1/19	1/20	1/21	1/22	1/25	1/29	2/16	2/17	2/20	2/21	
Hardee	4	4	316	-	-	0/4	-	-	-	3/5	3/4	4/4	3/4	3/4	0/4	-	-	-	0/4	-	-	2
Highlands	10	10	297	-	-	10/10	-	-	-	10/10	10/10	10/10	8/10	8/10	0/10	-	-	-	7/10	+2	-	10
Hillsborough	15	15	336	-	-	6/15	+3	+4	-	13/15	11/15	13/15	7/15	7/15	5/15	+3	+3	+1	3/15	+2	+3	7
Marion	14	14	188	-	-	2/14	14/14	14/14	14/14	7/14	14/14	7/14	12/14	13/14	14/14	+14	14/14	7/14	7/14	+7	+7	59
Lake	51	51	2175	+8	+9	51/51	50/51	49/51	50/51	33/51	48/51	43/51	50/51	50/51	50/51	+48	42/51	18/51	35/51	-	+34	12
Orange	38	38	1134	-	-	31/38	38/38	38/38	38/38	37/38	38/38	38/38	37/38	38/38	38/38	+35	24/38	0/38	38/38	-	+30	53
Osceola	4	4	166	-	-	4/4	4/4	4/4	4/4	4/4	4/4	4/4	4/4	4/4	4/4	+4	4/4	0/4	4/4	-	+2	12
Polk	109	109	2644	-	-	100/109	+7	+2	+11	103/109	104/109	104/109	102/109	100/109	95/109	-	-	+2	101/109	+23	+32	132
Total	245	245	7256	-	-	204/245	106/107	105/107	106/107	210/245	232/245	223/245	228/245	223/245	206/245	-	84/107	25/107	195/245	-	-	287
Completion (%)		100		-	-	83.3	99.0	98.1	99.0	85.7	94.7	91.0	91.0	91.0	84.1	-	78.5	20.4	79.6	-	-	88%

Nightly Activity Reports:

2142 received of 2495 expected (85.8%)

Explanation:

1) Number of received forms/number of expected forms.

2) +9....no forms expected, but +9 forms were received. This indicates that some protection costs were incurred even though temperatures were forecast above the "trigger" level.

3) - indicates no forms expected or received since temperature forecasts in these counties were above the "trigger" level.

became clear that Damage Reports, in most cases, would not be forthcoming until after harvest when accurate damage assessments could be made. This meant that, since some citrus was harvested in early summer, Damage Reports were not expected to be completed prior to July. Damage Report completion did not occur until mid-fall. However, as with the activity reports, a very high response rate was achieved--287 reports were received out of 327 expected, for a response rate of approximately 88 percent.

After the completion of the control group data collection and analysis, a report was submitted to each of the growers for each of the groves for which he provided data. The reports (see Appendix B) contain a summary of all of the grove data as well as county average costs and losses so that the grower can compare grove performance with the county averages. These reports are provided to the growers via the county extension agents.

3.5 Measurement of Grove Temperature Profiles

Heaters and wind machines protect fruit and trees of a citrus grove by increasing the air temperature to levels where the potential damages are minimized. During the operation of the frost protection equipment, the temperature profile of a grove is substantially changed from that which would have occurred if the protection was not undertaken.

The evaluation and comparison of costs and losses experienced by a grower during a night with freezing temperatures requires a determination of a frost severity index, which is related to the temperature profile that would have occurred in a grove if frost protection measures were not initiated.

The following paragraphs describe the data collection procedures and the methods employed during the experiment to determine the temperature that would have occurred in the grove (the unperturbed temperature) if protection measures were not initiated. The importance of this results from the fact that it is necessary to compare costs and losses which are due to the same magnitude or severity of frost. As will be seen, the unperturbed temperature profile plays a major role in the establishment of grove frost severity.

The following methods were used in measuring and establishing grove unperturbed temperature profiles:

- Direct temperature measurement
- Grove minimum temperatures and use of NWS thermographs
- Grove shift temperatures and use of NWS thermographs.

The following paragraphs describe briefly how the methods listed above are used in establishing the grove unperturbed temperature profiles and the measurement of the required data.

3.5.1 Direct Temperature Measurements

Not all of the sample groves have control thermometers. When the groves have control thermometers, the thermometers may have either a temperature recording device (thermograph) or may record only a minimum temperature. Grove control thermometers are located outside the heated areas, and thus measure the "true" temperature, insofar as it is uninfluenced by the frost protection activites. A relation between the grove control thermometer and the average (spatial) temperature in a grove is established in the form of a shift temperature which indicates the temperature difference between a grove (in the absence of frost protection activities) and its control thermometer.

When the control thermometer has a thermograph, the temperature variation during the night is continuously recorded. The shift temperature between control thermometer and a grove is then used to establish the temperature profile for the grove which is thence used to establish the grove frost severity index.

3.5.2 Grove Minimum Temperatures and Use of NWS Thermographs

In the case of a grove control thermometer having only the ability to record minimum temperatures, the temperature versus time profile must be obtained by using NWS thermographs and adjusting them to the sample grove by using the measured minimum temperatures in the grove. This assumes that the same temperature versus time pattern would exist in the grove as is measured by the NWS control thermometer; the only difference being a shifting up or down of the whole temperature profile. Thirty-nine NWS control thermometers were selected as being reliable indicators of grove temperatures.

The NWS thermometers which were used were determined by two methods:

- Questionnaire response data from all participating growers determined the NWS thermometer which was used by a grower as a control thermometer for a particular grove.
- Study of grove locations and their proximity to existing NWS thermometers. Each sample grove is then associated with one NWS thermometer. However, one NWS thermometer can be associated with more than one grove.

3.5.3 Grove Shift Temperatures and Use of NWS Thermographs

Unfortunately, most sample groves do not have control thermometers. Because of this, major reliance has been placed upon the use of NWS thermographs and the relationship between the thermographs and the temperatures prevailing in sample groves has been estimated.* A set of 39 NWS control

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*The former meteorologist in charge of the Federal-State Agricultural Weather Service in Lakeland, Mr. James George, who has more than 20 years of experience in weather forecasting in Florida, determined grove associations with NWS thermometers and the grove shift temperatures which represent the differences in expected minimum temperatures between the grove and the NWS thermometer.

thermometers was found to be adequate to reliably represent the grove temperatures. Shift temperatures were also developed between related NWS control thermometers and groves. Shift temperature is defined as the difference between the grove's temperature* and the temperature of an associated NWS thermometer on a typical radiational frost night. Table 3.5 illustrates this method; the shift temperatures for all sample groves are presented in Appendix C.

3.5.4 General Procedure Used in the Determination of Grove Temperature Profiles

The methods used in the determination of grove temperature profiles were described in the preceding sections in a hierarchical order. Direct measurements of grove temperature profile (Section 3.5.1) are preferred to the use of grove minimum temperatures in conjunction with NWS thermographs (Section 3.5.2) and these again are preferred to the use of grove shift temperatures in conjunction with NWS thermographs (Section 3.5.3).

The questions concerning the control thermometers were included in the grove background report (Section 3.4.2). However, the relationship of average grove temperatures and control thermometer measurements and the grower's estimate of grove shift temperatures were determined later during the experiment by a survey conducted at the end of the control group data collection.

The general procedure which is followed for establishing grove temperature profiles is illustrated in Figure 3.5. The initial step in the procedure was to establish the association of all sample groves with appropriate NWS thermometers. The next step was to estimate the grove shift temperatures

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*Average spatial temperature as a function of time.

Table 3.5 Shift Temperatures Between Groves and NWS Thermometers									
NWS Thermometer Number	Sample Grove Number								
	1	2	3	4	5	. . . . . .	199	200	. . .
1	0	-3	0	+1	0		0	0	
2	-2	0	0	0	0		0	0	
3	0		-2				-1		
. . .									
39	0	0	0	0	+1		0	-3	

which adjusted the NWS control thermometer to the specific grove temperature data. Next, if it was indicated via the grove background reports that a grove control thermometer was available, grove control thermometer data and their minimum temperatures replaced the previously estimated grove shift temperatures (this procedure was repeated for every frost/freeze night).

3.6 Measurement of Frost/Freeze Severity

An understanding of many natural phenomena is necessary to explain the damages suffered by citrus fruit and trees as a result of exposure to freezing temperatures. Microclimate of a citrus tree, dormancy, effects of climate, drought and variety on dormancy and cold hardiness are but some.*

*Cooper, W. C., R. H. Young, and F. M. Turner, Microclimate and Physiology of Citrus: Their Relation to Cold Protection Agricultural Science Review, Winter 1964.

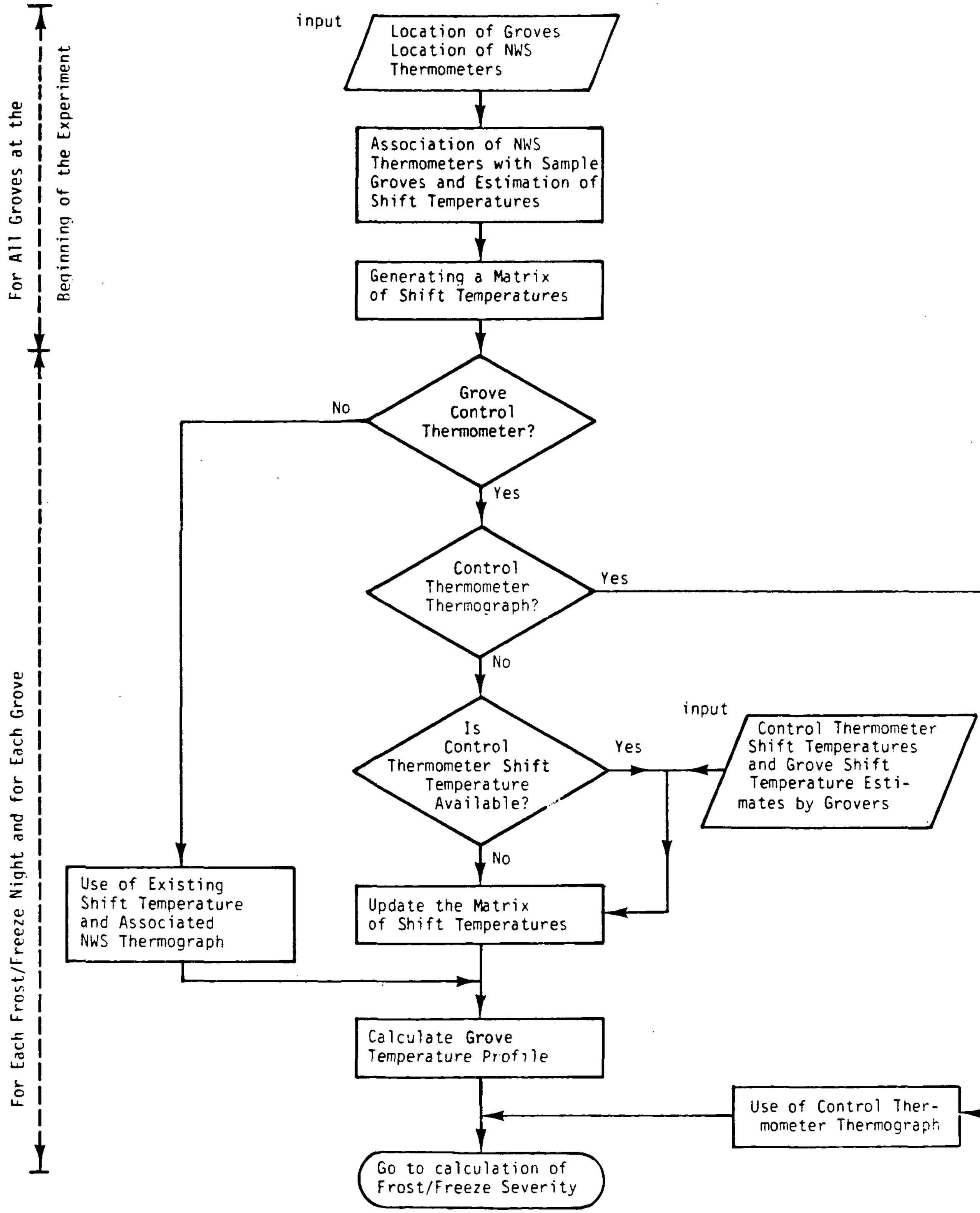


Figure 3.5 Flowchart Diagram of a Procedure Used in Determination of Shift Temperatures for Sample Groves

The heat exchange between the tree and the environment can be explained by an understanding of the microclimate of the tree (temperatures of the air, leaf, twig, fruit, bark of trunk and soil). The variation in the climatic properties of the grove can be best described by the variations in the air temperature. Leaf temperatures fluctuate more widely from day to night than do air temperatures; twig temperatures fluctuate about the same as the air; trunk temperatures much less than the air and soil temperatures considerably less than the air.

Dormancy of trees is important in determining the susceptibility to injuries due to freezing temperatures. The winter climate in citrus-growing regions is generally cold for citrus (temperatures around 55°F is the minimum for growth of oranges) and therefore orange trees have only three flushes of growth, occurring in early spring, early summer and late summer, followed by periods of growth interruptions. There is no flush of growth during the winter season and all buds remain quiescent from late fall to early spring. Consistently cold winter weather is beneficial to the dormancy of citrus, which then can tolerate temperature almost as low as 20°F without injury. In Florida, however, the winter temperatures are not consistently low (as they usually are in California) and the unseasonably warm weather in December or January induces a fourth flush of growth. If these warm temperatures are followed by a cold spell then citrus fruit and trees may sustain severe injuries.

Dormancy and consequently cold hardiness vary widely with citrus varieties. For example, trifoliate orange, which develops dormancy earlier in the fall and remains dormant till later in the spring, generally exhibits more cold hardiness in winter, while lemons and limes, which are not dormant and usually grow actively in winter, are very sensitive to cold weather.

Cold hardiness of citrus trees is also increased by moderate drought before winter cold weather, which serves as a kind of preconditioning. However, when drought is severe, the tree's food reserves may be greatly reduced by respiration, and the tolerance to cold weather is further reduced.

The physiological factors affecting the cold hardiness of the tree, which depends to a large extent on the winter dormancy, have thus great importance in determining the severity of frosts and/or freezes, especially in Florida with its inconsistent winter weather.

3.6.1 Frost/Freeze Severity Coefficients

The decision to protect a grove from damaging cold is based on detailed and timely knowledge of many variables. Besides the consideration of physiological and phenological factors of citrus described above, there is the grove's microclimate and the expected minimum temperatures, time of occurrence and duration. All of these variables have been extensively studied independently of each other. The complexity of situations increases when more than one variable influenced the decision to protect citrus groves. An attempt to secure a consensus of the temperatures at which citrus requires protection was made in 1974 by the University of Florida's Institute of Food and Agricultural Sciences. A survey of citriculturists and other experts at the University, as well as in the citrus industry at large, obtained estimates of temperatures at which it was necessary to protect the citrus,* in terms of citrus variety, rootstock, time of year, status of trees reflecting previous

*Gerber, J. I., University of Florida, private communications.

injuries due to cold, and possibility of a new growth or bloom. The statistical evaluation of the survey (from the University of Florida responses) showed that there can be a considerable variation of the estimated temperatures.

The design of the current experiment requires that a measure of severity of frosts and/or freezes be established so that like events can be compared. The frost severity index utilized in this experiment is a measure of the effect of temperature and its duration on citrus fruit and trees. It was therefore necessary to establish a relationship between temperature and duration of frost/freeze and its severity (which could then be related to costs associated with required protection and damages to fruit and/or trees) while taking into account all the variables described in the preceding paragraphs.

A frost/freeze severity table was therefore constructed which established the relative impact or severity of a frost event in terms of its duration at different temperature levels. Zero implies no damage and ten (10) implies total loss. Two different tables of frost/freeze severity coefficients have been developed; one is related to damage of citrus fruit (Table 3.6) and the other to damage of citrus trees (Table 3.7). Separate tables of relative impact of temperatures and durations have been developed since trees can tolerate much lower temperatures than fruit without sustaining any damage or requiring any protection.

A further differentiation of the severity measures exists for each different citrus variety. Grapefruits, for example, can tolerate, on the average, at least one degree (for a given duration) colder temperatures then oranges, while specialty fruit can tolerate temperatures a half degree

Table 3.6 Relative Severity Measure of Frost/Freeze for Early and Midseason Oranges*

Temp. [°F]	Hours At A Given Temperature											
	1	2	3	4	5	6	7	8	9	10	11	12
28	0	0	0	0	0.5	0.75	1	1.25	1.5	1.75	2	2
27	0	1	2	2	3	4	4.25	4.5	4.75	5	5	5
26	0	1	2	3	4	4.3	4.6	5	5	5	5	5.5
25	1	2	3	4	4.5	5	5.2	5.4	5.5	5.7	5.85	6
24	1.5	2.4	4	4	4.5	5	5.3	5.7	6	6.5	7	8
23	2	2.7	4	4.1	5	6	7	7.5	8	9	10	10
22	2.5	3	4	5.5	7	8	10	10	10	10	10	10
21	3	3.5	5	6.5	8	10	10	10	10	10	10	10
20	4	5	6	8	10	10	10	10	10	10	10	10
19	4.5	6	7.5	9	10	10	10	10	10	10	10	10
18	5	7	9	10	10	10	10	10	10	10	10	10

*Estimates provided by Dr. J. Gerber and Dr. J. Bartholic of the University of Florida.

Table 3.7 Relative Severity Measure of Frost/Freeze for Trees*

Temp. [°F]	Hours At A Given Temperature											
	1	2	3	4	5	6	7	8	9	10	11	12
28	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
24	0	1	1	1	1	1	1	1	2	2	2	2
23	1	1	1	1.2	1.5	1.75	2	2.2	2.4	2.6	2.8	3
22	1.3	1.6	1.8	1.9	2	2.3	2.6	2.9	3.2	3.5	3.8	4
21	2	2	2	2	3	3	3	3	3.5	4	4.5	5
20	2.5	2.75	3	3.3	3.6	4	4.3	4.6	5	5.6	6.3	7
19	3	4	5	5.5	6	6.3	6.6	7	7.5	8	9	10
18	4	5	6.5	8	9	10	10	10	10	10	10	10

*Estimates provided by Dr. J. Gerber and Dr. J. Bartholic of the University of Florida.

(average) warmer than oranges. As far as trees are concerned, the dependence of severity measures on variety is not as significant as dependence on the time of the season and damages suffered during previous frosts. During the months of January and February, trees are generally dormant and can tolerate at least one degree (for a given duration) colder temperatures than those shown in Table 3.7. However, if there was a period of unusually warm weather and a green flush of growth occurred (usually in February and March) then trees can tolerate, on the average, temperatures 3° higher than they would otherwise. A similar situation occurs if trees were injured during previous frosts or freezes in the same season (or very seriously injured during the previous season). Their cold temperature tolerance would be reduced on the average by one degree.

Tables similar to Table 3.6 were developed for specialty fruit and grapefruits by adjusting the critical threshold up for the specialty fruit and down for grapefruit.

3.6.2 Use of Severity Coefficients in a Classification of Weather Events

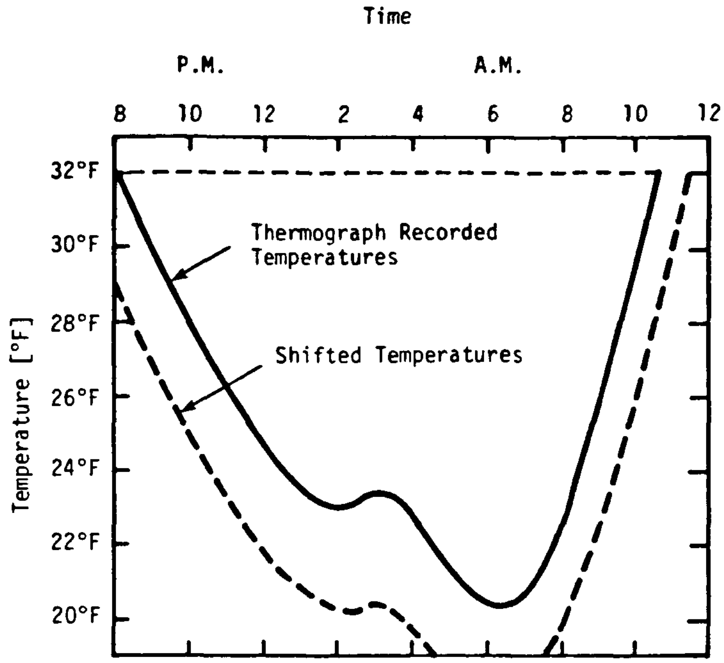
The severity coefficients for both fruit and trees, adjusted for variety, are used to establish a frost severity index for every grove in the sample and for every cold weather event.

Control thermometers to be used throughout the experiment were selected according to their proximity to groves in the sample and the reliability and accuracy of the data. Thermograph traces from all NWS control thermometers in central Florida are kept on file at the Federal-State Weather Service Office in Lakeland. Through the cooperation of the National Weather Service, ECON was able to obtain Xerox copies of all needed thermographs (those control thermometers registering a temperature of 32° or less on a given night). Although these reproductions are not of the highest quality, in most cases they were adequate for determination of durations of cold temperatures on each frost/freeze night. (A typical thermograph reproduction is included in Appendix C.)

Frost nights are selected according to both the forecasts before the event, and the observed minimum temperatures at the control thermometers selected. Both sets of data are provided on a regular basis by the Florida National Weather Service personnel. In this way, it is made certain that severity coefficients for all cold and predicted cold nights (when a grower may have taken cost-incurring action) will be calculated. This includes "false alarms" and "no-warning" freezes.

The specific procedure for establishing the grove severity index is illustrated in Figure 3.6. Once the durations of cold temperatures for each control thermometer on each cold night have been recorded, the shift coefficient matrix is used to adjust the control thermometer temperature profiles to obtain a profile for each grove in the sample. For each temperature and duration within a grove profile, a severity coefficient is obtained from the tables of coefficients for fruit and trees. These coefficients are then summed to achieve the value of the grove's severity index for this particular frost event. ECON has developed a set of computer programs which efficiently carry out the procedure outlined above. More detailed documentation of the WETHR programs is given in Appendix E.

Figure 3.7 illustrates the overall process of severity index determination, based upon a typical thermograph record.



Temperature Range, °F	Measured Duration, Hours	Shift Tempera-tures	Adjusted Duration, Hours	Duration at Temperature	Severity Coefficients (Fruit & Trees)
32-31	14				0
31-30	14				0
30-29	13				0
29-28	12		14		0
28-27	12		14	0	0
27-26	10		13	1	0
26-25	10		12	1	0
25-24	10	-3°F	12	0	0
24-23	7		10	2	3.4
23-22	4		10	0	0
22-21	2		10	0	0
21-20	1		7	3	7
20-19			4	3	9
19-18			2	2	10
18-17			1	1	9
			Weighted Severity Index for Grove		38.4

Figure 3.6 Sample Calculation of Frost/Freeze Severity Index Based Upon a Typical Thermograph

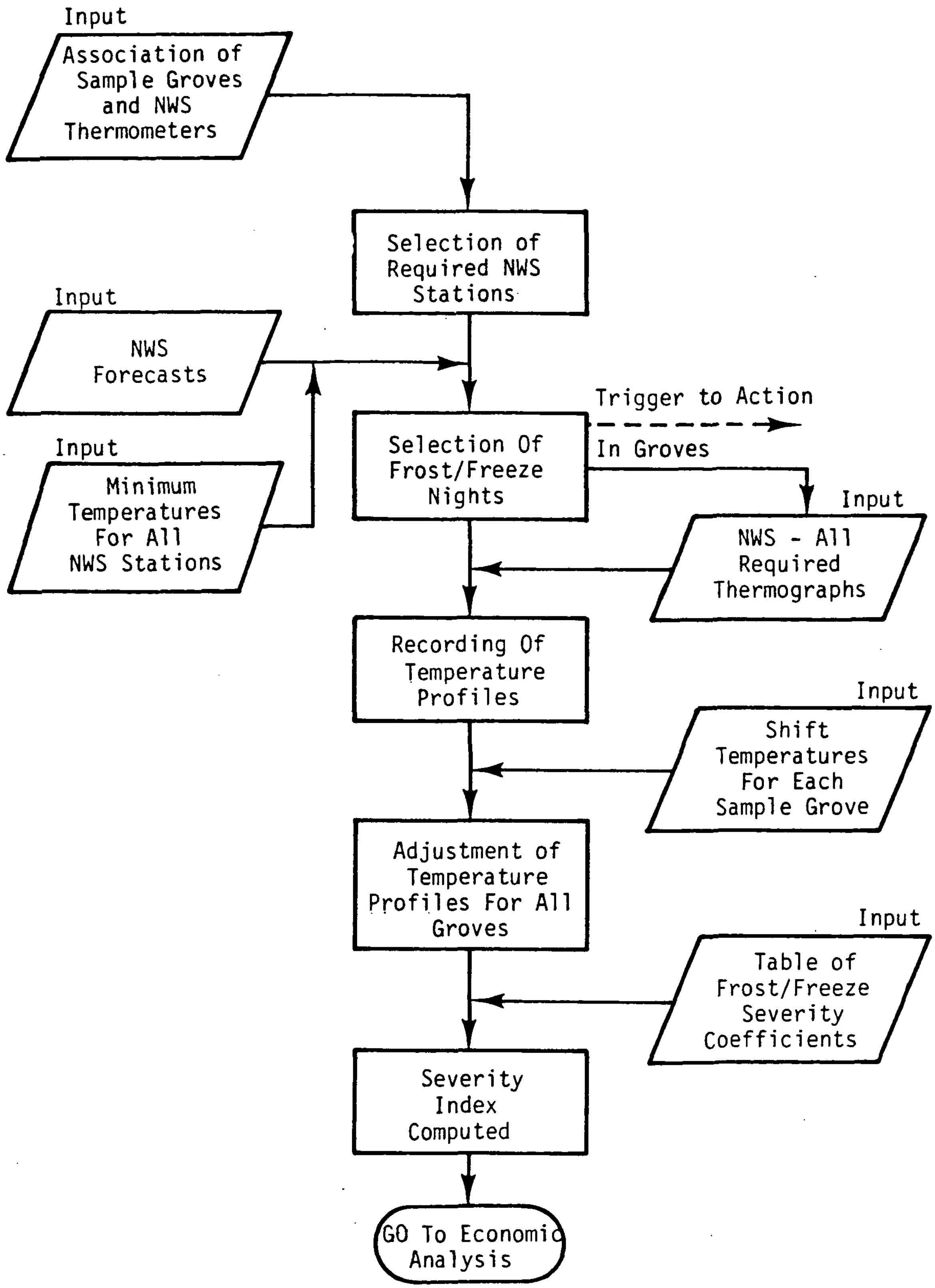


Figure 3.7 Development of Frost Severity Index for a Classification of Weather Events

The following steps are indicated:

- Control thermometer selection
- Frost/freeze night selection
- Recording of control thermometer temperature profiles
- Adjustment of temperature profiles according to shift coefficients
- Use of severity coefficients to calculate severity index for fruit and trees in each grove
- Grove frost severity index input into the economic analysis.

3.6.3 Measurement of Susceptibility of Groves to Frost/Freeze Damage

A classification of groves according to their susceptibility to frost/freeze damage is very desirable in studying the economic benefits of improved weather forecasting. It is particularly useful when scaling results from the sample population to the target population. The frost susceptibility of a grove depends on many factors such as the location, the terrain and the local microclimate, the type of fruit, the grove management techniques and the use of frost protection technology.

The Federal Crop Insurance Corporation of the U.S. Department of Agriculture determines the frost/freeze susceptibility of all lands which it chooses to insure. The FCIC indicates their assessment by assigning letters A (the least susceptible) through E (the most susceptible) to each grove. Ideally, the FCIC code provides an assessment of the land only, depending on the grove location, the type of terrain and the local microclimate. However, in actual practice, the fruit type, frost protection methods and management techniques are considered as well in the FCIC determination of its premium schedule.

Initially, determination of the code for any particular grove depends on observations of the terrain by an experienced FCIC representative who inspects the grove. The codes are revised at regular intervals and may be changed based on the frost history of a grove and surrounding areas, and the current condition of the land.

The premium structure is set to reflect the fact that certain types of fruit are more easily damaged than others by frost and/or freeze. Thus, premiums paid to insure tangerines and tangelos will ordinarily be higher than those paid to insure grapefruits or early and midseason oranges. The rate structure also reflects suitability of fruit grown to terrain and location; thus, it may cost more to insure fruit on A-rated land in one county than in another.

It is necessary to obtain the FCIC classification code of each of the sample groves of the experiment. All counties with groves which are part of the experiment are covered by FCIC. The Grove Background Report (Section 3.4.2) attempts to obtain the FCIC classification of the grove from the grower. If the code is not determined directly in this manner, then the FCIC records can be used.

The FCIC maintains detailed records in the form of actuarial maps, with dashed lines indicating the division between areas with different susceptibility codes. Yearly update sheets are included, listing any changes by section, subsection, and occasionally by owner. Each actuarial map contains four sections (2560 acres or 4 square miles); given a grove's location (section, range, and township), it is usually possible to determine which code is to be applied. Complications arise when the land in a particular section has more than one classification. In such cases, any additional information about the grove (size, shape, type of fruit grown, proximity to roads and bodies of water, etc.) is useful. The FCIC has in the past kept up-to-date ownership maps which aid in locating a particular grove within its section. These are now considerably out of date, but are still occasionally useful. Figure 3.8 illustrates the determination of the FCIC code for a grove in the sample, using both the actuarial and property maps.

By following the procedure outlined above, ECON was able to determine the correct FCIC susceptibility code for more than 65 percent of the groves in the sample. In order to unambiguously determine the FCIC codes for the remaining groves in the sample, pinpoint locations for these groves would be needed. This information can be collected either from the cooperating county extension agents, or from the growers themselves at a later date. However, for sample stratification purposes, the current data is sufficient.

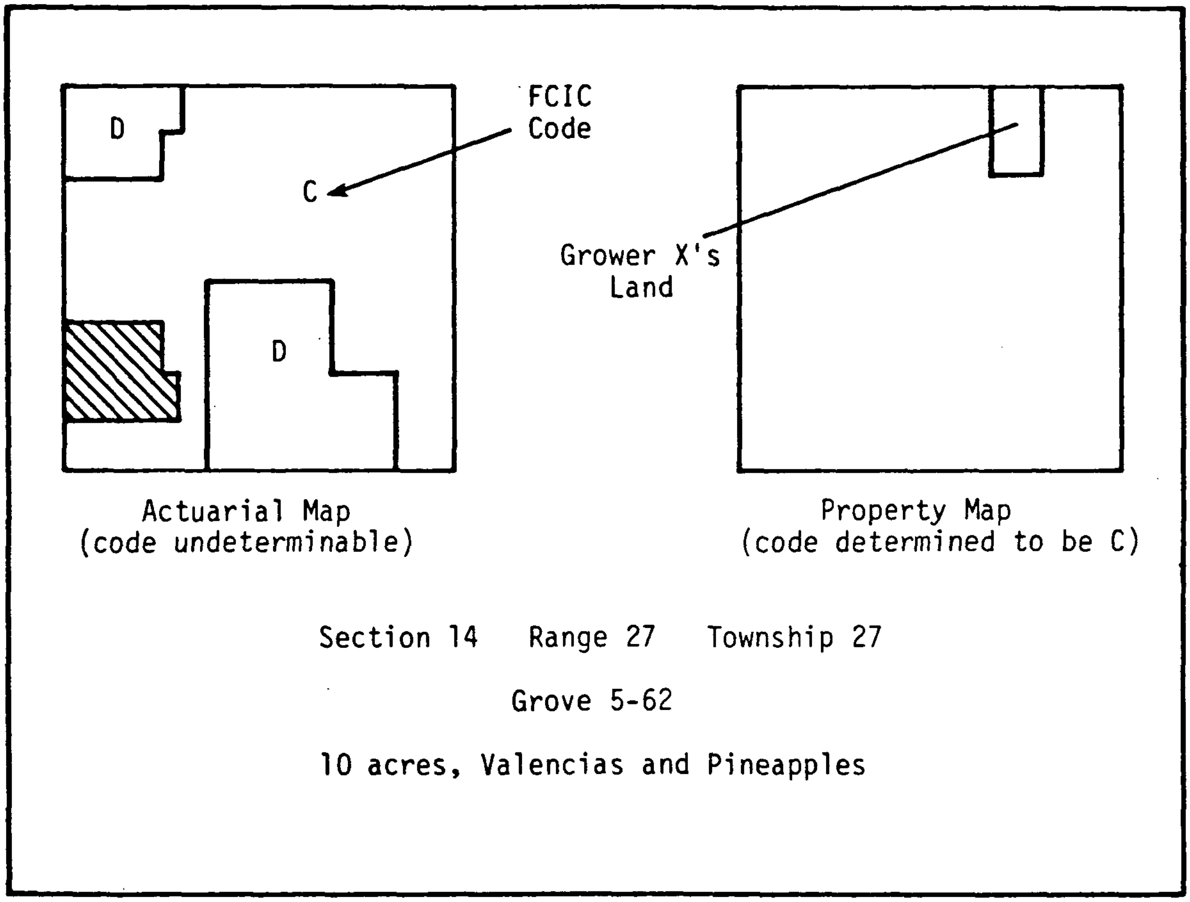


Figure 3.8 Determination of FCIC Grove Classification

4. ANALYSIS OF COSTS AND LOSSES

This section takes, as its beginning point, the grower-supplied data pertaining to costs and physical losses from freeze nights (nights which triggered Nightly Frost/Freeze Protection Reports; see Sections 3.4.3 and 3.4.4), weather event characteristics (see Section 3.5) and grove characteristics (see Section 3.4.2). The outputs generated by the work discussed in this section are several. The first is simply a statistical report of economic costs and losses from freezes and freeze warnings for the sample groves, for this control year; this is reported in Section 4.5, with more detail in Appendix F and Section 5.0. An intermediate, but important, output is the statistical relationship between weather event severity and economic costs and losses, based upon the 1976-77 experiment results; it is the hypothesis of this experiment that this relationship will change as a function of the accuracy of the weather forecasting system. Thirdly, using the relationship between weather and economic costs and losses and using historical weather data for the years 1937-66, costs and losses for these years are simulated and reported in a second statistical report. By comparing this second report, generated from data gathered in the control year (1976-77), with similar reports generated in the experiment test group year(s), a measure of the expected savings and benefit from the forecast improvements will be obtained.

Figure 4.1 serves as a flowchart reference for the material discussed in this section.

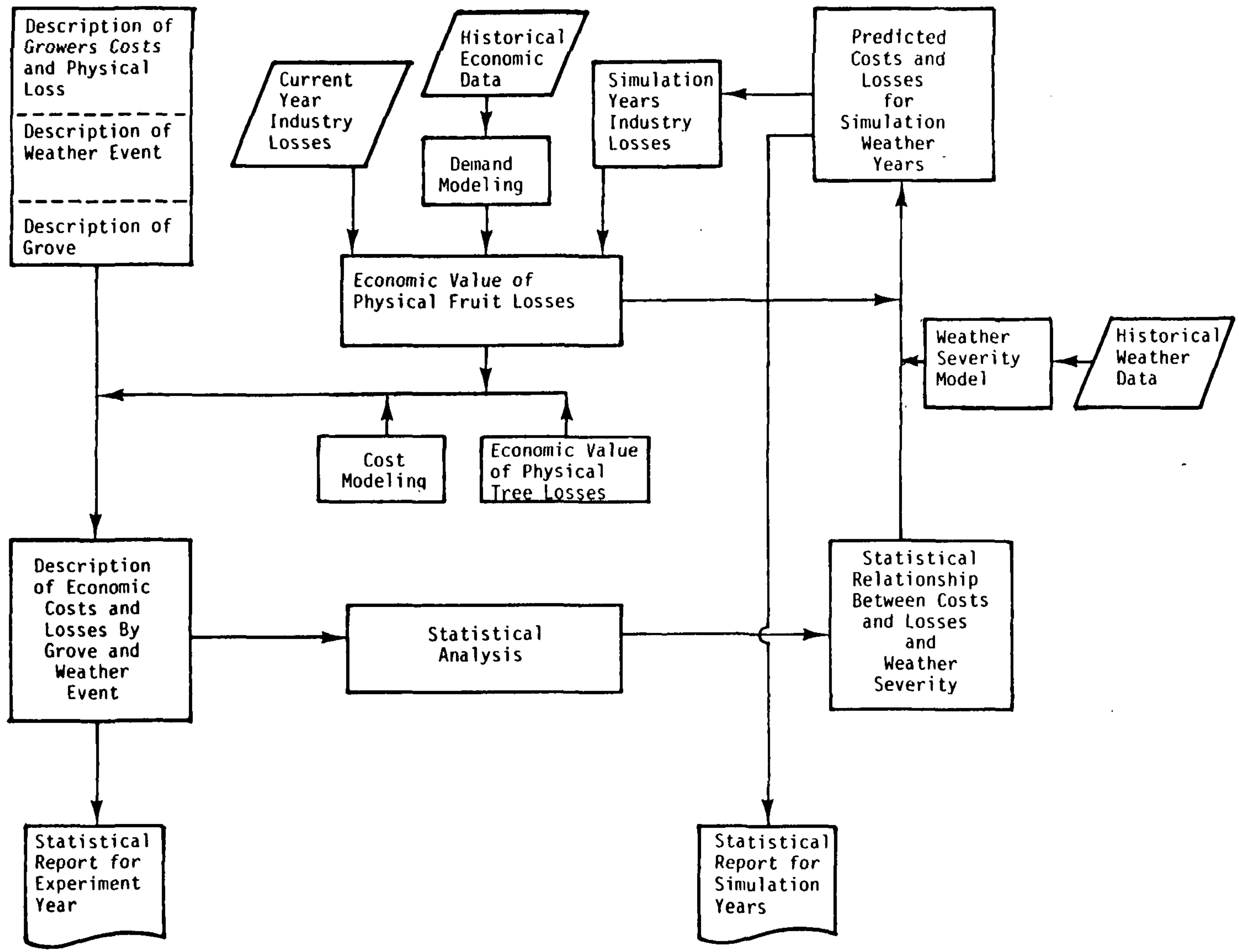


Figure 4.1 Flowchart of Cost and Loss Analysis

4.1 Analysis of Frost Protection Decision Making*

Like all economic decisions, the grower chooses the course of action which yields the greatest utility. This experiment is concerned with the situation where the grower is trying to minimize his expected loss from a forthcoming weather event of uncertain severity; where the grower is risk averse, he may wish to control his downside loss, if possible. His decision concerns whether or not to protect by lighting heaters or starting wind machines, or both. But the decision comes in two stages, since early in the evening, around 7:00 p.m., the grower must decide upon bringing in a labor crew to staff the heaters and wind machines. The decision to "fire" comes later that night, any time from, say, 10:00 p.m. until almost dawn. The grower may, of course, enlist a labor crew without firing, but it is not really possible to fire without having hired workers earlier in the evening.

The decision itself may well be an expensive one, for better or worse. In the 1976-77 season, growers protected their groves during the January 19 freeze at an average cost (for those who did protect) of over $80 per acre. The alternative, though, is to bear an increased risk of losing over $1,000** per acre of fruit, not including tree damage.

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*For more detail, see "A Plan for Application System Verification Tests--The Value of Improved Meteorological Information," Volume I, ECON Report No. 76-108-2, August 1976.

**For example, average 1975-76 yield for growers of white seedless grapefruit in the sample groves was 460 boxes per acre; 1975-76 "on-tree" average price for fresh grapefruit was $2.56. This provided a per acre return of $1177.5 per acre.

Among the factors which affect the protection decision, the most important usually is the expected severity of the coming freeze. This information, combined with the expected market price for the fruit, provides a measure of the amount which could be lost if no protection is undertaken. Given the expected severity of the freeze (including its duration), the grower usually has a good idea of how much it will cost to protect. In some years (the 1976-77 season provided a possible example), the price of fruit may be so low, and/or the price of fuel so high, that the grower will fire only to protect his trees. (One grower interviewed in December 1976 indicated that he expected the price of oranges to be so low that he was not even going to bring out his heaters for this season.)

In comparing the control group results with the test group results, it is, of course, important to control for the various confounding variables. This is done by maintaining the same growers in the sample and by normalizing with respect to weather severity. However, one possible confound not yet accounted for is the effect of year-to-year changes in the expected price of fruit. Investigation is continuing as to the importance of this effect.

4.2 Cost of Protection Modeling

Given the data provided in the Nightly Frost/Freeze Protection Reports (see Figure 3.3), the task of estimating the cost of protection each night, grove by grove, is very straightforward. Protection costs have three components: labor, fuel and "other" costs. Labor and "other" costs are identified directly by the grower on the Protection Report. Fuel costs are derived as follows:

$$C_F = \sum_{i=1}^{I_w} W_i*WFR_i*WFP_i + \sum_{i=1}^{I_h} H_i*HFR_i*HFP_i + (TM*TFR + AM*ARF)*PG$$

where W_i is the number of wind-machine-hours for the i^{th} type machine, WFR_i is the fuel consumption rate for the i^{th} type of machine and WFP_i is the price of fuel for the i^{th} type of machine. Correspondingly, H_i is the number of heater-hours for the i^{th} type of heater, etc. TM and AM are truck and automobile miles traveled, respectively, and TFR and AFR are truck and automobile fuel consumption rates. PG is the price of gasoline.

W_i, WFR_i, H_i, HFR_i, TM and AM are all obtained from the Nightly Frost/Freeze Protection Report. TFR and AFR estimates were obtained via the U.S. Department of Agriculture, from staff members working on energy consumption in agriculture. It was estimated that automobiles used on farms achieved 15 miles per gallon and trucks achieved 9.5 miles per gallon.* Fuel prices for the winter 1976-77 for the State of Florida were estimated from regional statistics provided by the State of Florida, State Energy Office.** The prices used in this study were:

Fuel	Price/Gallon (Current Dollars)
Gasoline	.583
Fuel Oil	.416
Diesel	.414
Propane	.429
Butane	.429

Total costs of protection, then, are computed as the sum of fuel, labor and "other" costs.

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*Personal communication. Tom Van Arsdall, USDA, March 16, 1977.

**Personal communication. Tim Shey, Florida State Energy Office.

4.3 Fruit Loss Modeling

The most complicated task under the general analysis of costs and losses is the fruit loss modeling. The complication is due to the following factors:

- Economic losses in the marketplace are nonlinear.
- The amount of the economic loss sustained by any grower depends upon what has happened in the rest of the industry.
- The size of the physical loss from any weather event depends upon previous damage and, thus, previous weather.
- The loss depends upon what the grower had intended to do with the fruit before a freeze and what he was eventually able to do with it, possibly after a significant disruption to the market caused by a freeze.

The general approach to estimating the social value of fruit losses is depicted in Figure 4.2. Growers will market all the fruit they have available,

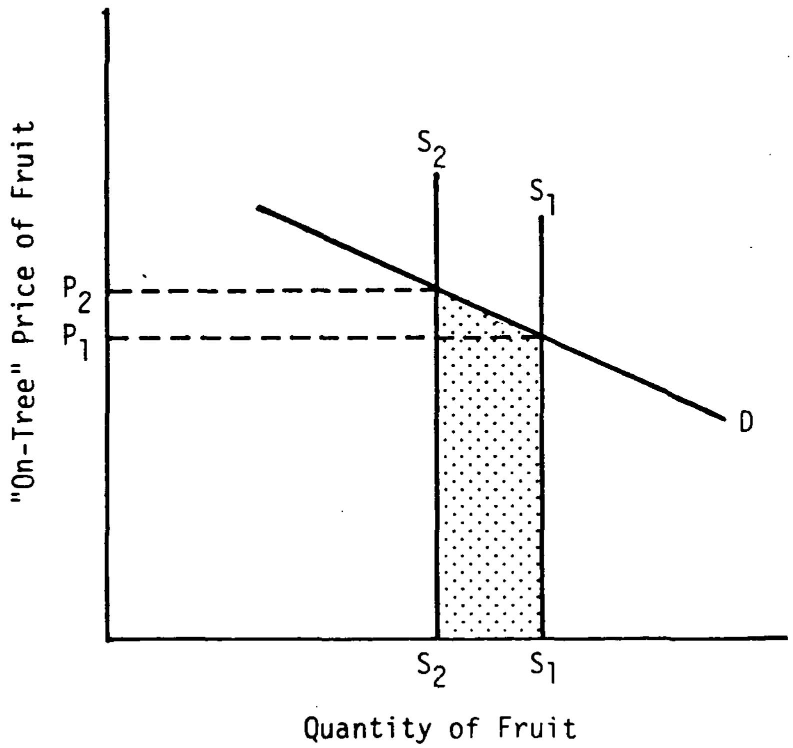

Figure 4.2 The Economic Value of Fruit Losses

so long as the price of the fruit exceeds the costs of pick and haul, that is, so long as "on-tree" prices exceed zero. ("On-tree" prices are reported by the Florida Crop and Livestock Reporting Service and are equal to the delivered-in price of fruit, less the estimated costs of pick and haul.) Typically, the reduction in industry supply of fruit due to a freeze (from S_1 to S_2 in Figure 4.2) moves prices upwards (P_1 to P_2). The total economic loss to society is the shaded area under the demand curve. This loss can be prorated to each grower by dividing the total value loss (the shaded area) by the physical loss (S_1-S_2) to obtain an economic loss per unit of physical loss. This process can be performed repetitively if there is more than one freeze during the season. The elements necessary to perform the operation shown in Figure 4.2 are (1) the supply "before", (2) the supply "after", and (3) the demand function.

This economic or "social" loss is to be distinguished from losses (or gains) to the grower in the form of reduced (or increased) revenues. In general, a reduction in the supply of citrus causes prices to increase sufficiently so that <u>industry</u> revenues increase in spite of physical losses. This phenomenon occurs when the market <u>elasticity of demand</u> is less (in absolute value) than one. Such is typically the case in agricultural commodities and is estimated to be the case with citrus, as is shown in the following section (see Table 4.1).

4.3.1 <u>Modeling the Demand for Citrus Fruits</u>

Estimates of the demand function were made using simple econometric models of the citrus markets. Separate demand function estimates were made for each fruit variety and according to whether the fruit is sold fresh or for

Table 4.1 Summary of Citrus Demand Modeling Results*

Market	Explanatory Variables									
	Constant	Supply	S^2	S^3	PDI	Yield	Trend	Cycle	R^2	Demand Elasticity
Early & Mid, Processed	7.357	-0.2896	0.00379	-0.0000168		0.927			.85	-0.5926
		(-3.217)	(2.218)	(-1.661)		(1.200)				
Early & Mid, Fresh	11.942	-0.5102			-2.4151			0.3164	.76	-0.4155
		(-4.050)			(-5.822)			(1.709)		
Valencias, Processed	13.114	-0.5581	0.00897	-0.0000486				0.1768	.91	-0.4331
		(-2.849)	(2.202)	(-1.820)				(1.362)		
Valencias, Fresh	14.331	-0.6222			-3.328			0.4900	.86	-0.4531
		(-6.381)			(-8.364)			(2.760)		
Grapefruit, Processed	-7.359	-0.0698			5.1397		-0.3143		.33	-0.1581
		(-1.940)			(2.179)		(-1.861)			
Grapefruit, Fresh	4.417	-0.1811					0.0489	0.2885	.51	-0.4063
		(-2.989)					(2.167)	(2.176)		
Temples, Fresh	7.348	-1.2809					-0.1751	0.2647	.81	-0.4976
		(-4.200)					(-5.583)	(1.240)		
Tangelos, Fresh	18.622	1.4180	-4.5363	1.2488	-7.2164		0.5596	0.5979	.97	-1.3732
		(0.387)	(-1.512)	(1.726)	(-2.254)		(2.123)	(3.715)		
Tangerines, Fresh	8.508	-1.1960			-1.0294			0.4376	.61	-0.9605
		(-3.039)			(-2.501)			(2.138)		

*NOTES:

1. The dependent variable throughout is "on-tree" prices, expressed in constant 1967 dollars.
2. The numbers shown are least squares regression coefficients; the numbers in parentheses are t-values for the corresponding variables.
3. SUPPLY represents boxes of fruit sold, in millions
4. S^2 and S^3 are the squared and cubed terms of SUPPLY.
5. PDI is real personal disposable income in 1967 constant dollars.
6. YIELD is expressed in gallons of concentrate per box.
7. Elasticity calculated from estimated demand curve slope and 1975-76 prices and quantities.

processing. Fresh fruit typically fetches a higher price but its demand is much less elastic and is easily saturated in times of large supply. Fruit originally intended to be sold fresh may go to processors either because a relative surplus of fresh fruit has forced down the price or because of freeze or pest damage. Fruit originally intended for processing typically is not of a high enough grade to be sold for fresh, except in times of large freezes when the standards for fresh fruit leaving the state are sometimes lowered by the Florida Division of Fruit and Vegetable Inspection.

The demand functions depicted in Figure 4.2 are estimated according to the following model. The real price paid (the consumer price index was used as a deflator throughout) to the grower for fruit is considered to be a function primarily of the amount of fruit available. Additional explanatory variables hypothesized for fresh fruit demand were the price of some substitute (fresh apples were used) and real personal disposable income (PDI). For processed fruit, real personal disposable income and per box yield were also tested as explanatory variables. For some markets, a trend term was also used.

The annual time series used for the establishment of the demand functions were found in the annual Citrus Summary published by the Florida Crop and Livestock Reporting Service; in Commodities Yearbook published by The Commodity Research Bureau, Inc.; Business Conditions Digest published by the U.S. Department of Commerce; and in the Statistical Summary of the Florida Canners Association.

Table 4.1 summarizes the results of the regression analyses. The demand equation for processed early and midseason oranges, for example, would be read from Table 4.1 as follows:

Price Per Box (on-tree, 1976$) = 7.357 - 0.2896 x supply (number of boxes of processed fruit)

+ 0.00379 x $(\text{supply})^2$ - 0.0000168 x $(\text{supply})^3$

+ 0.0 x personal disposable income (1967$)

+ 0.927 x Yield Per Box (gallons of concentrate)

+ 0.0 x (Year - 1959) + 0.0 x Cosine ((Year - 1959) x $\pi/2$).

The results were approximately as expected. All the demand elasticities* showed the correct sign. The elasticity values are similar to the elasticities found by Myers for retail frozen concentrated orange juice demand: - 0.546** (which compares favorably with the estimated -0.5926 for processed early and midseason oranges). The specialty fruits, tangelos and tangerines, were an exception and showed themselves to possess more elastic demands. This was somewhat surprising, but is probably due to their very small market share. The price of the substitute for fresh citrus (apples) was not significant in any of the regressions.

Surprisingly, income elasticity of demand for fresh citrus was estimated to be less than zero. Although it is possible that this could simply be a trend effect of diminishing fresh citrus demand over the years 1960-1976,

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*Demand elasticities are measures of the sensitivity of quantity demanded as price changes. The are calculated as $E = \frac{\partial p}{\partial q} \cdot \frac{q}{p}$, where p is price and q is quantity.

**L. H. Myers, <u>The Consumer Demand for Orange Beverages</u>, Economic Research Department, Report No. FCC-ERD-69-1, University of Florida, August 1969.

when real PDI was increasing, the negative coefficient on PDI remained even when a trend term was tested in the regression. The only exception to this was when PDI was tested in the demand for processed grapefruit. Here the sign was positive, but the regression as a whole was not significant.

Two other surprises were evident. First, only in the price of processed early and mid-season oranges did the yield per box become a significant explanatory variable. Secondly, a four-year cycle was found in the regression residuals for many of the markets (all except processed early and mid and processed grapefruit). When included in the regression, this cycle term usually proved quite significant and relatively strong. The presence of this effect is not fully understood; however, it is possible that it refers to the length of recovery periods after severe and extensive freezes.

4.3.2 Estimating Industry Fruit Losses

Estimates of supplies before and after freezes are made using Florida Crop and Livestock Reporting Service (FCLRS) Citrus Forecasts and their updates. In December 1976, prior to the severe freeze in January, the FCLRS made a forecast of citrus production for the 1976-1977 season. This forecast has been updated several times since and a "final" production estimate for the 1976-77 crop season was released October 6. Table 4.2 summarizes these forecasts and estimates. The later estimates take into account damage suffered from the January freeze and it is felt* that the best way to estimate the amount of that damage is a simple subtraction of later production estimates from the December estimate (i.e., the last one prior to the freeze). Utilization forecasts are not provided by FCLRS and average percentages utilized for fresh and processed for the last three years were used for the before-freeze estimates of utilization.

*Personal communication. Paul Messinger, FCLRS, 28 March 1977.

Table 4.2 Citrus Industry Physical Fruit Losses And Economic Losses**

Fruit Variety	Utilization of Citrus Crop (Millions of Boxes)					
	Fresh			Processed		
	Before	After	Physical Loss	Before	After	Physical Loss
Early & Mid	8.37	6.13	2.24	112.65	108.87	3.78
Valencias	6.16	2.75	3.41	81.84	69.05	12.79
Grapefruit	23.69	16.39	7.30	34.31	35.11	-0.80
Temples	2.18	1.18	1.00	3.52	2.62	0.90
Tangelos	2.46	2.30	0.16	3.04	2.51	0.53
Tangerines	4.14	2.32	1.82	1.66	0.98	0.68

	Estimated Citrus Industry Economic Loss (Millions of 1976 $)**							
	Fresh			Processed			Total	
	Revenue Gain	Societal Loss	Societal Loss Per Box Lost ($ Per Box)	Revenue Gain	Societal Loss	Societal Loss Per Box Lost ($ Per Box)	Revenue Gain	Societal Loss
Early & Mid	6.99	3.24	1.45	2.61	2.95	0.78	9.6	6.19
Valencias	2.21	9.38	2.75	33.24	23.41	1.83	35.45	32.79
Grapefruit	7.77	17.08	2.34	-2.61	-0.52	0.65	5.16	16.56
Temples	-1.93	2.60	2.60	-0.41	-0.41	0.45	-2.34	3.01
Tangelos	-0.08	0.32	7.00	*	*	*	-0.08	2.00
Tangerines	8.40	5.31	7.92	*	*	*	-8.40	2.92
						TOTALS:	39.39	63.47

*Insufficient information, but appears to be near zero

**Source: *Florida Crop and Livestock Reporting Service.*

4.3.3 Estimating Economic Value of Fruit Losses

Using the results of Sections 4.2.1 and 4.2.2, the social costs and revenue gains to the Florida citrus industry of the 1976-77 freezes (of which the January freeze dominated) were calculated. The first step in these calculations is the estimation of before- and after-freeze prices. After-freeze prices have already been estimated by the FCLRS in its October 6, 1977 report. Before-freeze prices are estimated by using the before-freeze production estimates shown in Table 4.2, the demand curve estimates of Table 4.1, and adjusting upwards from 1967 to 1976 dollars. In three instances (early and mid processed, grapefruit processed, and tangelos fresh), this procedure yielded unsatisfactory results when compared to what prices seemed to be forthcoming at the beginning of the season. This indicates that the demand curve for these products had shifted for the 1976-77 season when compared to the curve statistically estimated from 1960-1976 demand data. In these cases, a linear demand curve, with the elasticity estimated and shown in Table 4.1, was assumed passing through the season's-end price-quantity point as reported by the FCLRS. The results of these calculations, before- and after-freeze, on-tree prices, are reported in Table 4.3.

Some comment on the prices in Table 4.3 is in order. In general, 1976-77 was to be a record crop year. Even after sizable losses, in fact, several crops were produced at record quantities. The pattern which was found, then, is one of very low estimated, before-freeze prices. This is attributable not only to the record harvests which were forecast, but also to the inelastic demand for most citrus products: the existing demand is quickly saturated. Thus, some dramatic price reversals are predicted based on losses

Table 4.3 Estimated Before-Freeze and After-Freeze On-Tree Citrus Prices* (1976 $ Per Box)

Fruit Variety	Fresh		Processed	
	Before	After	Before	After
Early & Mid.	0.75	2.15	0.75	0.80
Valencias	1.45	4.05	1.45	2.20
Grapefruit	1.72	2.96	0.69	0.60
Temples	2.40	2.80	**	0.45
Tangelos	1.95	2.05	**	-0.35
Tangerines	0.80	5.05	**	-0.85

*After-freeze prices estimated by FCLRS; before-freeze prices estimated by ECON.

**Insufficient data for estimation.

from the January freeze. Fresh tangerines, for example, went from an estimated before-freeze price of $0.80 per box to an average grower return (on-tree price) of $5.04 per box after the industry lost nearly 44 percent of the crop. Tangelos, however, escaped relatively unscathed, losing less than 7 percent of the fresh crop, while prices increased only $0.10. In general, however, the fresh fruit left after the freeze fetched a considerably higher price than it would have without the freeze and growers in the control group sample as well as the industry benefited considerably in higher revenues.

The negative after-freeze "prices" for processed tangelos and tangerines refer, of course, to losses (costs exceeding revenues) in the production of these commodities. Negative on-tree prices for processed specialty fruit are not terribly uncommon. The abundance of freeze-damaged fruit intended for fresh but ultimately going processed aggravated an already weak market.

Using these estimated prices, industry's revenue gains and social losses attributable to the freeze were estimated. These figures are also presented in Table 4.2. Further, in order to facilitate the estimation of social losses from the sample groves, social-loss-per-box-lost figures were estimated and are also shown in Table 4.2.

The bottom line of this analysis is that growers in the Florida citrus industry benefited substantially from the January freeze; revenues for the crops investigated increased more than $39 million. This gain derived solely from increased prices and was therefore entirely at the expense of the citrus consumer. The revenue gain has no overall social benefit impact as it is simply a transfer payment with society none the worse off from it, per se. The physical loss of the crop, however, did translate into a societal, economic loss, estimated here at over $63 million.

4.4 Tree Loss Modeling

An input to the analysis is a vector of lost production in future years attributable to tree damage on a night-by-night, grove-by-grove basis. This information is derived from data obtained in the Damage Reports (see Figure 3.4). The costs associated with cultural activities (pruning dead twigs, etc.) necessitated by tree damage were not estimated in this study.

The model used is a simple one. The objective is to obtain the present value of the foregone citrus production. Given the vector of future production losses, $L = (L_1, L_2, l_3, \ldots, L_T)$, this present value is expressed as

$$PV = \sum_{t=1}^{T} \frac{\hat{P}_t}{(1 + d)^t} L_t$$

where T is the number of years until full production, $\hat{P}_t$ is forecasted price for the particular citrus variety t years from the present, and d is the annual discount rate. A discount rate of 7.5 percent is used in this study.

The above equation implicitly assumes that industry tree losses are sufficiently small so as not to affect $\hat{P}_t$. Although this is a questionable assumption, the only alternative is to estimate the vector in future <u>industry</u> reductions in production attributable to particular freezes, a task which is far beyond the scope of this study. The use of the above equation leads to a small bias in favor of underestimating the economic losses.

Toward the estimation of $\hat{P}_t$ in the above equation, much analysis could be performed. However, unless a very large task was undertaken, the resulting forecasts would not likely be any more accurate than using current year prices. As a consequence, 1975-76 prices were used as forecasts of future prices, $\hat{P}_t$.

4.5 <u>Costs and Losses for the Sample Groves: Results</u>

This section summarizes, in tabular form, the economic costs and losses attributable to freezes and freeze protection during 1976-77 for the control group citrus groves. More detailed results are presented in Appendix F.

Due to an inability to obtain sufficient information with which to make estimates of losses from tree damage, no tree losses are reported.

Tables 4.4 and 4.5 summarize reported total and per acre costs of protection for the sample by county and fruit type. Total and per acre revenue gains and social losses are presented in Tables 4.6 through 4.9. The results largely speak for themselves. The total social cost of the freeze and frosts would be calculated by summing protection costs with the social

Table 4.4 Reported Total Costs of Protection (Thousands of Dollars) Attributable to Impact of Frosts and Freezes for 1976-77 Crop Year--For Entire Sample--By County and Fruit Variety

County	Fruit Variety						All Varieties
	Early & Mid Oranges	Valencia (Late) Oranges	Temples	Tangelos	Tangerines	Grapefruit (All Types)	
Hillsborough	4.0	9.5	0.3	14.3	29.5	5.4	63.0
Polk	50.1	100.2	13.1	1.0	37.4	5.1	206.9
Orange	22.1	27.1	30.8	*	1.3	0.2	81.5
Lake	20.4	33.5	8.3	6.2	1.2	4.1	73.7
Marion	6.1	0	*	*	0	0	6.1
Osceola	8.5	2.1	*	*	0.8	2.2	13.6
Highlands	2.4	0.7	11.0	*	*	*	14.1
Hardee	7.2	2.0	0	5.1	0	*	14.3
All Counties	120.8	175.1	63.5	26.6	70.2	17.0	473.2

*The sample contains no groves with this fruit variety in this county.

Table 4.5 Reported Per Acre Costs of Protection (Dollars Per Acre) Attributable to Impact of Frosts and Freezes for 1976-77 Crop Year--For Entire Sample--By Country and Fruit Variety

County	Fruit Variety						All Varieties
	Early & Mid Oranges	Valencia (Late) Oranges	Temples	Tangelos	Tangerines	Grapefruit (All Types)	
Hillsborough	16	102	150	146	280	150	109
Polk	76	95	110	75	168	49	95
Orange	50	148	103	*	22	10	81
Lake	59	25	56	72	7	43	33
Marion	48	0	*	*	0	0	32
Osceola	95	15	*	*	35	2	39
Highlands	29	13	92	*	*	*	54
Hardee	73	46	0	146	0	*	73

*The sample contains no groves with this fruit variety in this county.

Table 4.6 Estimated Total Revenue Gains (Thousands of Dollars) Attributable to Impact of Frosts and Freezes for 1976-77 Crop Year--For Entire Sample--By County and Fruit Variety

County	Fruit Variety						All Varieties
	Early & Mid Oranges	Valencia (Late) Oranges	Temples	Tangelos	Tangerines	Grapefruit (All Types)	
Hillsborough	56.7	46.2	0.2	2.5	137.7	4.3	247.6
Polk	81.3	163.5	-50.3	0.8	11.2	7.9	214.4
Orange	233.0	9.4	-66.5	*	89.2	-11.1	254.0
Lake	1.6	288.5	0.8	3.9	31.2	5.1	331.1
Marion	8.6	11.1	*	*	10.6	-0.2	30.1
Osceola	-0.1	47.8	*	*	25.8	74.5	148.0
Highlands	-0.5	28.0	-115.3	*	*	*	-87.8
Hardee	0.7	20.7	2.0	-9.8	17.0	*	30.6
All Counties	381.3	615.2	-229.1	-2.6	322.7	80.5	1168.0

*The sample contains no groves with this fruit variety in this county.

Table 4.7 Estimated Per Acre Revenue Gains (Dollars Per Acre) Attributable to Impact of Frosts and Freezes for 1976-77 Crop Year--For Entire Sample--By County and Fruit Variety

County	Fruit Variety						All Varieties
	Early & Mid Oranges	Valencia (Late) Oranges	Temples	Tangelos	Tangerines	Grapefruit (All Types)	
Hillsborough	232	495	100	26	1,306	119	428
Polk	124	155	-422	60	50	76	98
Orange	523	51	-222	*	1,487	-566	250
Lake	5	212	5	23	185	53	147
Marion	67	247	*	*	1,060	-40	160
Osceola	-1	348	*	*	1,137	745	423
Highlands	6	532	-961	*	*	*	-335
Hardee	7	476	200	-280	1,889	*	156

*The sample contains no groves with this fruit variety in this county.

Table 4.8 Estimated Total Social Value of Fruit Loss (Thousands of Dollars) Attributable to Impact of Frosts and Freezes for 1976-77 Crop Year--For Entire Sample--By County and Fruit Variety

County	Fruit Variety						All Varieties
	Early & Mid Oranges	Valencia (Late) Oranges	Temples	Tangelos	Tangerines	Grapefruit (All Types)	
Hillsborough	0	8.4	0	0	21.6	0	30.0
Polk	173.2	312.0	66.5	0	121.2	8.7	681.6
Orange	46.6	51.0	103.8	*	0	18.8	220.2
Lake	23.9	141.6	13.1	0	53.7	0	232.3
Marion	7.4	1.3	*	*	0	0.1	8.8
Osceola	15.0	5.0	*	*	2.0	0	22.0
Highlands	10.7	5.1	126.3	*	*	*	142.1
Hardee	0.5	0	0	10.6	0	*	11.1
All Counties	277.3	524.4	309.7	10.6	198.5	27.6	1,348.1

*The sample contains no groves with this fruit variety in this county.

Table 4.9 Estimated Per Acre Social Value of Fruit Loss (Dollars Per Acre) Attributable to Impact of Frosts and Freezes for 1976-77 Crop Year--For Entire Sample--By County and Fruit Variety

County	Fruit Variety						All Varieties
	Early & Mid Oranges	Valencia (Late) Oranges	Temples	Tangelos	Tangerines	Grapefruit (All Types)	
Hillsborough	0	90	0	0	205	0	52
Polk	264	296	558	0	545	84	311
Orange	105	278	347	*	0	959	216
Lake	69	104	88	0	318	0	103
Marion	58	29	*	*	0	20	47
Osceola	168	36	*	*	88	0	63
Highlands	131	97	1,053	*	*	*	543
Hardee	5	0	0	303	0	*	57

*The sample contains no groves with this fruit variety in this county.

loss figures of Tables 4.8 and 4.9. The net impact of the freeze and frosts upon growers in the sample is calculated by subtracting protection costs from revenue gains, then obtaining net revenue gains. In summary, the severity of the 1976-77 crop year benefited the growers in the control group sample by $695,000. The total social cost of the weather year to the control group was $1,821,000. Consumers of Florida citrus products fared even worse, as they bore the brunt of the $1.8 million social cost and, additionally, provided all the growers net benefit in the form of a transfer payment.

4.6 Expansion of Costs and Losses

In order to expand the control group sample results to the state of Florida, it is necessary to develop expansion or scaling factors which relate the sample to the industry. The costs and losses are to be expanded only to the protected acreage within the state of Florida. The total protected acreage within the state is not known with a high level of accuracy. In order to estimate the protected acreage, the county extension agents were asked for their estimate of the protected acreage by fruit type, in their respective counties. The agents were able to estimate aggregate protected acres for the county but were unable to break down the acreage by fruit type. The estimates of protected acreage are shown in Table 4.10. Also shown in Table 4.10 are the results of a survey of heater inventory made several years ago by the Florida Citrus Mutual. This survey was made prior to the drastic increase in the price of fuel, which may explain some of the discrepancies (many heaters were retired).

Table 4.10 Protected Acreage			
County	Estimates*	Protected Acreage*	Florida Citrus Mutual Survey (Heaters)
Marion	60% of 11,327	6,796	7,134
Lake/Orange	15% of 180,023	27,003	8,350
Hillsborough	~5% of 39,750	1,988	23,293
Hardee	5% of 44,812	2,241	3,042
Polk	15,000 acres	15,000	30,000
Highlands	7,000 acres	7,000	6,200

*Estimated by county extension agents.

In the absence of detailed data it was decided to assume that the ratio of protected acreage of a particular fruit type to the total acreage of that fruit type equals the ratio of the county total protected acreage to the county total acreage.

$$\frac{\text{County Total Protected Acreage}}{\text{County Total Acreage}} = \frac{\text{Protected Acreage For Fruit Type}}{\text{Total Acreage For That Fruit Type}}$$

This assumption was for early and midseason oranges and valencias. The county total acreage, and the acreage in each county by fruit type was obtained from the 1976 Citrus Summary prepared by the Florida Crop and Livestock Reporting Service. It was assumed that 90 percent of the specialty fruit was protected acreage, and that 10 percent of the grapefruit was protected. Using these assumptions, it was possible to estimate the protected acreage by fruit type and by county as indicated in Table 4.11. The data presented in Table 4.11 also includes adjustments to the county extension agents' estimates to take into account the fact that in several instances, the sample groves contained more protected acreage than was estimated for the county as a whole.

Table 4.11 Estimated Protected Acreage By County And Fruit Type (1976)

County	Early And Midseason	Valencia	Grapefruit	Specialty Fruit	Total
Polk	5,058	6,134	2,459	8,694	22,745
Orange	3,980	2,988	241	6,760	13,969
Lake	8,221	7,065	2,683	1,710	19,679
Marion	5,282	826	40	590	6,738
Hillsborough	1,013	645	254	2,979	4,891
Osceola	1,177	915	125	1,560	3,777
Highlands	1,407	3,767	452	3,933	9,559
Hardee	1,230	781	90	2,125	4,226
Total	27,368	23,121	6,744	28,351	85,584

Table 4.12 Control Group Sample Average Yield Per Acre For The 75-76 Crop Season, In Boxes, By County And Variety Of Citrus

County	Early And Midseason	Valencia	Grapefruit	Specialty Fruit	Total
Polk	421.5	344.9	437.4	390.1	384.2
Orange	420.4	333.9	545.0	334.5	373.6
Lake	429.9	396.2	393.0	345.1	392.6
Marion	400.2	298.3	180.0	280.0	354.1
Hillsborough	361.8	323.7	69.0	248.2	284.7
Osceola	293.0	436.5	600.0	209.5	372.3
Highlands	517.3	508.5	0.0	389.5	478.3
Hardee	288.3	451.7	0.0	427.0	389.0

It was not possible to make these same assumptions for the production (yield) of citrus in order to expand the sample data. This is because the yield for protected acres differs from the yield for unprotected acres. Therefore, in order to estimate the production by county and fruit type, it was necessary to assume that the yield per acre for the control group sample is the same as the average yield per acre for protected acres. Table 4.12 lists the yield per acre for the sample by county and fruit type. The eight counties represented in the control group sample accounted for approximately 55 percent of the total citrus acreage, and 60 percent of the total citrus production for the state of Florida in 1976.

By dividing the control group sample acreage by the estimated protected acreage (for each county and fruit type), the percentage is obtained (by county and by fruit type), that is represented by the sample (see Table 4.13).

Table 4.13 Percentage Of Total Protected Acreage Represented By The Control Group Sample

County	Early And Midseason	Valencia	Grapefruit	Specialty Fruit	Total
Polk	13.0	17.2	4.2	4.3	9.8
Orange	11.2	6.1	8.3	5.5	7.3
Lake	4.2	19.3	8.0	26.6	12.2
Marion	2.4	5.5	12.5	16.9	2.8
Hillsborough	24.1	14.4	14.2	6.9	11.8
Osceola	7.6	15.1	80.0	1.5	9.3
Highlands	5.8	1.4	0.0	3.2	2.7
Hardee	8.0	5.6	0.0	2.5	4.6
Total					8.4

The total costs and losses (by county and by fruit type) are obtained by dividing the sample results (by county and by fruit type), by these percentages. In cases where the percent represented equals zero, it is not possible to expand. By summing these quotients, the total costs and total losses are obtained for the eight counties represented by the control group sample. The results are summarized in Tables 4.14* to 4.16.

4.7 Statistical Analysis of Relationship Between Costs and Losses and Weather Severity

So far, Section 4 has been concerned with the cost and loss estimation methodology and results from the control group sample for the 1976-77 season. Additionally, these results have been expanded or extrapolated to the entire Florida citrus industry. However, the costs and losses presented herein so far are very much dependent upon the particular weather experienced during the 1976-77 crop season. Any attempt to relate these costs and losses to

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*It should be noted that it is tempting to multiply the protection costs as given in Figure 1.9 by the total protected acreage This will lead to erroneous results as can be seen from the following two methods of computing protection cost for a single frost night.

(1) $$\text{Protection Cost} = \bar{C} * \sum_{M,N} A_{M,N}$$

$$\bar{C} = \sum_{M,N,G} A'_{M,N,G} * C'_{M,N,G} \Big/ \sum_{M,N,G} A'_{M,N,G}$$

(2) $$\text{Protection Cost} = \sum_{M,N} \bar{C}_{M,N} * A_{M,N}$$

$$\bar{C}_{M,N} = \sum_{G} A'_{M,N,G} * C'_{M,N,G} \Big/ \sum_{G} A'_{M,N,G}$$

where A = acreage, M = county, N = fruit type, G = grove, and primed terms refer to measured sample data. Also $A_{M,N} = TA_{M,N} * CP_M/CT_M$ where TA = total Florida citrus acreage, CP = total county protected acreage, and CT = total county citrus acreage. It can be seen that only under very special circumstances will methods (1) and (2) provide the same results. Method 2 yields more accurate results.

Table 4.14 Total Cost of Protection by County and Fruit Type, '76-'77 Crop Year ($, Thousands)					
County	Early & Midseason	Valencia	Grapefruit	Specialty Fruit	Total
Polk	385	583	121	1198	2287
Orange	197	444	2	584	1228
Lake	486	174	51	59	770
Marion	254	0	0	0	254
Hillsborough	17	66	38	639	760
Osceola	112	14	3	53	182
Highlands	41	50	*	344	435
Hardee	90	36	*	204	330
Total	1582	1366	216	3081	6244

*Indicates no sample points in database.

Table 4.15 Grower Revenue Change by County and Fruit Type, '76-'77 Crop Year ($, Thousands)					
County	Early & Midseason	Valencia	Grapefruit	Specialty Fruit	Total
Polk	625	951	188	-891	873
Orange	2080	154	-134	413	2513
Lake	38	1495	64	135	1732
Marion	358	202	-2	63	621
Hillsborough	235	321	30	2035	2621
Osceola	-1	317	93	1720	2128
Highlands	-9	2000	*	-3603	-1612
Hardee	9	370	*	368	746
Total	3336	5808	240	239	9624

*Indicates no sample points in database.

Table 4.16 Social Loss by County and Fruit Type, '76-'77 Crop Year ($, Thousands)					
County	Early & Midseason	Valencia	Grapefruit	Specialty Fruit	Total
Polk	1332	1814	207	4365	7719
Orange	416	836	227	1887	3366
Lake	569	734	0	251	1554
Marion	308	24	1	0	333
Hillsborough	0	58	0	313	371
Osceola	197	33	0	133	364
Highlands	184	364	*	3947	4496
Hardee	6	0	*	424	430
Total	3014	3863	435	11321	18632

*Indicates no sample points in database.

those from other years (when a different weather forecasting system may be in effect), will be tremendously confounded unless the differences in weather are accounted for.

Thus, ECON undertook the effort of disassociating the costs and losses from the particular weather pattern of 1976-77. Referring back to Figure 4.1, the steps leading to the "description of economic costs and losses by grove and weather event" have already been performed and reported, while the statistical analysis of the relationship between costs, losses and weather severity, and predictions for historical weather years, are yet to be discussed.

The objective of the statistical analysis was to establish an explicit relationship between costs and losses and weather severity. Once this relationship was enumerated, weather years other than 1976-77 could be "played" through it to simulate what costs and losses would have been for different weather years. Thus, some statistics could be generated (say, average annual costs and losses for weather years represented by weather data 1959-1969) which are independent of the particular weather pattern in effect when the data were gathered.

The statistical analysis employed to establish the explicit relationship between costs and losses and weather severity started with a model of the following form:

$$C_i = \alpha + \beta S_i + \gamma T_i + \delta F_i \tag{4.1a}$$

$$L_i = \varepsilon + \zeta S_i + \eta T_i + \theta F_i + K C_i. \tag{4.1b}$$

The above model is refered to as the <u>linear</u> form. An alternative form is:

$$C_i = \alpha S_i^{\beta} T_i^{\gamma} F_i^{\delta} \tag{4.2a}$$

$$L_i = \varepsilon S_i^{\zeta} T_i^{\eta} F_i^{\theta} C_i^{K}. \tag{4.2b}$$

This model is refered to as the <u>log</u> form. The variables are defined for each observation, i (where each white form for each grove represents an observation), as:

C_i = costs of protection per acre

S_i = weather severity

T_i = time of year (number of days from November 1)

F_i = annual FCIC insurance premium per acre

L_i = net revenue loss per acre, constant prices at 1975-76 averages assumed.

Costs of protection, then, are assumed to be a function of the weather severity, the crop susceptibility (represented by the time of year) and the grove susceptibility (represented by the premium). Losses are a function of the same parameters and the amount of protection employed as measured by the costs of protection. The sample is stratified in various ways and the equations above pertain to each subsample. The most important stratification is by fruit variety such that a model is estimated for each variety.

The normalization was not carried out completely, however, because of insufficient time to develop statistically significant results. It should be noted that the statistical analysis could not be initiated until all loss data was received from the growers. This data was not forthcoming until October (plans were to receive all data shortly after the last harvest--July). Even when only those observations with positive costs were considered, the cost regressions were very weak. For example, our best regression for costs of protection of valencias in the northern counties yielded an R^2 of only 0.05 (that is, only 5 percent of the variation in cost was explained by our model). Similar results were obtained for costs with the other fruit varieties. The percentage variation explained improved for the loss equations: 31 percent for early and mids, 72 percent for valencias, 43 percent for specialty fruit, and back down to 5 percent for grapefruit. Although these are considerably improved, they still do not produce the kind of estimates with which it is comfortable to work.

Since there exists a trade-off between costs and losses, a variable representing their sum was also tested. These cost-plus-loss regressions yielded somewhat better results. Table 4.17 presents a partial listing of the regression results found. In general, the regressions not shown here yielded somewhat poorer results.

Exactly why the statistical analysis produced such poor results is currently being analyzed and will continue to be analyzed during the early part of the test group year. It is anticipated that different types of

Table 4.17 Estimated Statistical Relationships Between Costs and Losses and Weather Severity

Fruit Variety	Dependent Variable	Model	Explanatory Variables				R^2
			Constant	Severity	$(\text{Severity})^2$	Time	
Early and Midseason	Loss, Northern Counties	Linear	44.85	3.73 (4.25)			0.31
	Cost + Loss, Northern Counties	Linear	6.06	6.09 (10.98)	-0.012 (0.83)	-0.051 (0.46)	0.53
	Loss, Southern Counties	Linear	125.5	6.13 (3.07)			0.22
	Cost + Loss, Southern Counties	Linear	19.87	11.77 (5.45)	-0.022 (0.26)	-0.141 (0.58)	0.48
Valencia	Loss, Northern Counties	Linear	31.9	4.25 (10.63)			0.72
	Cost + Loss, Northern Counties	Linear	1.59	4.41 (8.05)	-0.006 (0.50)	0.007 (0.07)	0.55
	Loss, Southern Counties	Log	3.88	0.507 (2.90)			0.13
	Cost + Loss, Southern Counties	Linear	13.65	22.79 (7.17)	-0.382 (3.12)	-0.235 (0.47)	0.28
Specialty Fruits	Loss, Northern Counties	Log	3.63	0.55 (4.22)			0.42
	Cost + Loss, Northern Counties	Linear	-10.39	11.95 (8.93)	-0.104 (4.10)	0.120 (0.42)	0.40
	Cost + Loss, Southern Counties	Linear	121.54	14.39 (3.07)	-0.096 (0.73)	-1.08 (1.06)	0.15
Grapefruit	Cost + Loss Northern Counties	Linear	33.81	-35.47 (7.43)	2.83 (13.04)	-0.073 (0.27)	0.90
	Loss, Southern Counties	Log	8.6	-1.37 (1.08)			0.23
	Cost + Loss Southern Counties	Linear	-11.02	104.19 (3.29)	-6.15 (2.05)	0.073 (0.04)	0.22

Notes: 1. The numbers shown are regression coefficients; the numbers in parenthesis are the t - values.

2. Losses calculated as physical losses multiplied by average 1975-76 prices.

3. ECON's fruit severity index used as measure of weather severity; see Section 3.6.

4. Losses are regressed only on those observations where positive losses are indicated; costs + losses are regressed on all observations where white form existed in data base.

stratification (by type of protection technology, for example) or the addition of other variables--grove area (representing returns to scale in protection), weather forecasts and cumulative damage to date--will significantly improve the preliminary estimates.

As this analysis could not begin until all data were received from the growers and were processed, this task did not commence until mid-October. Current results are very preliminary and require that further analysis be carried out during the test group year.

5. ASSESSMENT OF CONTROL GROUP RESULTS

5.1 Conditions for Florida Citrus in 1976/77

Florida experienced its first major freeze since 1971 in the winter of 1976/77. On the night of January 18, southern counties of Florida experienced the first snowfall since weather records began over 60 years ago. During the period November 1, 1976 through March 1, 1977, there were 26 nights on which the minimum temperature forecasted was 28°F or below in some part of central Florida.

The effects of the unusually severe winter of 1976/77 on the citrus industry and on the control group in particular were impressive. A record citrus harvest had been forecast by the Florida Crop and Livestock Reporting Service before the big freeze occurred. It is estimated that approximately 14 percent reduction in supply (from 217 million boxes to 186 million boxes) occurred due to the January freeze. Further reductions were observed later due to lower yield in pounds-solid per box. Prices increased markedly, nearly doubling after the January freeze, offsetting the growers' fruit losses in many cases. Gains from price increases exceeded losses from fruit damage for the industry as a whole, although certain sectors, notably limes and tangerines, were badly hurt.

5.2 Trends in Florida Citrus Protection Against Freezing Temperatures

High fuel prices have been a reality since 1973. The cost of oil for fueling orchard heaters is currently a significant part of the total production cost of citrus on protected acres. Some growers, in early winter 1976, faced with low prices for citrus fruit and high prices for fuel oil, decided to forego protection of fruit, or at least to stop protecting their fruit after the existing stocks of oil were depleted. The continuing trend towards less protection of citrus fruit was noticeable to county extension agents, such as John Jackson. On the other hand, protection of the trees (at 22°F or less) is clearly desirable even at high fuel costs. Loss of a tree affects the grower's income for many years, and is not offset by salvage operations and higher post-freeze fruit prices. Freezes which damage large numbers of citrus trees in Florida are relatively rare; the last one before the January 1977 freeze was in 1962. Thus the grower can rationalize the high expenditure for protection of the citrus orchard as an extraordinary one, and, averaged over 15 years, it is quite acceptable. Protection of the fruit (at 28°F or lower) is indicated several nights per season, and thus the current expenditure for fuel oil must be included as part of the seasonal production cost. As such, it is essential for the grower to analyze carefully the decision to protect fruit in terms of the price expectation for the fruit after the freeze with and without protection, relative to the cost of protection. During the data collection process, several growers informed ECON that they did not consider it economical to protect citrus fruit in the winter of 1976/77. They may since have changed their minds in the light of substantial increases in citrus prices and the severity of the winter weather in Florida.

5.3 Experimental Results

The costs and losses reported in Section 4 reveal that protection of citrus orchards was practiced in the experimental sample* in 1976/77 (the control gruop) and was generally worthwhile for the growers. The total

*Nearly 100 percent of the sample had protection capability.

reported cost of protection for the control group was $473,200; net gains for the control group due to price increases after accounting for losses due to freeze damage were $1,168,000. Table 5.1 shows the breakdown of the costs and losses by county. The results are unique for Highlands county, this being the only case in the control group showing a net loss. Most of the net loss in Highlands was due to the damage to temples which, in spite of the freeze damage, experienced only a small price increase, from $2.40 to $2.80 per box. Another factor in the Highlands loss was the lack of adaptability of fresh temples to processed, which for other varieties of citrus allowed much of the freeze-damaged fresh fruit to be sold to processors. In contrast, the tangerines in Hillsborough County, which also suffered considerable damage, showed a dramatic price increase from $0.80 to $5.05 per box. Clearly the sensitivity of the market to supply reductions, as well as the sensitivity of the fruit to freezing temperatures must be taken into account by the grower in forming his decision to protect citrus acreage. Further analysis of this relationship will be conducted in the next phase of the experiment.

Table 5.1 Comparison of Reported Costs of Protection and Net Gains Due to Price Increase After Accounting for Freeze Damage Losses: The Control Group

County	Total Costs of Protection ($)	Net Gains ($)	Ratio
Hillsborough	63,000	247,600	3.93
Polk	206,900	216,400	1.04
Orange	81,500	254,000	3.12
Lake	73,700	331,100	4.49
Marion	6,100	30,100	4.93
Osceola	13,600	148,000	10.88
Highlands	14,100	-87,800	-6.23
Hardee	14,300	30,600	2.14
Total	473,200	1,168,000	2.47

6. PLAN FOR 1977-78 AND 1978-79 TEST GROUP MEASUREMENTS AND ANALYSES

In order to estimate the benefits that may be realized by the citrus growers as a result of improved frost forecasting capability, control and test groups have been established. Effective separation between the two groups of sample growers is accomplished temporally. The control group, utilizing current forecasting capability, was observed during the 1976-77 frost season. It is anticipated that the test group, benefiting from improved frost forecasting capability which will result from the utilization of SMS/GOES data in combination with forecast models being developed by the University of Florida, will be observed during the 1977-78 and 1978-79 frost seasons. The economic benefits of the improved forecasting capability will then be the difference between the normalized costs and losses of these two groups extrapolated across the State of Florida.

During the previous year's activity, the details of the experiment design were developed, data collection methodology and procedures were determined, control group data collection undertaken and completed, data reduction techniques developed and implemented, and economic analyses undertaken. The previous year's work also resulted in the development of the experiment sampling plan, the methodology for establishing protection costs and losses resulting from inadequate protection in terms of temperature forecasting capability, and the development of the means for collecting data which would demonstrate the economic consequences of improved temperature forecasting.

ECON established a sampling plan concerned with the determination of the specific growers (and groves) who would participate in the conduct of the experiment. Specific grower selection considered the desired number of samples to be included in the test and control groups. This included consideration of the accuracy of the data and the segmentation requirements (in terms of geographic location, frost protection practices, soil types, citrus crop types, etc.) A major consideration was County Extension Service experience with growers and the population of growers which was expected to be cooperative. The sampling plan concept was developed and reviewed with the county extension agents and resulted in a selection of growers who participated in the experiment. After completion of the determination of grower data requirements and data forms, discussions were held with the growers to make a final determination of which growers would participate in the experiment. As part of this initial effort, the specific procedures for data gathering were determined, including the role of information provided by the National Weather Service, the County Extension Service, the University of Florida, the Federal Crop Insurance Corporation and the citrus growers.

Preliminary cost and loss determination methodologies were determined and detailed citrus grower and National Weather Service data requirements were determined. These data requirements were reviewed with the County Extension Service, Citrus Growers Association and National Weather Service. The result was the determination of the specific data needs matched with the availability of data from the growers and the National Weather Service. Finally, data forms were developed which placed major emphasis upon minimizing the data collection burden on the grower. Three data forms were developed: one to gather data which remained invariant during the frost season; one to gather data on the daily protection costs, events, decisions and actions; and one to gather data on fruit and tree damage. These forms were filled out for each of the groves in the sample. Sources were also developed and data obtained for citrus spot and future prices, and fuel prices.

Cost and loss determination methodologies were developed in detail and used to determine average cost and loss per frost event per grove. The methodology allows a "normal" frost season to be defined in terms of number of days of different levels of frost severity. Normalized annual costs and losses for both the control and test group are to be established, the difference between these costs and losses will be the annual benefit of the improved forecasts to the citrus growers comprising the sample. Procedures have also been developed for extrapolating these results across the Florida citrus industry, taking into account grower location, frost protection practices, and frost occurrences.

Methods and procedures were developed for establishing a frost severity index based upon the duration of different levels of frost and its impact (damage) on fruit and trees. This requires knowledge of the grove temperature (as a function of time) that would have occurred in the grove if protective action were not taken. To accomplish this, methods were devised for relating National Weather Service control thermometer thermographs to grove temperature (for each grove in the database) which are then used to establish the grove frost severity index for each night of frost.

The developed data collection procedures were implemented for a control group consisting of 245 groves. With the assistance of the County Extension Service, Grove Background Reports were obtained for the 245 groves; 2150 Nightly Frost/Freeze Protection Activity Reports were obtained, as were 287 Damage Reports. Additional data was provided by the Florida Crop and Livestock Reporting Service and the Federal Crop Insurance Corporation. The

NWS provided all necessary weather forecasts and control thermometer thermographs. In addition, the NWS has provided detailed temperature records of the past thirty years so that a "normal" year could be ascertained for control and test group comparisons.

The collected data forms were reviewed, data transformed and entered into the computerized database. This database (of the control group) is utilized in the determination of events and average annual costs and losses. Daily costs and losses have been established for each grove and classified by event type, citrus grower type, and frost severity. Average costs and losses have been determined and annual costs and (preliminary) losses established for this control group. The capability being developed will allow the results of the control and test groups to be compared and the annual demonstrated benefits to be established. These benefits, based upon the sample population, will be extrapolated to total Florida citrus industry annual benefits, taking into account grower geographic locations, geographic temperature patterns, grower crop protection capabilities, and crop type. The net result will be the establishment of demonstrated benefits and extrapolated (from the measured benefits) benefits which are the direct result of improved frost protection decisions made possible by improved temperature forecasting capability.

To summarize, the experiment for measuring the economic value of improved temperature forecasts to the Florida citrus growers has been designed, data requirements and data collections methods and procedures have been determined, and control group data collection completed. The data has been entered into a computer database. The methodology for establishing annual costs and losses has been established and initial control group analyses completed. The preliminary control group results have been extrapolated to all applicable protected citrus acreage in Florida. It is this economic value (protection costs plus economic crop losses) which is to be compared with similar data to be obtained from the experiment test group. It is anticipated that the test group results will be established during the 1977-78 and 1978-79 frost seasons. It is important to note that it is desirable to obtain test group results for two frost seasons. The reasons for this are: (1) the NWS learning processes associated with the incorporation of the new data into improved forecasts; (2) the grower learning processes associated with the realization that there has been an improvement in the temperature forecasts (i.e., grower confidence in forecasts) and the incorporation of the improved forecasts into the grower decision processes; and (3) the variability of the weather which may adversely affect the quantity of available data.

6.1 Statement of Tasks

The successful completion of the economic experiment requires that the following major tasks continue through the duration of the experiment: Data Collection, Data Reduction, Economic Analysis, and Reporting. These proposed tasks, for the time period 1 December 1977 through 30 November 1978, are described below and are to be performed in accordance with the schedule shown in Figure 6.1. Also shown in Figure 6.1 is the schedule of similar tasks which would be performed during the December 1, 1978 to November 30, 1979 time period.

Task 1 - Data Collection

The data collection task is concerned with gathering the necessary data from citrus growers, the National Weather Service and other data sources, which will lead to the establishment of citrus grower test group results that can be compared with the previously developed control group results. In particular, a test group will be developed which will contain in excess of 200 groves. ECON will continue to work closely with the county extension agents and citrus growers in order to obtain the necessary (a) new or updated Grove Background Report data, (b) Nightly Frost/Freeze Protection Activity Reports, and (c) Damage Reports. ECON will continue to work closely with the National Weather Service to ensure an orderly flow of daily weather forecasts and control thermometer thermograph data. ECON will also continue to obtain other necessary data such as spot and futures prices, fuel prices, and other data necessary for the economic experiment.

Task 2 - Data Reduction

The data reduction task will be concerned with the review of all collected data (Grove Background Reports, Nightly Frost/Freeze Protection Activity Reports, Damage Reports, NWS daily weather forecasts, control thermometer thermographs, fuel prices, etc.) and transformation of the data into suitable form for entry into a general database. As data is received, it will be reviewed for correctness and consistency. If problems are encountered, data forms and data collection procedures will be reviewed and altered accordingly.

Task 3 - Economic Analysis

The economic analysis task will be concerned with the determination of annual savings which occurs as a result of improved temperature forecasts and is based upon the data obtained from the citrus growers and the National Weather Service. In order to establish the level of frost severity, an important input for event segmentation, control thermometer temperature from NWS or grower control thermometers will be used to compute grove temperature. Cost and loss per event will then be established and segmented accordingly. ECON will review the results of these computations with the county extension agents in order to determine errors in methodology and/or input data and to maintain quality control throughout the data collection periods. Since the control and test groups are separated temporally, the economic analysis methodology will incorporate the necessary detail to ensure the validity of results (for example, the impact of citrus prices on protection decisions will be considered). Daily costs and losses will be established for each grove and classified by event type, citrus grower type and frost severity. At the end of each frost season, average costs and losses will be determined so that annual costs and losses can be established for the control and test groups. Regression analyses will be performed to determine the explanatory variables which need to be considered so as to lead to meaningful control and test group comparisons. The results of the control and test groups will be compared and the annual demonstrated savings will be established. These savings, based upon the sample population, will be extrapolated to total Florida citrus industry annual savings, taking into account grower geographic locations, geographic temperature patterns, grower crop protection capabilities, and crop type. The net result will be the establishment of demonstrated benefits and extrapolated (from the measured benefits) benefits which are the direct result of improved frost protection decisions made possible by the improved temperature forecasting capability.

Task 4 - Reporting

ECON will provide both oral briefings and written reports. Oral briefings will be given as required. It is anticipated that briefings will be given after the frost seasons and will detail the experiment design and results obtained to date. Other briefings will be given as required. Monthly activity reports will be provided. An annual report will be provided and will describe in detail the methodology, the data collection techniques, the collection data (growers, NWS and others) and established results.

6.2 Schedule

The schedule of events for the Florida citrus crop economic experiment is illustrated in Figure 6.1. The schedule, to a large extent, is dictated by the Florida frost season, which extends from December through March, during which most of the necessary data must be obtained. It is anticipated, based upon the collection procedures and experience with the control group, that data collection will continue through July (since Damage Reports are prepared shortly after harvest time and harvesting extends through June) and possibly, for the damage data, through the end of September.* The data reduction task will closely follow the data collection task. The initial portion of the economic analysis task will be devoted to analyses which insure that valid results will be obtained in spite of the temporal separation of control and test groups (for example, it will be necessary to consider the impact of citrus prices on protection decisions if significant price differences are noted at the start of and during the control and test group frost seasons). As test group cost and loss data become available, attention will focus on the determination of costs and losses and savings which may result from the improved forecasts.

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*This possible slippage in the data collection schedule is illustrated by the dotted lines in Figure 6.1.

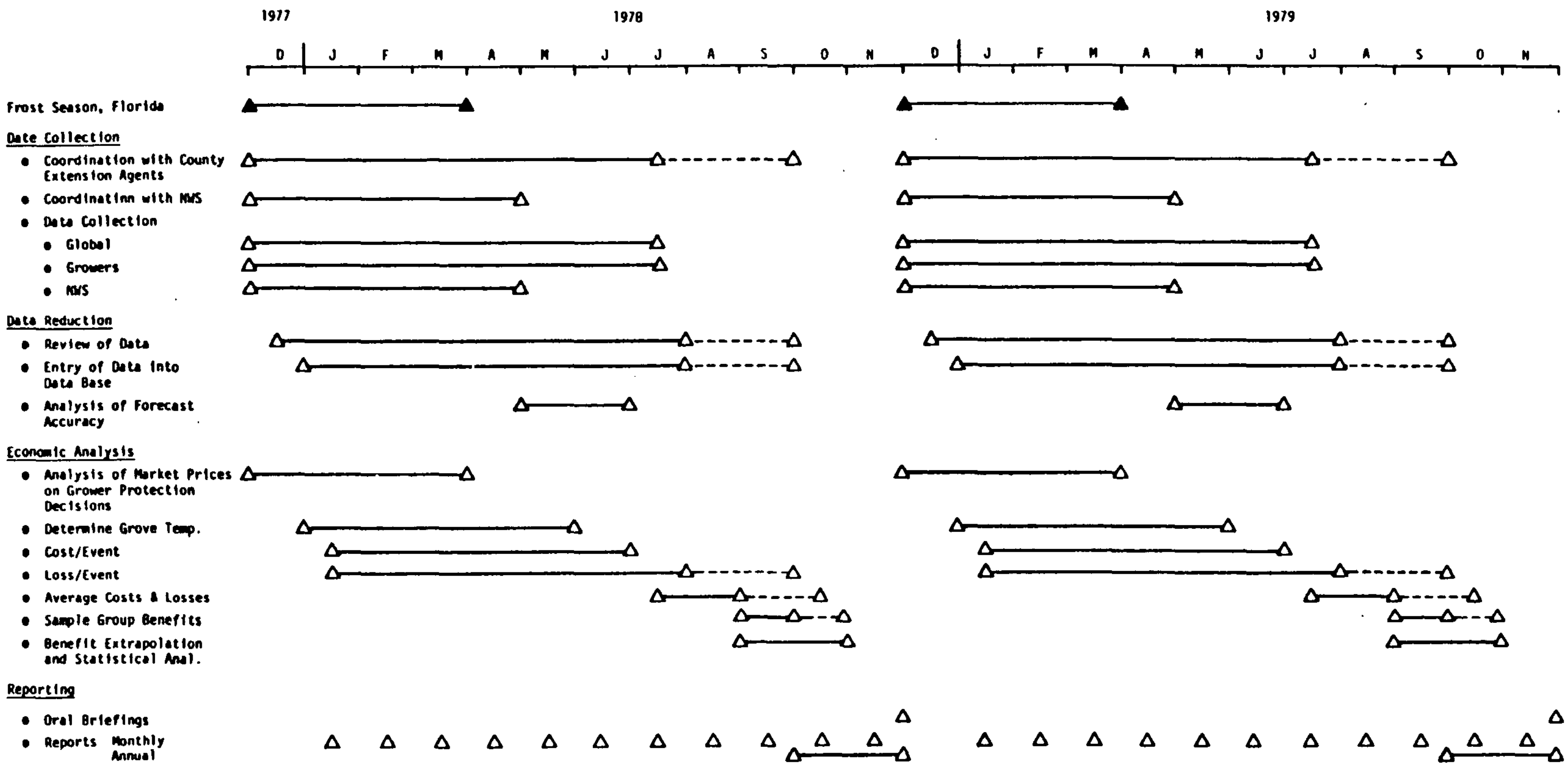

Figure 6.1 Schedule of Events for Florida Citrus Crop Economic Experiment

APPENDIX A

CITRUS GROWER DATA FORMS
PACKAGE

ECON INCORPORATED

NINE HUNDRED STATE ROAD
PRINCETON, NEW JERSEY 08540
609 924-8778

Mr. John Smith
999 Citrus Road
Orange City, Florida

Dear Mr. Smith:

As you are probably aware, the National Aeronautics and Space Administration, National Weather Service and University of Florida are developing techniques which will lead to improved temperature and frost/freeze forecasting by making use of thermal mapping from the SMS/GOES satellite. It is anticipated that these efforts will lead to an operational capability prior to the start of the 1977/78 frost season. An experiment has been initiated to measure the economic benefits which may occur to the Florida citrus growers as a result of the improved temperature and frost/freeze forecasting. This is a somewhat unique opportunity in that a direct attempt is being made to measure and evaluate the economic benefits which may result from a research and development program. It is hoped that the results of this experiment will provide an added stimulus for further research and systems aimed at improving the various aspects of meteorological forecasting.

Your County Extension Agent, Tom Oswalt, has advised us of your willingness to cooperate in this experiment. We want to thank you since this experiment would not be possible without your cooperation and the cooperation of other citrus growers. It is anticipated that approximately fifty growers will participate in the experiment and will provide data on a total of several hundred groves. This level of cooperation will allow the economic benefits to be measured for the experiment population and thence carefully projected across the Florida citrus industry.

ECON, Inc., a Princeton, NJ based economics and policy research and consulting firm, has overall responsibility for the planning and conduct of the economic experiment. We will be ably assisted by the Florida Cooperative Extension Service, University of Florida and the National Weather Service. We look forward to a very informative and successful experiment.

The experiment, in general, will be concerned with measuring the citrus protection costs and losses throughout the frost season. It is anticipated that the costs and losses will be measured during the current and the 1977/78 frost seasons. During the current frost season the NWS will provide temperature and frost/freeze forecasts in their normal manner. During the 1977/78 frost season the NWS will have available improved temperature data

ECONOMICS OPERATIONS RESEARCH SYSTEMS ANALYSIS POLICY STUDIES TECHNOLOGY ASSESSMENT

obtained from the SMS/GOES satellite and improved forecasting techniques developed by the University of Florida. It is anticipated that the differences in forecasting capability will result in reduced grower protection costs and losses. The economic benefits are thus the differences in the growers costs and losses during the two frost seasons properly adjusted for differences in the severity and number of frost/ freeze occurrences.

Your County Extension Agent has given you a looseleaf book containing a set of report forms and instructions for filling out these reports. Three different report forms are provided, namely

(1) a Grove Background Report, to be filled out once per frost season at the start of the frost season,

(2) a Nightly Frost/Freeze Protection Activity Report, to be filled out if the NWS frost bulletin predicted temperatures of 28°F or less, and

(3) a Damage Report, to be filled out when there is fruit and/or tree damage.

A set of these reports must be filled out for each grove for which you will be providing data. All data will be treated as confidential. A set of self-addressed and stamped envelopes is also provided. These should be used for mailing all reports at the end of each week to Tom Oswalt. If you have any questions upon reviewing the contents of the looseleaf book or throughout the course of the experiment, please contact Tom Oswalt. If further information is required the undersigned should be contacted (call collect: 609-924-8778).

At the end of the frost season and after all the data has been analyzed we anticipate providing you with a report which summarizes your protection costs and losses for each grove for which you provided data. This report will indicate how your costs and losses compared with the average cost and losses of all other groves which are similar to yours.

Again, we want to thank you for your cooperation. We believe that, through cooperative efforts such as this, the value of space technology can be correctly assessed and future research and new systems oriented toward helping to solve real problems.

Sincerely,

Joel S. Greenberg Director,
Techno-Economic Analyses

JSG/jmw

ECON INCORPORATED

NINE HUNDRED STATE ROAD
PRINCETON, NEW JERSEY 08540
609 924-8778

FLORIDA CITRUS EXPERIMENT

to measure the value of improved
frost/freeze forecasting

Instructions and forms for the Florida Citrus Experiment in the following order:

1. Instructions for the Grove Background Report (Green)
2. Grove Background Report (Green)
3. Instructions for the Nightly Frost/Freeze Protection Activity Report (White)
4. Nightly Frost/Freeze Protection Activity Report (White)
5. Instructions for Damage Report (Pink)
6. Damage Report (Pink)

ECONOMICS OPERATIONS RESEARCH SYSTEMS ANALYSIS POLICY STUDIES TECHNOLOGY ASSESSMENT

INSTRUCTIONS FOR THE GROVE BACKGROUND REPORT

The questions in this grove background report refer to specific information about one grove only. Most of this information will not change from December to March. The background report questions are answered once only at the beginning of the winter season

"Grove"

For the purpose of this study, a "grove" is defined as a land area a) with citrus of the same variety, b) planted at the same time (except resets), c) having a uniform degree of frost/freeze protection and d) subjected to the same management and agricultural practices. If you have a large grove with a number of blocks, each of them with different variety of citrus, then these blocks would be called "groves" in this study.

"Grower"

A "grower" is considered to be a person who is in charge of the particular grove. In the case of an absentee owner it would be the grove manager or a person who is responsible for the grove management. That person would then fill out all data forms.

In order to avoid ambiguities and to minimize misunderstandings, the following is a brief explanation of how the questions in this report should be filled out.

1. Fill in the name which you have given to the particular grove. If you will be providing data for more than one grove, care must be taken to keep the data separately. To help in this separation you will find a list of grove I.D. numbers—please identify one of your groves with each of these I.D. numbers and maintain this list as a reference. This will be referred to each time a form is filled out. It is important to fill out one form for each grove. Each grove's assigned identification number will be used in the nightly reports.

2. Identify the location, section, range and township of your grove.

3. Circle one number which would identify a variety of citrus grown in this grove.

4. Circle one number which would identify the predominant type of rootstock of citrus grown in this grove.

5. Fill in the year in which the grove was planted. Do not fill in the year when the resets were planted.

6. If there are in this grove resets which are less than 7 years of age and not yet in full production or skips (trees which are out of production or empty spaces) then fill in the precentage of the total number of trees which they represent.

7. Specify the area of citrus bearing tree acres excluding the roads, empty spaces, etc. contained within this grove.

8. Identify the topographical location of this grove by circling the (one) applicable number.

9. Identify the soil type associated with the topographical location by circling the (one) applicable number.

10. If this grove is located near a lake, a river, or a reservoir which would influence your frost/freeze protection for this grove, then circle yes.

11. A control thermometer is a thermometer located in the vicinity of the grove which records the true temperature which would have occurred in the grove if the frost/freeze protection devices were not utilized.

12. The answer to this question would help us in a better understanding of your long-term frost/freeze protection strategy.

13-17. These questions pertain to the grove status and are self-explanatory. The average yield estimates for the past years would indicate if there was any damage of this grove due to frost or freeze and if it influenced your frost/freeze protection measures.

18-19. Answers to these questions would help in the better understanding how your marketing plans influenced your frost/freeze protection measures.

20-21. Describe the use of wind machines in this grove. List the various types of machines in this grove (example: single propeller, with tower mounted engine or an engine at base, dual wind machines with dual gasoline engines tower mounted, etc.) number of machines of each type used at the grove, the fuel type (gasoline electricity, propane), and their average rate of fuel consumption.

22-23. Describe the use of heaters in this grove. List various types of heaters (spot, jumbo cone, lazy flame 24 inch stack, lazy flame 18 inch stack, etc.), the number of heaters of each type used in this grove, the fuel type (diesel fuel, propane, etc.), and their average fuel consumption.

24-25. Try to estimate as accurately as possible the approximate amount of fuel on hand at the beginning of the frost/freeze season, indicate the storage capacity and the average price you paid for fuel especially if you have had this fuel for several years.

26. If you use any other kind of frost/freeze protection method for this grove, then circle an appropriate number.

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NINE HUNDRED STATE ROAD
PRINCETON, NEW JERSEY 08540
609 924-8778

GROVE BACKGROUND REPORT

I.D. No. ______

This section records some specific information about one of the groves selected for this study. Most of this information will not change from December to March. Please be as specific as possible in answering these questions.

DESCRIPTION AND CHARACTERISTICS OF THE GROVE

1. Your own grove identification: ______

2. Grove location: ______ / ______ / ______
   Section / Township / Range

3. Variety of Citrus grown in this grove:

   CIRCLE ONE NUMBER

   1 Early Oranges
   2 Midseason Oranges
   3 Late (Valencia) Oranges
   4 Temples
   5 Tangelos
   6 Tangerines & Honey Tangerines
   7 Seedy Grapefruit
   8 White Seedless Grapefruit
   9 Red-Pink Seedless Grapefruit
   10 Some other variety; PLEASE SPECIFY: ______

4. Type of rootstock: CIRCLE ONE NUMBER

   1 Rough Lemon
   2 Sour Orange
   3 Cleopatra Mandarin
   4 Trifoliate Orange
   5 Carrizo Citrange
   6 Other

5. Year grove was planted: ______

6. Percentage of all trees that are resets less that 7 years of age or skips: ______ percent

7. Grove area (If possible be as specific as tenths of an acre of actual citrus bearing tree acres.): ______ acres

8. Grove terrain: CIRCLE ONE NUMBER

   1 High Ground
   2 Low Ground
   3 Other; PLEASE DESCRIBE ______

9. Grove soil type: CIRCLE ONE NUMBER

   1 Ridge
   2 Flatwoods
   3 Other; PLEASE DESCRIBE ______

10. Are there any large bodies of water which may influence your grove?
    1 Yes
    2 No

11. Is there a control thermometer associated with this grove which is outside of the protected area?
    1 Yes
    2 No

12. If you know the Federal Crop Insurance Corporation classification of this grove would you please write it down? ______

If you have any questions, call your county extension agent.

GROVE STATUS

13. Month of expected harvest: CIRCLE ONE NUMBER

    1 January
    2 February
    3 March
    4 April
    5 May
    6 June
    7 July
    8 August
    9 September
    10 October
    11 November
    12 December

14. Average yield in this grove in the

    1973-74 season: ______ boxes per grove
    1974-75 season: ______ boxes per grove
    1975-76 season: ______ boxes per grove

15. Estimate of yield for the 1976-77 season: ______ boxes per grove

16. Grove has experienced frost/freeze damage in the past three years which has reduced the grove's productivity or damaged the trees:

    1 Yes → When did this damage occur? Month: ______ Year ______
    Month: ______ Year ______
    Month: ______ Year ______
    2 No

17. Did this damage prompt any additional frost/freeze protection measures for this grove?
    1 Yes
    2 No

MARKETING PLANS

18. At this time, do you intend to produce the citrus from this grove for fresh or processed market? CIRCLE ONE NUMBER

    1 Fresh
    2 Processed
    3 Don't know

19. What are the primary reasons you plan to market this fruit in this manner? CIRCLE AS MANY AS APPLY

    1 Variety or quality of fruit
    2 Expected market price
    3 Anticipated costs of freeze/frost protection
    4 Other; PLEASE EXPLAIN: ______

PLEASE CONTINUE ON NEXT PAGE

FROST/FREEZE PROTECTION MEASURES

20. Wind machines used in this grove?
    1 Yes
    2 No...GO TO QUESTION 22

21. Wind machine data for this grove:

Type of Machines	Number of Machines	Type of Fuel	Average Fuel Consumption Rate*

*diesel........gallons/hour
gasoline......gallons/hour
electricity...kilowatts/hour
propane.......pounds/hour

22. Heaters used in this grove?
    1 Yes
    2 No...GO TO QUESTION 26

23. Heater data for this grove:

Type of Heaters	Number of Heaters	Type of Fuel	Average Fuel Consumtion Rate*

*diesel fuel...gallons/hour
propane.......pounds/hour

24. Storage capacity and fuel on hand:

Type of Fuel	Storage Capacity	Fuel on Hand
diesel	gal.	gal.
propane	lbs.	lbs.
other		

25. Average price of fuel on hand:
    diesel fuel ________ ¢/gallons
    propane ________ ¢/pound
    other ________

26. Other frost/freeze protection methods used in this grove?
    1 Yes → What kind?
    1 Permanent Oil Heating System
    2 Sprinklers
    3 Flood Irrigation
    4 Other; PLEASE DESCRIBE: ________

OTHER INFORMATION

27. What other information can you provide that would be helpful in understanding the management of this particular grove?

PLEASE DESCRIBE ________________________________

INSTRUCTIONS FOR THE NIGHTLY FROST/FREEZE PROTECTION ACTIVITY REPORT

The answers should be limited to one "grove" only (see Instructions for the Grove Background Report for the definition of a "grove"). You should fill out the nightly report everytime when a frost fruit bulletin by NWS forecasts the lowest temperatures to be 28°F or less even if you do not initiate any frost/freeze protection action. However, if you initiated some kind of protection during which you incurred costs then please fill out a nightly report regardless of the lowest predicted temperatures (i.e., even if the predicted temperatures were higher than 28°F).

1. Fill in your own identification of this grove and the I.D. number which was assigned to this grove.

2. Fill in the date.

3-4. Answers to these questions would provide information about which of NWS forecasts influenced your decision to initiate some kind of protective action and the degree of confidence you have in the NWS forecasts.

5. Specify if any action associated with frost/freeze protection was taken which lead to a financial cost to you including:
   a) calling in laborers (seasonal or high school students) and paying them wages even if they do not perform any work and are later sent home,
   b) asking some members of your permanent staff to perform activities associated with frost/freeze protection (such as monitoring the weather, checking and preparing the equipment, operating the wind machines, etc.) for which they are paid extra beyond and above their regular wages.

6. Labor costs have to be prorated to the one grove for which the nightly report is filled in. This is especially important when your crews fire and extinguish heaters in several groves of various sizes. Each one of these groves can be protected by different number of heaters requiring different amounts of time for their firing and extinguishing. Please take this into account when answering this question.

7. This grove can be protected by wind machines of different types which were turned on and off at different times. A group of wind machines are all wind machines of the same type, having the same rate of fuel consumption and which are turned on and off at the same time. If you, for example, have four machines of the same type, but two of them were turned off at 7 a.m., then there are two groups: fill two in Group 1 and two in Group 2 with the appropriate times of turning on and off.

   It may take some time to turn on and off several wind machines of one group. It is assumed that turning them on is done in the same sequence as turning them off and therefore all machines are in operation approximately the same time. The recorded times on the nightly report are those times at which the first machine in a group was turned on and off, respectively.

8. The same concept as was used for wind machines applies for heaters. A group of heaters are all heaters of the same type, having the same rate of fuel consumption and which are turned on and off at the same time. Example: a grove is heated by forty heaters. Twenty are fired at 1 a.m. and the other twenty are tired at 2 a.m. All heaters are extinguished at 6 a.m. You have, therefore, two different groups each of twenty heaters.

   Always record the time the first heater in the group was fired and extinguished. It may take an hour or even more before all heaters are fired (or extinguished) but it is assumed that they are fired and extinguished in the same order and therefore all the heaters of one group are in operation approximately the same time.

9. In case you use any other frost/freeze protection method, such as overhead sprinkling, flood irrigation, etc., please fill in the total cost of operating these protection systems for this particular night. Please prorate all costs to this particular grove.

10. During the frost/freeze protection activities your trucks had to pick up some equipment and automobiles were used to transport the personnel between the homes, offices, groves, etc. Please try to estimate the total mileage of the cars and trucks, prorated to this particular grove, even if they are not your vehicles.

11. The question is answered only if you have at this grove a control thermometer outside of the protected area which would record the true temperature at the grove (i.e. temperatures which would be obtained throughout the entire grove if it would be unprotected).

12. If there is any damage to fruit and/or trees as a result of frost/freeze which was not previously reported, then please fill out a damage report.

13. You may have decided not to take any protective action or limited action at no cost even if the temperature was predicted by NWS to be 28°F or less. You incurred no costs and you may have observed some damage to fruit and/or trees (see Question 12) or not. Circle as many reasons as might apply when you made your decision.

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NIGHTLY FROST/FREEZE PROTECTION ACTIVITY REPORT

Please limit your answer to one grove only (see the instruction sheet for the definition of a "grove" as used in this report). Please answer the following questions only if a fruit frost bulletin by NWS predicted the lowest temperatures to be 28°F or less for the zone in which this grove is located or you had taken any frost/freeze protection during which you incurred costs regardless of predicted temperatures.

1. Your own grove name: ______________ grove I.D. number: ________

2. Date of frost/freeze . . . . Month: __________ Day: ________

3. Which of the NWS forecasts influenced you to initiate some form of frost/freeze protection? . . . .
   CIRCLE ONE NUMBER
   1 10:15 a.m.
   2 4:15 p.m.
   3 10:15 p.m.

4. On a scale of one to ten, how much confidence do you have in the NWS forecast identified in Question 3?

   CIRCLE ONE NUMBER

   no confidence 1 2 3 4 5 6 7 8 9 10 absolute confidence

5. On this night, did you take any action which incurred costs (including calling in laborers, paying someone extra to check the equipment, starting wind machines, firing heaters, etc.)?
   1 Yes
   2 No...GO TO QUESTION 12

6. Labor costs associated with this night's frost/freeze protective action, prorated to this grove:
   1 Total direct wages of laborers called in . . . . . .$ ______
   2 Extra direct wages of other personnel to supervise, to monitor weather, check or operate equipment, etc. $ ______

7. Wind machines:

	Number of Machines	Fuel Type	Fuel Consumption Rate*	Time (hours and minutes) On	Time (hours and minutes) Off
Group 1					
Group 2					
Group 3					

*gasoline......gallons/hour
diesel........gallons/hour
propane.......pounds/hour
electricity...kilowatts/hour

8. Heaters:

	Number of Heaters	Fuel Type	Fuel Consumption Rate*	Time (hours and minutes) Fired	Time (hours and minutes) Extinguished
Group 1					
Group 2					
Group 3					
Group 4					
Group 5					
Group 6					

*diesel........gallons/hour
propane.......pounds/hour

9. Operating costs of any other used frost/freeze protection method: $ ______

10. Total approximate mileage incurred during frost/freeze protection travel, prorated to this grove: . . . Trucks: ________ miles
    Automobile ________ miles

11. Minimum temperature recorded on the control thermometer for this grove: . . . . ________°F

12. Was there observed any damage to fruit and/or trees not previously reported? . . . . .
    1 Yes...DO NOT FORGET TO FILL OUT A DAMAGE REPORT
    2 No

13. If you took no action which incurred costs what were the reasons for not taking it?
    1 Weather conditions did not seem to warrant it
    2 Market conditions
    3 Anticipated protection costs too high
    4 Frost previously damaged
    5 Started too late—not enough time
    6 Took limited action. No additional expense incurred (alerting laborers, having checked equipment at no additional cost, etc.)
    7 Other reason; PLEASE EXPLAIN ____________

____

If you have any questions, call your county extension agent.

INSTRUCTIONS FOR DAMAGE REPORT

When any damage to fruit and/or trees is observed then fill out a damage report. Please limit the answers for one grove to one report. If you observed damage in several of your groves which are part of the study then fill out several reports.

1. The grove identification and grove number are identical to those in your nightly reports and the grove background report.

2. The date when you fill out the damage report.

3. The damage due to frost/freeze can usually be determined only several days after the night when it actually happened. Fill in the date of the frost/freeze (could be one night or several nights) which resulted in the damage to fruit and/or trees in this grove.

4. If there is damage to fruit then fill out Questions 5 to 8. If there is damage to trees, then fill out Questions 5 to 8 and 9 to 11.

5-6. Answers to these questions would indicate if the damages due to frost/freeze changed your marketing plans.

7-8. The approximate loss of fruit could best be determined if you specify your estimates of yield from this grove in boxes per acre (if you produce for the fresh fruit market) or in lbs-concentrate per acre (if you produce for the processed fruit market) before the damage (i.e. the yield which would be achieved if the grove would not have been damaged) and after the damage to this grove.

9. Circle yes if there is any damage to the trees.

10. When trees in the grove are damaged then, depending on the severity of the damage, part of the next year or even part of the next several years' crop could be lost. Estimate the number of years before this grove would return to the full production.

11. Only certain sections of a grove may be damaged. Estimate the percentage of grove which was damaged.

12. Please enter any other comments you may have which would be helpful in the evaluation of damages.

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DAMAGE REPORT

Please answer the following questions when you observed damage to your fruit and/or trees. Please limit the answers for one grove to one page.

1. Your own grove identification: ____________________ and grove I.D. number: __________

2. Today's date . . . . Month: __________ Day: __________

3. On what night (or nights) was the damage done? . . . . Month: __________ Day(s): __________

4. In this grove, was there any damage to the fruit? . . . . 1 Yes
   2 No...GO TO QUESTION 9

5. How did you intend to market the fruit before the damage? . . . . 1 Fresh
   2 Processed

6. How do you intend to market the fruit now? . . . . 1 Fresh
   2 Processed

7. How would you estimate the yield before the damage? . . . . __________ boxes per acre
   or __________ lbs-solids per acre

8. How would you estimate the yield after the damage? . . . . __________ boxes per acre
   or __________ lbs-solids per acre

9. Was there any damage to the trees? . . . . 1 Yes
   2 No...GO TO QUESTION 12

10. If there was damage to the trees, in how many years do you expect full production from this grove? . . . . __________ years

11. What is the approximate percentage of the grove which was damaged? . . . . __________ percent

12. Would you wish to make any other comment? PLEASE DESCRIBE . . . . ______________________________
____
____

If you have any questions, call your county extension agent. ______________________________

APPENDIX B

END OF SEASON REPORT FOR WINTER 1976-1977
GROVE X-Y

ECON INCORPORATED

NINE HUNDRED STATE ROAD
PRINCETON, NEW JERSEY 08540
609 924-8778

November 15, 1977

Mr. X.X. Xxxxxx
XXX Xxxxxxxx Xxxxxx
Xxxxxx, Florida

Dear Mr. Xxxxxxx:

As the frost season is fast approaching, we are preparing for the second phase of our economic analysis of the Florida Freeze Experiment. This means collecting, as we did last winter, the data on your protection costs and frost/freeze damages. The forms have been streamlined this year and we have tried to minimize the burden of filling them out. Your county extension agent will be handling the forms and assuming a large share of the burden of collecting this data. We think he did a terrific job at it last year and have full confidence that things will go even better this year.

It has taken us longer than expected to analyze all the data we collected last year (and some of the data was still being collected in October 1977) but we are finally ready to send you the computer reports on the costs of cold protection for the winter of 1976/77, mentioned in my May 18th letter. The reports contain feedback information on your groves and summaries of nightly protection costs for your groves, and protection costs averaged across all sample groves (i.e., the groves participating in our experiment) in your county which were protected. We did not offer the same comparison for losses caused by freeze damage because of the difficulty of accounting for price changes caused by the January 1977 big freeze. The loss of fresh fruit (column 4 on part 4 page 2) shows your reported loss due to cold, in boxes by date. The next column on the same page shows the change of fresh fruit sales to processed fruit sales necessitated by the freeze in either lbs-solid or gallons per acre, depending on citrus variety. Although the units are different, these two columns frequently refer to the same fruit, which are lost as fresh fruit sales but gained as processed fruit sales. Thus, the change in processed fruit may be a gain (+) or a loss (-); the gain coming about by fresh fruit switching to processed which more than offsets the loss of yield of fruit planned originally to be marketed as processed.

For your general information, the attached table shows average fruit damage losses recorded in our sample by county and by citrus variety including market price effects (in other words, these figures are related to economic losses). The sample consists of protected acreage only, so these losses are not typical of the entire citrus industry.

We look forward to working with you in the next phase of the Experiment and thank you for your cooperation in supplying the data on protection costs and damages.

Yours sincerely,

Joel Greenberg
Project Director

Enclosure

JG:jw

Estimated Revenue Gains or Losses (Dollars Per Acre) Attributable to Impact of Frosts and Freezes for 1976-77 Crop Year--For Entire Sample--By County and Fruit Variety+

County	Fruit Variety					
	Early & Mid Oranges	Valencia (Late) Oranges	Temples	Tangelos	Tangerines	Grapefruit (All Types)
Hillsborough	394	495	100	26	1,306	119
Polk	124	155	-422	60	50	76
Orange	523	51	-222	*	1,487	-566
Lake	5	212	5	23	185	53
Marion	67	247	*	*	1,060	-40
Osceola	-1	348	*	*	1,137	745
Highlands	6	532	-961	*	*	*
Hardee	7	476	200	-280	1,889	*

+These figures are for protected groves, as almost 100% of the sample acres are protected.

*The sample contains no groves with this fruit variety in this county.

AN EXPERIMENT
TO MEASURE THE ECONOMIC BENEFITS
OF IMPROVED WEATHER INFORMATION

CASE STUDY: THE FLORIDA CITRUS INDUSTRY

* * * END OF SEASON REPORT FOR WINTER 1976-1977 * * *
GROVE X-Y

ECON, INCORPORATED
NINE HUNDRED STATE ROAD
PRINCETON, N.J.
08540

JULY 1, 1977

FLORIDA CITRUS STUDY
* * * END OF SEASON REPORT FOR GROVE X-Y * * *
PART 1 PAGE 1

PART ONE: GROVE BACKGROUND INFORMATION

A. CHARACTERISTICS OF GROVE

LOCATION: SECTION XX TOWNSHIP YY RANGE ZZ
VARIETY OF CITRUS: EARLY ORANGES
MONTH OF HARVEST: DECEMBER

YIELD IN 73-74: 287 BOXES PER ACRE
YIELD IN 74-75: 304 BOXES PER ACRE
YIELD IN 75-76: 389 BOXES PER ACRE
EXPECTED YIELD 76-77: 367 BOXES PER ACRE

ROOTSTOCK: ROUGH LEMON
YEAR GROVE PLANTED: 1956
PERCENTAGE OF RESETS AND SKIPS: 2%

GROVE AREA: 15.0 ACRES
GROVE TERRAIN: LOW GROUND
SOIL TYPE: RIDGE
BODIES OF WATER NEARBY: NO

FCIC CODE: A
CONTROL THERMOMETER FOR GROVE: YES
FROST DAMAGE IN PAST THREE YEARS: NO

B. MARKETING INFORMATION

BEGINNING OF SEASON MARKETING PLANS: FRESH
REASONS FOR MARKETING PLANS:
EXPECTED MARKET PRICE

C. FROST PROTECTION INFORMATION

WIND MACHINES USED: YES

TYPE	NUMBER	FUEL	FUEL CONSUMPTION
PMC (TYPE UNKNOWN)	1.0	GASOLINE	9.0 GPH

NOTE: FRACTIONS OF WIND MACHINES IN THE ABOVE CHART INDICATE THAT THE TOTAL NUMBER OF WIND MACHINES HAS BEEN PRORATED TO THIS GROVE, ON THE BASIS OF ACREAGE

HEATERS USED: YES

TYPE	NUMBER	FUEL	FUEL CONSUMPTION
JUMBO CONE	890	#2 DIESEL	1.0 GPH

D. FUEL INFORMATION

TYPE	FUEL STORAGE	FUEL ON HAND	AVG PRICE
DIESEL	20000 GAL	20000 GAL	34.0¢

E. OTHER BACKGROUND INFORMATION

LOCATED IN XXXXXXX COUNTY; HAS CONTROL THERMOMETER.

PART TWO: NIGHTLY AND SEASON SUMMARY OF FROST PROTECTION ACTIVITY

DATE	FORECAST IN YOUR ZONE	ACTION TAKEN WITH COSTS?	% TAKING ACTION IN YOUR COUNTY	HEATERS USED?	WIND MACHINES USED?
12/21	28 TO 32. 26 TO 28 COLD LOCATIONS. FROST.	NO	39.0%	NONE	NONE
1/17	23 TO 27 WITH POCKETS 21 TO 23.	YES	75.7%	445 HEATER HOURS: 2892.5	NONE
1/18	24 TO 28. WINDS GUSTY 10-20 MPH.	YES	35.6%	NONE	NONE
1/19	20 TO 24 WITH 16 TO 20 POCKETS. FROST.	YES	97.1%	445 HEATER HOURS: 4450.0	NONE
1/20	28 TO 32 WITH 26 TO 28 POCKETS. SCATTERED FROST.	NO	39.2%	NONE	NONE

FLORIDA CITRUS STUDY
* * * END OF SEASON REPORT FOR GROVE X-Y * * *
PART 2 PAGE 2

DATE	FORECAST IN YOUR ZONE	ACTION TAKEN WITH COSTS?	% TAKING ACTION IN YOUR COUNTY	HEATERS USED?	WIND MACHINES USED?
1/21	28 TO 32 WITH 24 TO 28 POCKETS. FROST.	NO	30.0%	NONE	NONE
1/22	28 TO 32 WITH 26 TO 28 POCKETS. FROST.	NO	12.6%	NONE	NONE
2/17	28 TO 32 EXCEPT 26 TO 28 COLDER POCKETS. FROST.	YES	23.8%	NONE	1.0 W/M HOURS: 0.0
2/20	32 TO 36. PATCHY FROST.	YES	69.6%	NONE	1.0 W/M HOURS: 5.0
2/21	32 TO 36 EXCEPT 28 TO 32 POCKETS AND HUCKLANDS. FROST.	YES	68.8%	NONE	1.0 W/M HOURS: 5.9

PART THREE: NIGHTLY AND SEASON SUMMARY OF FROST PROTECTION COSTS

DATE	YOUR TOTAL COST OF PROTECTION	YOUR PER ACRE COST OF PROTECTION	AVG. PER ACRE COST FOR YOUR COUNTY
12/21	$ 0.0	$ 0.0	$ 1.74
1/17	$ 1381.63	$ 92.11	$ 25.92
1/18	$ 66.80	$ 4.45	$ 7.17
1/19	$ 2035.30	$ 135.69	$ 95.64
1/20	$ 0.0	$ 0.0	$ 4.56
1/21	$ 0.0	$ 0.0	$ 4.43
1/22	$ 0.0	$ 0.0	$ 1.90
2/17	$ 5.00	$ 0.33	$ 3.37
2/20	$ 28.32	$ 1.89	$ 2.67

FLORIDA CITRUS STUDY
* * * END OF SEASON REPORT FOR GROVE X-Y * * *
PART 3 PAGE 2

DATE	YOUR TOTAL COST OF PROTECTION	YOUR PER ACRE COST OF PROTECTION	AVG. PER ACRE COST FOR YOUR COUNTY
2/21	$ 32.60	$ 2.17	$ 2.55
SEASON	$ 3549.65	$ 236.64	$ 154.76 *

* NOTE: THIS TOTAL ALSO INCLUDES AVERAGE PER ACRE PROTECTION COSTS FOR THOSE COLD NIGHTS FOR WHICH YOU DID NOT SUBMIT A REPORT BUT SOME PROTECTION ACTIVITY OCCURED IN YOUR COUNTY

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PART FOUR: NIGHTLY AND SEASON SUMMARY OF LOSSES DUE TO COLD

DATE	REPORTED FRUIT DAMAGE?	REPORTED TREE DAMAGE?	YOUR LOSS OF FRESH FRUIT DUE TO COLD*	YOUR CHANGE IN PROCESSED FRUIT DUE TO COLD*
12/21	NO	NO	0.	0.
1/17	NO	YES	0.	0.
1/18	NO	NO	0.	0.
1/19	NO	NO	0.	0.
1/20	NO	NO	0.	0.
1/21	NO	NO	0.	0.
1/22	NO	NO	0.	0.
2/17	NO	NO	0.	0.
2/20	NO	NO	0.	0.

FLORIDA CITRUS STUDY
* * * END OF SEASON REPORT FOR GROVE X-Y * * *
PART 4 PAGE 2

DATE	REPORTED FRUIT DAMAGE?	REPORTED TREE DAMAGE?	YOUR LOSS OF FRESH FRUIT DUE TO COLD*	YOUR CHANGE IN PROCESSED FRUIT DUE TO COLD#
2/21	NO	NO	0.	0.
SEASON	------	------	0.	0.

* NOTE: IN BOXES PER ACRE

\# NOTE: IN LBS-SOLIDS PER ACRE FOR ROUND ORANGES AND TEMPLES; IN GALLONS PER ACRE FOR GRAPEFRUIT, TANGELOS AND TANGERINES. ESTIMATED USING WEEKLY YIELDS FOR THE 76-77 SEASON.

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PART FIVE: GROWER'S CONFIDENCE IN NWS FORECASTS

DATE	YOUR CONFIDENCE IN NWS FORECASTS	AVG. CONFIDENCE IN NWS FOR YOUR COUNTY
12/21	8	8.02
1/17	8	8.09
1/18	8	8.22
1/19	8	8.20
1/20	8	8.36
1/21	8	8.28
1/22	8	8.31
2/17	8	8.27
2/20	8	8.09

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DATE	YOUR CONFIDENCE IN NWS FORECASTS	AVG. CONFIDENCE IN NWS FOR YOUR COUNTY
2/21	8	7.56
SEASON	8.00	8.21 *

* NOTE: THIS AVERAGE INCLUDES DAYS FOR WHICH YOU MAY NOT HAVE SUBMITTED A REPORT

APPENDIX C

TEMPERATURE-RELATED DATA

APPENDIX C

TEMPERATURE-RELATED DATA

This Appendix presents a compilation of temperature-related data.

Figure C-1 illustrates a typical NWS forecast issued at 4:15 p.m. on Wednesday, 19 January 1977. The NWS provided to ECON copies of all pertinent temperature forecasts during the conduct of the control group portion of the economic experiment. This same data will again be provided during the conduct of the test group portion of the experiment.

Table C-1 through C-4 summarize, for December 1976 through March 1977, respectively, the minimum reported temperatures in each of the forecast zones within which control group sample groves are located. Temperatures for the 10:15 a.m., 4:15 p.m. and 10:15 p.m. forecasts are indicated.

Table C-5 indicates the NWS thermometers which are used as the control thermometers for each of the control group sample groves. This is presented for each county. Also indicated is the shift temperature (°F) between the control thermometer and the specific grove(s) with which it is associated.

Finally, Figure C-2 illustrates a typical thermograph record provided by the NWS for each of the control thermometers utilized in the experiment (see Table C-5). Indicated on the thermograph is the number of hours between the occurrence of the same temperature (for example, on 19 January, 12 hours elapsed from the time temperature fell below 32°F till temperatures rose above 32°F).

NNNNATT↓AX
ZCZC
FXUS8 RWRB 192115
↑T BW
PENINSULAR FLORIDA FARM AREA MINIMUM TEMPERATURE FORECAST
NATIONAL WEATHER SERVICE TAMPA BAY AREA RUSKIN FL
4 15 PM EST WED JAN 19 1977

FREEZE WARNING ALL AREAS TONIGHT

TONIGHT..CLEAR AND COLD. NORTHWEST WINDS DIMINISHING OVERNIGHT WITH PERIODS OF CALM POSSIBLE AFTER MIDNIGHT. TEMPERATURES FALLING STEADILY THROUGH THE NIGHT WITH LOWS TO OCCUR BETWEEN 5 AM AND SUNRISE.

LOWEST TEMPERATURES

ZONES 6 7	10 TO 14
ZONE 8	12 TO 16
ZONE 9	14 TO 18
ZONES 10 12	18 TO 22 WITH 16 TO 18 COLD POCKETS
ZONE 11	16 TO 20 WITH 14 TO 16 POCKETS AND MUCKLANDS. SCATTERED FROST
ZONES 13 14 15 16	20 TO 24 WITH 16 TO 20 POCKETS. FROST
ZONE 17	22 TO 26 FROST
ZONES 18 19 INCLUDING IMMOKALEE	22 TO 26 WITH 20 TO 22 BACKLANDS. FROST
ZONES 20 21	24 TO 28 FROST
ZONE 22	26 TO 30 EXCEPT 28 TO 32 ALONG THE COAST. FROST.

TEMPERATURE OUTLOOK...CONTINUED COLD WITH FREEZING TEMPERATURES AGIN MOST FARMING AREAS FRIDAY MORNING.

VC

Figure C.1 Typical NWS Forecast

Table C.1 NWS Minimum Temperature Forecasts for December 1976

Date	Zone 9			Zone 11			Zone 12			Zone 13			Zone 14			Zone 15			Zone 16			Zone 22		
	10:15 AM	4:15 PM	10:15 PM	10:15 AM	4:15 PM	10:15 PM	10:15 AM	4:15 PM	10:15 PM	10:15 AM	4:15 PM	10:15 PM	10:15 AM	4:15 PM	10:15 PM	10:15 AM	4:15 PM	10:15 PM	10:15 AM	4:15 PM	10:15 PM	10:15 AM	4:15 PM	10:15 PM
1	32	40	40	38	40	40	38	40	40	38	45	45	38	45	45	38	45	45	38	45	45	48	55	45
2	40	40	40	40	40	40	40	40	40	45	45	45	45	45	45	45	45	45	45	45	45	57	57	57
3	34	34	40	38	38	45	38	38	44	44	44	44	44	44	44	44	44	44	44	44	44	54	54	54
4	40	40	40	44	44	44	44	44	44	46	46	46	46	46	46	46	46	46	46	46	46	55	55	55
5	42	42	-	48	48	-	48	48	-	48	48	-	48	48	-	48	48	-	48	48	-	55	55	-
6				ranging		from	50s			north to			60s central			and 70s			south					
7	36	36	36	40	40	40	40	40	40	46	46	46	46	46	46	46	46	46	46	46	46	55	55	55
8	27	28	27	31	32	31	31	32	31	31	34	31	31	34	31	35	36	35	35	36	35	48	48	48
9	=	ranging					from	mid		40s		to	upper			50s						→		
10	=		ranging				from	mid		50s		to	almost			70						→		
11				"			"	near		60		to	low			70s						→		
12				"			"		"	50			upper			60s						→		
13				"			"	mid		40s		to	mid			60s						→		
14				"			"	mid		50		to	upper			60s						→		
15				"			"	mid		40		to	mid			60s						→		
16	42	42	42	=			ranging			from	upper		40s			to mid			50s		→	in 50s		
17	32	30	35	36	34	38	36	34	38	38	36	38	38	36	38	38	36	38	38	36	38	52	46	55
18	—				ranging			from		low 40s			to		mid	50s					→	mid 50s		
19	=				"			"		near 50			"			"	50s					near 60		
20	34	32	32	36	36	36	30	30	30		in		the		40s						→	mid 50		
21	24	24	22	26	26	26	26	26	26	28	28	28	28	28	28	28	28	28	28	28	28	34	34	36
22	34	34	36	38	38	40	38	38	40	42	42	46	42	42	46	42	42	46	42	42	46	46	46	52
23	34	34	34	38	38	38	38	38	38	42	42	42	42	42	42	42	42	42	42	42	42	45	45	45
24	34	32	32	38	36	36	38	36	36	44	44	42	44	44	42	44	44	42	44	44	42	46	46	46
25	<	-		ranging			from			40s	north		to		50s	central		to	60s	south				
26	30	30	30	30	30	32	34	34	32	34	34	34	34	34	34	34	34	34	34	34	34	44	44	44
27	36	34	34	40	36	36	40	36	36	40	36	36	40	36	36	40	36	36	40	36	36	48	40	40
28	34	34	=		ranging			from	upper	30s		to	50s	central		—					→	52 in 50s		
29	34	34	34	36	36	36	36	36	36	38	38	38	38	38	38	38	38	38	38	38	38	44	44	44
30	in 40s	—	—	48	—		48	—	—	48	—		48	—		48	—		48		—	in 50s		
31	30	—	—	34			34	—		38	—		38			38	—	—	38	—		near 50		

Table C.2 NWS Minimum Temperature Forecasts for January 1977

Date	Zone 9			Zone 11			Zone 12			Zone 13			Zone 14			Zone 15			Zone 16			Zone 22		
	10:15 AM	4:15 PM	10:15 PM	10:15 AM	4:15 PM	10:15 PM	10:15 AM	4:15 PM	10:15 PM	10:15 AM	4:15 PM	10:15 PM	10:15 AM	4:15 PM	10:15 PM	10:15 AM	4:15 PM	10:15 PM	10:15 AM	4:15 PM	10:15 PM	10:15 AM	4:15 PM	10:15 PM
1	28	28	28	32	32	32	32	32	32	36	36	36	36	36	36	36	36	36	36	36	36	43	43	43
2	← ranging from near 40 (north) near 50 (central) low 60s south																							
3	36	36	36	← low to mid 40s →						← mid to upper 40s ——→												upper 50s		
4	← ranging from near 40 northern zones, upper 40s to low 50s central, upper 50s																							
5	← " " " " " " " →																							
6	← low 40s northern zones, upper 40s central zones and in upper 50s south →																							
7	32	34	34	34	38	38	34	38	38	38	40	40	38	40	40	38	40	40	38	40	40	44	[illegible]	40
8	← ranging from near 40 north to near 50 south ——→																							
9	← from 40s north to 50s central to 60s south —→																							
10	22	24	24	24	26	28	24	26	28	28	30	30	28	30	30	28	30	32	28	30	32	36	42	40
11	26	26	26	30	30	30	28	28	28	32	32	32	32	32	32	32	32	32	32	32	32	40	mid 40s	mid 40s
12	34	34	34	38	38	38	38	38	38	38	38	38	38	38	38	42	42	42	42	42	42	in 50s		
13	← ranging from 40s north to 50s central and south ——→																							
14	← " " " " and 60s south —→																							
15	36	36	[illegible]	40	40	[illegible]	40	40	[illegible]	44	44	[illegible]	44	44	[illegible]	44	44	[illegible]	44	44	[illegible]	[illegible]	50s	[illegible]
16	25	25	25	25	27	27	29	30	30	29	30	30	29	30	30	29	30	30	29	30	30	35	35	[illegible]
17	24	18	18	24	22	22	24	22	22	22	23	24	22	23	24	22	23	24	22	23	24	33	33	33
18	20	20	20	22	22	22	22	22	22	20	24	24	24	24	24	20	24	24	24	24	24	30	30	30
19	16	[illegible]	[illegible]	18	18	18	18	18	18	21	20	20	21	20	20	21	20	20	21	20	20	26	26	26
20	22	24	24	20	26	26	24	26	26	26	28	28	26	28	28	26	28	28	26	28	28	29	30	30
21	24	24	22	26	26	28	26	26	28	28	28	28	28	28	28	28	28	28	28	28	28	32	32	32
22	24	24	24	26	26	28	26	26	28	30	28	28	30	28	28	30	28	28	30	28	28	35	32	32
23	← from upper 30s north to the 40s central and near 50 south —→																							
24	← " 40s north to 50 central and south ——→																							
25	28	28	28	32/28	32/28	32/28	32/28	32/28	32/28	34/32	34/32	34/32	34/32	34/32	34/32	34/32	34/32	34/32	34/32	34/32	34/32	42	42	42
26	30	34	32	34	36	34	34	36	34	36	36	34	36	36	34	36	36	34	36	36	34	50	50	45
27	← mostly 40s all zones, ~~almost~~ mainly 50s in zone 22 ——→																							
28	28	28	28	32	32	32	32	32	32	36	36	36	36	36	36	36	36	36	36	36	36	60	60	60
29	27/15	27/15	27/15	27/25	27/25	27/15	27/15	27/15	27/13	29/27	29	29	29/27	29	29	29/27	34	34	29/27	30	30	38	40	40
30	← ranging from the mid 30s north to the 40s central and the 50s south																							
31	[illegible]	[illegible]	[illegible]	34	34	34	34	34	32	40	38	38	40	38	38	40	38	38	40	38	38	50	50	50

Example: 27/15 forecast temp / precip

Table C.3 NWS Forecasted Temperatures (Minimum) for February 1977

DATE	Zone 9			Zone 11			Zone 12			Zone 13			Zone 14			Zone 15			Zone 16			Zone 22		
	10:15 AM	4:15 PM	10:15 PM	10:15 AM	4:15 PM	10:15 PM	10:15 AM	4:15 PM	10:15 PM	10:15 AM	4:15 PM	10:15 PM	10:15 AM	4:15 PM	10:15 PM	10:15 AM	4:15 PM	10:15 PM	10:15 AM	4:15 PM	10:15 PM	10:15 AM	4:15 PM	10:15 PM
1	28		34	30	30	36	30	30	30	34	34	38	34	34	38	34	34	38	34	34	38	40's - 50's		
2	Mid to Upper 40's									In The 50's												60's		
3	Ranging from near 40 North to 50's Central and 60's South																							
4	Ranging from 40's North to 50's Central and 60's South																							
5	28	28	28	32	32	32	32	32	32	36	36	36	36	36	36	36	36	36	36	36	36	40's	40's	40's
6	25	28		32	32		32	32		36/34	36/34		36/34	36/34		36/34	36/34		36/34	36/34		40's	40's	
7	32	32		34/32	34		34/32	34		36	36		36	36		36	36		36	36		40's	40's	
8	lowest temperature ranging from 30's North 40's Central 50's South																							
9			32	Mid 40's						Mid to Upper 40's												Mainly 50's		
10	30	30	30	Ranging from Near 40 North Central to 50's South Central 60's extreme South																				
11	Ranging from near 40 north to 50's Central and 60's Southeast Coast →																							
12	Lowest 50's North to 60's South																							
13	Lowest [illegible] North to 60's South																							
14			36	Range from 40's Central to 60's South																				
15	30	30	30	34	34	34	34	34	34	38	38	38	38	38	38	38	38	38	38	38	38	50's →		
16	26		26	28		28/26	28		28/26	31		31/28	31		31/28	31		31/28	31		31/28	42		42
17	26	26	26	28/26	28/26	28/26	28/26	28/26	28/26	28/26	28/26	28/26	28/26	28/26	28/26	28/26	28/26	28/26	28/26	28/26	28/26	30	30	30
18	← Lowest temp in the 40's except low 50's southeast coast →																							
19	← in the 40's →															← in the 50's →								
20	28	28	28	30	30	30	30	30	30	32	32	32	32	32	32	32	32	32	32	32	32	40's	40's	40's
21	32	30/28	36/28	36/32	32	32/28	32/28	32/28	32/28	36/32	32	32	32/28	32/28	32/28	32/28	32/28	32/28	32/28	32/28	32/28	36	36	36
22	← ranging from 40's north and central zones to the 50's southeast coast																							
23	← near 50 north to 60's south → 60's →																							
24	← ranging from 40's north to 50's south																							
25	← Ranging from 40's North to 50's Central to 60's South																							
26	← Lows in the 50's and 60's																							
27	32	36	36	40	40	40	40	40	40	44	44	44	44	44	44	44	44	44	44	44	44	50's →		
28	30	30	30	34/32	34/32	34/32	34/32	34/32	32	36	36	36	36	36	36	36	36	36	36	36	36	40's →		

Table C.4 NWS Forecasted Temperatures (Minimum) for March 1977

	[illegible]			Zone 11			Zone 12			Zone 13			Zone 14			Zone 15			Zone 16			Zone 22		
	[illegible] Am	[illegible] Pm	[illegible]:15 Pm	10:15 Am	4:15 Pm	10:15 Pm	10:15 Am	4:15 Pm	10:15 Pm	10:15 Am	4:15 Pm	10:15 Pm	10:15 Am	4:15 Pm	10:15 Pm	10:15 Am	4:15 Pm	10:15 Pm	10:15 Am	4:15 Pm	10:15 Pm	10:15 Am	4:15 Pm	10:15 Pm
1	3[illegible]	24	8	34/32	34/[illegible]	34/32	[illegible] 32	34/32	[illegible]/32	38/34	36/[illegible]	[illegible]4/[illegible]4	38/34	36/34	34/[illegible]	34/34	3[illegible]/34	[illegible]/34	36/34	[illegible]/34	36/24	40's →		
2	← Ranging [illegible] south →																							
3	← Ranging from 50's north to 60's south →																							
4	← Ranging from 60's north to 70's South →																							
5	← Ranging from 50's north [illegible] 70's South →																							
6	← Ranging from mid 40's to 60's South →																							
7	[illegible]	36	[illegible]	40	40	40	40	40	40	Mostly 40's to lower 50's												50's		
8	33			Mostly 40's						Mostly 40's to lower 50's												50's		
9	← [illegible] from 50's north and 60's South →																							
10	← Ranging from [illegible] north to 70's South →																							
11	← Ranging [illegible] 70's [illegible] South →																							
12	← [illegible] north to [illegible] 60's [illegible] South →																							
13	← Ranging from 50's north to 60's central and [illegible] 70's South →																							
14	← Ranging from 50's north 60's Central and [illegible] 70's South →																							
15	← Ranging from 50's north to 60's central to [illegible] South →																							
16	← Ranging from 50's north to 60's South [illegible] →																							
17	← Ranging from 50's north to 60's South →																							
18	← Ranging from 50's north to 60's South →																							
19	← Ranging from 60's north to 70's South →																							
20	← Ranging from 50's north to 70's South →																							
21	← Ranging from 60 north to 70's South →																							
22	[illegible]	36	36	← Ranging from 40's north to 60's South →																				
23	36	36	36	← Ranging from 40's to 60's South →																				
24	← Ranging from 40's north to 60's South →																							
25	← Ranging from 40's north to 60's South →																							
26	← Ranging from 50's north to [illegible] 70's South →																							
27	← Ranging from high 50's north to 70's South →																							
28	← Ranging from upper 50's north to 70's South →																							
29	← [illegible] from 60's north to 70's South →																							
30	← [illegible] from 60's north to 70's South →																							
31																								

Table C.5 Shift Temperatures Between {NWS Thermometers and Sample Groves}

	NWS Thermometers	Grove Numbers														County: Orange							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Ridge	2 Templeton																						
	3 Polk City																						
	5 Dundee																						
	6 Prine																						
	7 Highland City																						
	9 Lake Garfield																						
	10 Lake Garfield N.																						
	11 Babson Park																						
	12 Frostproof W.																						
	13 Highland Lake																						
	14 Timberlake																						
	19 Davenport																						
	20 Lake Hamilton																						
	65 Avon Park																						
	67 Pinecrest																						
	68 Lake Placid																						
Bartow	21 Tiger Bay																						
	22 Hatchet Hill																						
	56 Wauchula																						
	58 Lily																						
	64 Mammoth																						
West Coast	60 Lake Fern																						
	61 Ruskin																						
	62 Hillsborough																						
	63 Lutz																						
Gains-ville	25 Evinston																						
	29 Weirsdale																						
	31 E. Weirsdale																						
Orlando	37 Umatilla																					+2	
	38 Tavares Ag.																						
	41 Plymouth															-2	+2	+2	-1	-1	-1		
	42 Howey																						
	44 Groveland																						
	45 Monteverde																						
	46 Avalon	+1	+1	+1	-1	+3	-1	-1	-1	+2	+2	+2	+1	+1	+1								-1
	47 Hi-Acres																						
	48 Kissimmee																						

Table C.5 (continued) Shift Temperatures Between {NWS Thermometers and Sample Groves}

	NWS Thermometers	Grove Numbers																	County: Orange & Osceola				
		23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39		1	2	3	4
Ridge	2 Templeton																						
	3 Polk City																						
	5 Dundee																						
	6 Prine																						
	7 Highland City																						
	9 Lake Garfield																						
	10 Lake Garfield N.																						
	11 Babson Park																						
	12 Frostproof W.																						
	13 Highland Lake																						
	14 Timberlake																						
	19 Davenport																						
	20 Lake Hamilton																						
	65 Avon Park																						
	67 Pinecrest																						
	68 Lake Placid																						
Bartow	21 Tiger Bay																						
	22 Hatchet Hill																						
	56 Wauchula																						
	58 Lily																						
	64 Mammoth																						
West Coast	60 Lake Fern																						
	61 Ruskin																						
	62 Hillsborough																						
	63 Lutz																						
Gainsville	25 Evinston																						
	29 Weirsdale																						
	31 E. Weirsdale																						
Orlando	37 Umatilla																						
	38 Tavares Ag.																						
	41 Plymouth									-1	+1		+2										
	42 Howey																						
	44 Groveland																						
	45 Monteverde																						
	46 Avalon	-1	+2	+2																			
	47 Hi-Acres				+4	+4	+4	+4	+4														
	48 Kissimmee														-1	-1	-1			-3	-3	-3	-3

Table C.5 (continued) Shift Temperatures Between {NWS Thermometers and Sample Groves}

	NWS Thermometers	Grove Numbers														County: Lake							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Ridge	2 Templeton																						
	3 Polk City																						
	5 Dundee																						
	6 Prine																						
	7 Highland City																						
	9 Lake Garfield																						
	10 Lake Garfield N.																						
	11 Babson Park																						
	12 Frostproof W.																						
	13 Highland Lake																						
	14 Timberlake																						
	19 Davenport																						
	20 Lake Hamilton																						
	65 Avon Park																						
	67 Pinecrest																						
	68 Lake Placid																						
Bartow	21 Tiger Bay																						
	22 Hatchet Hill																						
	56 Wauchula																						
	58 Lily																						
	64 Mammoth																						
West Coast	60 Lake Fern																						
	61 Ruskin																						
	62 Hillsborough																						
	63 Lutz																						
Gains-ville	25 Evinston																						
	29 Weirsdale																						
	31 E. Weirsdale																						
Orlando	37 Umatilla															+2	+0			+2	+2	-2	-2
	38 Tavares Ag.						-2	-2	-2														
	41 Plymouth																						
	42 Howey																	+3	+3				
	44 Groveland									-2													
	45 Monteverde										+1	+1	+1	-3	+1								
	46 Avalon																						
	47 Hi-Acres	-1	-1	-2	-1	-1																	
	48 Kissimmee																						

Table C.5 (continued) Shift Temperatures Between {NWS Thermometers and Sample Groves}

	NWS Thermometers	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
		Grove Numbers															County: Lake						
Ridge	2 Templeton																						
	3 Polk City																						
	5 Dundee																						
	6 Prine																						
	7 Highland City																						
	9 Lake Garfield																						
	10 Lake Garfield N.																						
	11 Babson Park																						
	12 Frostproof W.																						
	13 Highland Lake																						
	14 Timberlake																						
	19 Davenport																						
	20 Lake Hamilton																						
	65 Avon Park																						
	67 Pinecrest																						
	68 Lake Placid																						
Bartow	21 Tiger Bay																						
	22 Hatchet Hill																						
	56 Wauchula																						
	58 Lily																						
	64 Mammoth																						
West Coast	60 Lake Fern																						
	61 Ruskin																						
	62 Hillsborough																						
	63 Lutz																						
Gains-ville	25 Evinston																						
	29 Weirsdale																						
	31 E. Weirsdale																						
Orlando	37 Umatilla																						
	38 Tavares Ag.																						
	41 Plymouth																						
	42 Howey	+0	+0	+2	+2	+2	+2	+2										+3	+3	+3	+3		
	44 Groveland								-2	-2	+0	+0	+4	+4	+4	+4	+4						
	45 Monteverde																						
	46 Avalon																						
	47 Hi-Acres																						
	48 Kissimmee																						

Table C.5 (continued) Shift Temperatures Between { NWS Thermometers and Sample Groves

	NWS Thermometers	Grove Numbers															County: Lake						
		45	46	47	48	49	50	51															
Ridge	2 Templeton																						
	3 Polk City																						
	5 Dundee																						
	6 Prine																						
	7 Highland City																						
	9 Lake Garfield																						
	10 Lake Garfield N.																						
	11 Babson Park																						
	12 Frostproof W.																						
	13 Highland Lake																						
	14 Timberlake																						
	19 Davenport																						
	20 Lake Hamilton																						
	65 Avon Park																						
	67 Pinecrest																						
	68 Lake Placid																						
Bartow	21 Tiger Bay																						
	22 Hatchet Hill																						
	56 Wauchula																						
	58 Lily																						
	64 Mammoth																						
West Coast	60 Lake Fern																						
	61 Ruskin																						
	62 Hillsborough																						
	63 Lutz																						
Gains-ville	25 Evinston																						
	29 Weirsdale																						
	31 E. Weirsdale																						
Orlando	37 Umatilla																						
	38 Tavares Ag.																						
	41 Plymouth																						
	42 Howey						+3	+2															
	44 Groveland																						
	45 Monteverde																						
	46 Avalon																						
	47 Hi-Acres	-1	-1	-1	-1	-1																	
	48 Kissimmee																						

Table C.5 (continued) Shift Temperatures Between {NWS Thermometers and Sample Groves}

	NWS Thermometers	Grove Numbers 1	2	3	4	5	8	9			10	11	12	13	14	15	16	County: Marion					
Ridge	2 Templeton																						
	3 Polk City																						
	5 Dundee																						
	6 Prine																						
	7 Highland City																						
	9 Lake Garfield																						
	10 Lake Garfield N.																						
	11 Babson Park																						
	12 Frostproof W.																						
	13 Highland Lake																						
	14 Timberlake																						
	19 Davenport																						
	20 Lake Hamilton																						
	65 Avon Park																						
	67 Pinecrest																						
	68 Lake Placid																						
Bartow	21 Tiger Bay																						
	22 Hatchet Hill																						
	56 Wauchula																						
	58 Lily																						
	64 Mammoth																						
West Coast	60 Lake Fern																						
	61 Ruskin																						
	62 Hillsborough																						
	63 Lutz																						
Gains-ville	25 Evinston	+4	+4	+1	+3	+3																	
	29 Weirsdale						-3	-3							-1	-1	-1						
	31 E. Weirsdale										+1	+1	+1	-1									
Orlando	37 Umatilla																						
	38 Tavares Ag.																						
	41 Plymouth																						
	42 Howey																						
	44 Groveland																						
	45 Monteverde																						
	46 Avalon																						
	47 Hi-Acres																						
	48 Kissimmee																						

Table C.5 (continued) Shift Temperatures Between NWS Thermometers and Sample Groves

	NWS Thermometers	Grove Numbers 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
Ridge	2 Templeton																						
	3 Polk City																						
	5 Dundee																						
	6 Prine																						
	7 Highland City																						
	9 Lake Garfield																						
	10 Lake Garfield N.																						
	11 Babson Park																						
	12 Frostproof W.																						
	13 Highland Lake																						
	14 Timberlake															+5							
	19 Davenport																						
	20 Lake Hamilton																						
	65 Avon Park																						
	67 Pinecrest																						
	68 Lake Placid																						
Bartow	21 Tiger Bay																						
	22 Hatchet Hill																						
	56 Wauchula																						
	58 Lily																						
	64 Mammoth																						
West Coast	60 Lake Fern							-2	-3	-2	+0												
	61 Ruskin											+2					+0	+0	+0	-1	-1		
	62 Hillsborough																						
	63 Lutz	-2											+2	+2	+2								
Gains-ville	25 Evinston																						
	29 Weirsdale																						
	31 E. Weirsdale																						
Orlando	37 Umatilla																						
	38 Tavares Ag.																						
	41 Plymouth																						
	42 Howey																						
	44 Groveland																						
	45 Monteverde																						
	46 Avalon																						
	47 Hi-Acres																						
	48 Kissimmee																						

County: Hillsborough

Table C.5 (continued) Shift Temperatures Between {NWS Thermometers and Sample Groves}

	NWS Thermometers	Grove Numbers															County: Highlands						
		1	2	3	4	5	6	7	8	9	10	11	12	13									
Ridge	2 Templeton																						
	3 Polk City																						
	5 Dundee																						
	6 Prine																						
	7 Highland City																						
	9 Lake Garfield																						
	10 Lake Garfield N.																						
	11 Babson Park																						
	12 Frostproof W.																						
	13 Highland Lake																						
	14 Timberlake																						
	19 Davenport																						
	20 Lake Hamilton																						
	65 Avon Park				-2	+0	-2																
	67 Pinecrest		-2																				
	68 Lake Placid	-1		+0							+1	+1	+0	+0									
Bartow	21 Tiger Bay																						
	22 Hatchet Hill																						
	56 Wauchula																						
	58 Lily																						
	64 Mammoth																						
West Coast	60 Lake Fern																						
	61 Ruskin																						
	62 Hillsborough																						
	63 Lutz																						
Gains-ville	25 Evinston																						
	29 Weirsdale																						
	31 E. Weirsdale																						
Orlando	37 Umatilla																						
	38 Tavares Ag.																						
	41 Plymouth																						
	42 Howey																						
	44 Groveland																						
	45 Monteverde																						
	46 Avalon																						
	47 Hi-Acres																						
	48 Kissimmee																						

Table C.5 (continued) Shift Temperatures Between {NWS Thermometers and Sample Groves}

Grove Numbers — County: Hardee

	NWS Thermometers	1	2	3	4	5	6																
Ridge	2 Templeton																						
	3 Polk City																						
	5 Dundee																						
	6 Prine																						
	7 Highland City																						
	9 Lake Garfield																						
	10 Lake Garfield N.																						
	11 Babson Park																						
	12 Frostproof W.																						
	13 Highland Lake																						
	14 Timberlake																						
	19 Davenport																						
	20 Lake Hamilton																						
	65 Avon Park				-2	-2																	
	67 Pinecrest																						
	68 Lake Placid																						
Bartow	21 Tiger Bay																						
	22 Hatchet Hill																						
	56 Wauchula		-2				-2																
	58 Lily			-2																			
	64 Mammoth																						
West Coast	60 Lake Fern																						
	61 Ruskin																						
	62 Hillsborough																						
	63 Lutz																						
Gains-ville	25 Evinston																						
	29 Weirsdale																						
	31 E. Weirsdale																						
Orlando	37 Umatilla																						
	38 Tavares Ag.																						
	41 Plymouth																						
	42 Howey																						
	44 Groveland																						
	45 Monteverde																						
	46 Avalon																						
	47 Hi-Acres																						
	48 Kissimmee																						

Table C.5 (continued) Shift Temperatures Between {NWS Thermometers and Sample Groves}

Region	NWS Thermometers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
		Grove Numbers															County: Polk						
Ridge	2 Templeton																						
	3 Polk City																+3	+3	+3				
	5 Dundee																						
	6 Prine			+3	+3	+3			+3			+2	+3	+3	+3	+3				+3	+3	+3	+3
	7 Highland City																						
	9 Lake Garfield																						
	10 Lake Garfield N.																						
	11 Babson Park																						
	12 Frostproof W.																						
	13 Highland Lake																						
	14 Timberlake																						
	19 Davenport	+2	+3							+2	+2												
	20 Lake Hamilton																						
	65 Avon Park																						
	67 Pinecrest																						
	68 Lake Placid																						
Bartow	21 Tiger Bay																						
	22 Hatchet Hill																						
	56 Wauchula																						
	58 Lily																						
	64 Mammoth						+2	+2															
West Coast	60 Lake Fern																						
	61 Ruskin																						
	62 Hillsborough																						
	63 Lutz																						
Gains-ville	25 Evinston																						
	29 Weirsdale																						
	31 E. Weirsdale																						
Orlando	37 Umatilla																						
	38 Tavares Ag.																						
	41 Plymouth																						
	42 Howey																						
	44 Groveland																						
	45 Monteverde																						
	46 Avalon																						
	47 Hi-Acres																						
	48 Kissimmee																						

Table C.5 (continued) Shift Temperatures Between {NWS Thermometers and Sample Groves}

	NWS Thermometers	Grove Numbers															County: Polk						
		23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
Ridge	2 Templeton													+2	+2	+0	+2		+2				
	3 Polk City																	+2					
	5 Dundee				-3															-3	-1		
	6 Prine	+3																					
	7 Highland City																						
	9 Lake Garfield											+2											
	10 Lake Garfield N.									-2	-2		-4										
	11 Babson Park		-3																				
	12 Frostproof W.						-1																
	13 Highland Lake					+3																	
	14 Timberlake																						
	19 Davenport																						
	20 Lake Hamilton																					+2	+2
	65 Avon Park																						
	67 Pinecrest																						
	68 Lake Placid																						
Bartow	21 Tiger Bay																						
	22 Hatchet Hill																						
	56 Wauchula																						
	58 Lily																						
	64 Mammoth			+2				+2	+2														
West Coast	60 Lake Fern																						
	61 Ruskin																						
	62 Hillsborough																						
	63 Lutz																						
Gains-ville	25 Evinston																						
	29 Weirsdale																						
	31 E. Weirsdale																						
Orlando	37 Umatilla																						
	38 Tavares Ag.																						
	41 Plymouth																						
	42 Howey																						
	44 Groveland																						
	45 Monteverde																						
	46 Avalon																						
	47 Hi-Acres																						
	48 Kissimmee																						

Table C.5 (continued) Shift Temperatures Between {NWS Thermometers and Sample Groves}

	NWS Thermometers	Grove Numbers														County: Polk							
		45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66
Ridge	2 Templeton																						
	3 Polk City								+3	+3													
	5 Dundee																						
	6 Prine	+3																					
	7 Highland City																						
	9 Lake Garfield											+4											
	10 Lake Garfield N.																						
	11 Babson Park					-3																	
	12 Frostproof W.																						
	13 Highland Lake																						
	14 Timberlake																						
	19 Davenport																						
	20 Lake Hamilton		+2					+2											+2				
	65 Avon Park																						
	67 Pinecrest																						
	68 Lake Placid																						
Bartow	21 Tiger Bay												+3	+3	+3								
	22 Hatchet Hill										-3											-3	-3
	56 Wauchula																						
	58 Lily																						
	64 Mammoth			+2	+2		+2									-1	-1						
West Coast	60 Lake Fern																						
	61 Ruskin																						
	62 Hillsborough																				-3		
	63 Lutz																						
Gainsville	25 Evinston																						
	29 Weirsdale																						
	31 E. Weirsdale																						
Orlando	37 Umatilla																						
	38 Tavares Ag.																						
	41 Plymouth																						
	42 Howey																						
	44 Groveland																						
	45 Monteverde																						
	46 Avalon																						
	47 Hi-Acres																						
	48 Kissimmee																	-3		-3			

Table C.5 (continued) Shift Temperatures Between {NWS Thermometers and Sample Groves}

	NWS Thermometers	Grove Numbers															County: Polk						
		67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88
Ridge	2 Templeton						-1																
	3 Polk City	+0		+3																			
	5 Dundee																						
	6 Prine																						
	7 Highland City							+2	+3	+2	+2	+2	+2	+2	+2	+2							
	9 Lake Garfield																						
	10 Lake Garfield N.																						
	11 Babson Park																					-2	
	12 Frostproof W.																						
	13 Highland Lake																						
	14 Timberlake																						
	19 Davenport		-1																				
	20 Lake Hamilton																						
	65 Avon Park																						
	67 Pinecrest																						
	68 Lake Placid																						-3
Bartow	21 Tiger Bay																						
	22 Hatchet Hill																						
	56 Wauchula				-3	-3																	
	58 Lily																				+0		
	64 Mammoth																+6	+6	+4	+4			
West Coast	60 Lake Fern																						
	61 Ruskin																						
	62 Hillsborough																						
	63 Lutz																						
Gains-ville	25 Evinston																						
	29 Weirsdale																						
	31 E. Weirsdale																						
Orlando	37 Umatilla																						
	38 Tavares Ag.																						
	41 Plymouth																						
	42 Howey																						
	44 Groveland																						
	45 Monteverde																						
	46 Avalon																						
	47 Hi-Acres																						
	48 Kissimmee																						

Table C.5 (continued) Shift Temperatures Between {NWS Thermometers and Sample Groves}

	NWS Thermometers	Grove Numbers																County: Polk				
		89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109
Ridge	2 Templeton																					
	3 Polk City																					
	5 Dundee																					
	6 Prine																					
	7 Highland City																					
	9 Lake Garfield																				+1	+1
	10 Lake Garfield N.																					
	11 Babson Park			-2																		
	12 Frostproof W.																					
	13 Highland Lake																					
	14 Timberlake																					
	19 Davenport																	-1				
	20 Lake Hamilton																					
	65 Avon Park				-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2					
	67 Pinecrest																					
	68 Lake Placid	-3	-3																			
Bartow	21 Tiger Bay																					
	22 Hatchet Hill																					
	56 Wauchula																					
	58 Lily																					
	64 Mammoth																		+0			
West Coast	60 Lake Fern																					
	61 Ruskin																					
	62 Hillsborough																			-3		
	63 Lutz																					
Gainsville	25 Evinston																					
	29 Weirsdale																					
	31 E. Weirsdale																					
Orlando	37 Umatilla																					
	38 Tavares Ag.																					
	41 Plymouth																					
	42 Howey																					
	44 Groveland																					
	45 Monteverde																					
	46 Avalon																					
	47 Hi-Acres																					
	48 Kissimmee																					

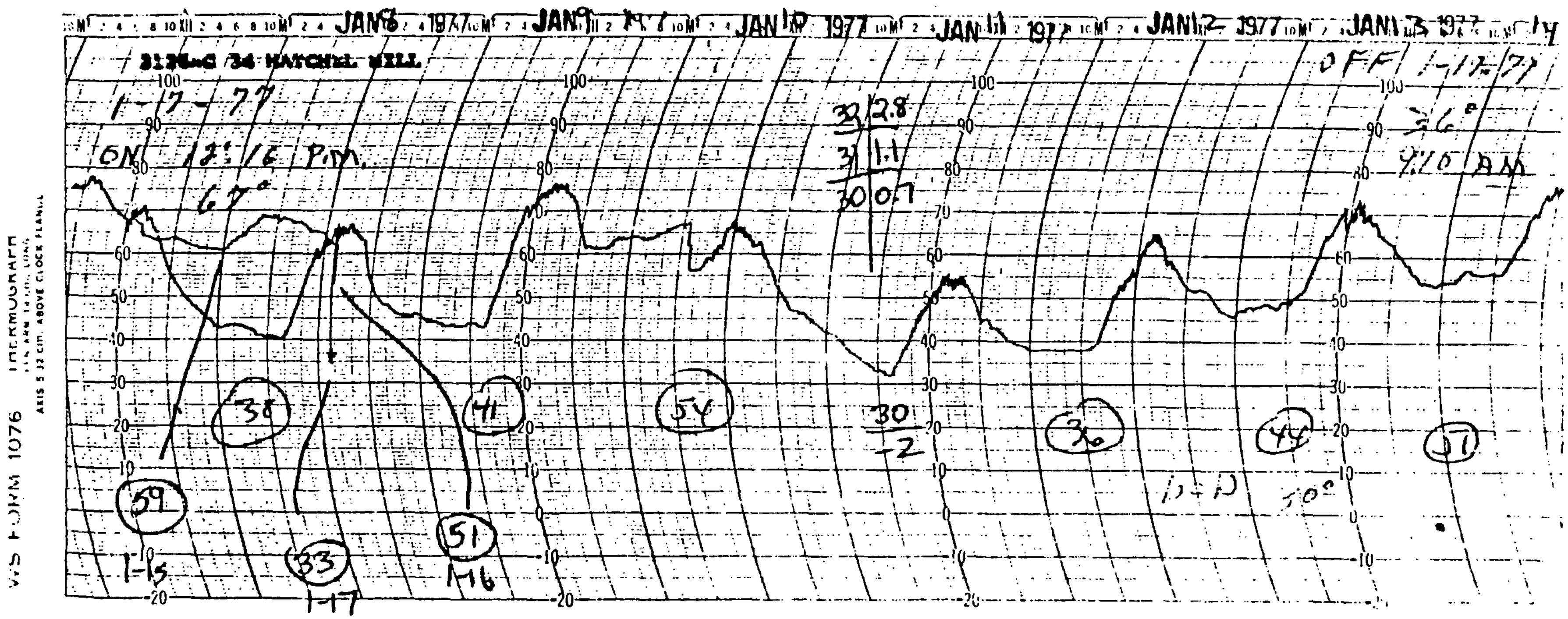

Figure C.2 Typical Thermograph Record

APPENDIX D

ANALYSIS OF SEVERITY FOR 30 YEARS TEMPERATURE DATA

APPENDIX D

30-YEAR WEATHER ANALYSIS

In order to establish the benefits which may result from improved meteorological forecasts, made possible by SMS/GOES data and the University of Florida temperature forecasting model, protection costs and crop losses associated with the test and control groups must be compared. This comparison presumes that the actual weather conditions and their impact are similar for both the control and test group years and therefore the costs and losses are primarily due to differences in the timeliness and accuracy of the information. However, if in fact the weather conditions differ between years, then the difference between the control and test groups' costs and losses may be due almost entirely to the difference in the weather. In order to prevent this from biasing the calculation of the benefits, it is necessary to "normalize" the results of the control and test groups to a standard, normal or average set of weather conditions (temperatures). To achieve this it was necessary to obtain several years of actual observed temperature data and simulate the impact of these temperatures.

The NWS provided ECON with a computer tape which contains 30 years of temperature data. The tape consists of temperature profiles for all of the nights, from November 1 to April 1, on which the observed temperature fell below 32°F. These profiles were recorded at 72 thermometers, from 1937 to 1967. Each record represents one night at one thermometer. There are over 18,000 records on the tape. The records are organized by thermometer, in chronological order. Each record contains the thermometer number, township, range, calendar date, minimum observed temperature for that night, and the durations below 32°F measured at each one-degree interval. Figure D.1 presents a sample of this data. The records are interpreted as follows. Consider, for example, the first record in Weirsdale:

01724202337112131032010

Col	1	Blank
	2-5	Thermometer ID
	6-7	Township
	8-9	Range
	10-11	Last two digits of year
	12-13	Month
	14-15	Day
	16-17	Minimum temperature that night
	18-57	Durations in F3.1 format
	58-80	Durations in F2.1 format

The thermometer ID is 1724

The township is 20

The range is 23

The year is 1937

The month is November

The date is the 21

The minimum recorded temperature is 31°F

All the records in this group have the same thermometer ID, township, and range. The next record:

01724202337120725100090080068055045020005

```
FILE: TAPEDUMP OUTPUT    1    PRINCETON UNIVERSITY TIME-SHARING SYSTEM

01724102105012632003
0172410210512193003902015
01724102105122529092040082030
01724102105122030030011000
01724102104011474113102090087072042047020010
01724102104011527142122095040021011
01724102104021231010010
0172410210501172010710207030050050 1
01724102105011020131120112096002501500
01724102105012932007
01724102105022031112009
0172410210601280030015007
01724102106013025070008001050044040020013
0172410210601312315014512911 1030740020420223000
0172410210600204300430021007
01724102106020531032010
017241021060200290703050042021
01724102106122531020006
0172410210702202009709000707305030020005
017241021070227310120010

1724-6    WEIRSDALE             GAINESVILLE DIS AVG LOW              0297
01724202337112131032010
0172420233712072510009008006055045021005
0172420233712062213212612517211511101000600600 4002
0172420233601103220
017242023360127260303009120070 02
0172420233601282707000004501200 0 1
017242023360129240000005705204004002202002
017242023360722032007
01724202336121124113100100090000700050040010
01724202336122032 2 0
0172420233601221290150100 0 002
0172420233901202900004703000 5
01724202339012131025006
0172420233901202605004504903 023
0172420233902242604204003502001200 6003
0172420233941243 0 0
0172420233911262050 07607000 3020 11 07
01724202339112931040015
0172420233912043 2 005
01724202339121531012003
0172420233912223005003701 2
01724202339123127 9307 05505042 00
0172402340010426 9200307005502
017242023400117260930600430220 1 0
0172420234001163003202 3005
0172420234001202010006700505 0400 2 7012
017242023400121310 2010
0172420234001 43 07
01724202340012529053032013002
017242023400120270800700580040022006
017242023400127221501271121000600505 7043027022006
01724202340012823155147135117002072057023018005
017242023400125101 2 12211011511010510209009008800200700 32210
```

Figure D.1 Sample of NWS Temperature Data Records is for the night of December 7, 1937. The minimum observed temperature was 25°F and the temperature was below 32°F for ten hours.

Two problems were encountered with this tape. At the beginning of the set of records for each thermometer there is a descriptive record (see Data Sample). This descriptive record contained the thermometer number, thermometer name, and the number of records for that thermometer. The number of records was incorrect for several thermometers which made it impossible to use the data. To correct this a program was written which read the tape, calculated the correct number of records, and substituted the correct value in place of the incorrect value.

Another problem was that for some records the duration increased as the temperature fell. The durations recorded on the tape were the number of hours at <u>and</u> below the temperature. Therefore, it is not possible for the durations to increase as the temperature falls. The records with increasing durations were not used in this weather analysis.

Once the temperature profile is established its impact on fruit and tree damage is established in terms of a severity index. The severity index takes into account the duration of temperatures below 32°F and the impact of this temperature duration on fruit and trees as indicated in Table D.1. In Table D.1, each column heading is the duration at a temperature, and the row headings are the temperatures. By moving down the temperature values to the appropriate one, and then across to the duration at that temperature, the measure of severity is found. The records on the tape are the duration below specific temperatures. By subtracting the durations below each temperature, the duration at a temperature is found.

Table D.1 Severity Measure of Frost/Freeze*

Temp. [°F]	Degree Hours Under A Given Temperature [hrs.]**											
	1	2	3	4	5	6	7	8	9	10	11	12
28	0/0	0/0	0/0	0/0	.5/0	.75/0	1/0	1.25/0	1.5/0	1.75/0	2/0	2/0
27	0/0	1/0	2/0	2/0	3/0	4/0	4.25/0	4.5/0	4.75/0	5/0	5/0	5/0
26	0/0	1/0	2/0	3/0	4/0	4.3/0	4.6/0	5/0	5/0	5/0	5/0	5.5/0
25	1/0	2/0	3/0	4/0	4.5/0	5/0	5.2/0	5.4/0	5.5/0	5.7/0	5.85/0	6/0
24	1.5/0	2.4/1	4/1	4/1	4.5/1	5/1	5.3/1	5.7/1	6/2	6.5/2	7/2	8/2
23	2/1	2.7/1	4/1	4.1/1.2	5/1.5	6/1.75	7/2	7.5/2.2	8/2.4	9/2.6	10/2.8	10/3
22	2.5/1.3	3/1.6	4/1.8	5.5/1.9	7/2	8/2.3	10/2.6	10/2.9	10/3.2	10/3.5	10/3.8	10/4
21	3/2	3.5/2	5/2	6.5/2	8/3	10/3	10/3	10/3	10/3.5	10/4	10/4.5	10/5
20	4/2.5	5/2.75	6/3	8/3.3	10/3.6	10/4	10/4.3	10/4.6	10/5	10/5.6	10/6.3	10/7
19	4.5/3	6/4	7.5/5	9/5.5	10/6	10/6.3	10/6.6	10/7	10/7.5	10/8	10/9	10/10
18	5/4	7/5	9/6.5	10/8	10/9	10/10	10/10	10/10	10/10	10/10	10/10	10/10

*Estimates provided by Dr. J. Gerber and Dr. J. Bartholic of the University of Florida.

**Note: Measure of severity for fruit / measure of severity for trees
Zero(0) represents no damage or loss and ten (10) represents total loss.

The calculation of severity is as follows using the second record from the previous example, 01724202337120725100090080068055045020005. The first step is to change the duration below to the duration at the corresponding temperature. The severity associated with each duration and temperature is then found by entering Table D.1. Summing these values yields the severity for that night and is indicated below for the fruit severity calculation. The total severity is the sum of the fruit and tree severities. The tree severities. The tree severity computation is similar to that of fruit. In this example on December 7, 1937 a severity of 4.0 occurred at thermometer 1724-A.

Temperature	Durations Below	Adjusted Durations	Severity
32°F	10.0	1.0	0
31	9.0	1.0	0
30	8.0	1.2	0
29	6.8	1.3	0
28	5.5	1.0	0
27	4.5	2.5	2
26	2.0	1.5	1
25	0.5	0.5	1
		Total Fruit Severity	4.0

In order to determine the impact of temperature at a specific grove, it is necessary to adjust the temperature data to reflect the difference between the location of the grove and the thermometer. In addition, the impact varies according to the variety of citrus and harvest date. Different varieties have different susceptibility to frost damage. The threshold temperature for frost damage occurs at 28°F for Oranges, 29°F for Specialty Fruit, and 27°F for Specialty Fruit, and 27°f for Grapefruit. If the temperature falls below the threshold temperature, the fruit sustains damage based on the duration below the threshold and the minimum temperature. In addition, trees sustain damage if the temperature falls below 24°F. Table D.2 lists each grove with the corresponding control thermometer number, the adjustment factor for location, the fruit type, and the month of harvest. The fruit type is coded numerically as follows:

Code No.	Variety of Citrus
1	Early Oranges
2	Midseason Oranges
3	Valencia
4	Temples
5	Tangelos
6	Tangerines and Honey Tangerines
7	Seedy Grapefruit
8	White Seedless Grapefruit
9	Red-Pink Seedless Grapefruit
10	Other

The adjustment factor for location is needed to take into account normal differences in temperature due to elevation and proximity of bodies of water. This temperature difference is referred to as the shift temperature. The elevation of a grove is positively related to the temperature. The shift temperature, ΔT, was obtained by initially using the Bartholic and Sutherland Temperature Function, $\Delta T = 0.044 * \Delta$ Elevation, for each grove. Since groves which are near bodies of water are warmer on cold nights than groves which are not near water (due to the thermal properties of water), the shift temperature estimates required modification. The initial estimates of the shift temperatures were reviewed with Jim Georg of the NWS and were, based upon his many years of experience in forecasting temperatures in Florida, modified where necessary to take into account the effects due to proximity of water.

Table D.2 Summary of Grove-Control Thermometer Data

Grove	Control Thermometer	Shift Temperature, °F	Fruit Type	Month of Harvest
14008	1724-A	-3	1	1
14009	1724-A	0	1	1
14014	1724-A	-1	6	12
14015	1724-A	-1	2	1
14016	1724-A	-1	3	5
14010	1724-B	1	7	1
14011	1724-B	1	3	5
14012	1724-B	1	2	1
14013	1724-B	-1	3	5
12009	2225	-2	1	1
12030	2225	-2	1	1
12031	2225	-2	3	7
12032	2225	0	3	6
12033	2225	0	5	12
12034	2225	4	4	1
12035	2225	4	8	12
12036	2225	4	3	5
12037	2225	4	2	2
12038	2225	4	1	1
7015	2026-A	-2	10	10
7016	2026-A	2	2	1
7017	2026-A	2	1	1
7018	2026-A	-1	1	11
7019	2026-A	-1	3	6
7020	2026-A	-1	1	1
7031	2026-A	-1	4	2
7032	2026-A	1	3	4
7034	2026-A	2	1	11
12017	2125	3	2	1
12018	2125	3	3	5
12023	2125	0	9	12
12024	2125	0	10	10
12025	2125	2	9	12
12026	2125	2	4	1
12027	2125	2	3	6
12028	2125	2	2	2
12029	2125	2	1	4
12039	2125	3	1	12
12040	2125	3	2	2
12041	2125	3	3	5
12042	2125	3	5	12
12050	2125	3	6	2
12051	2125	2	3	4
5061	2526	-3	3	4
5063	2526	-3	10	2
7036	2526	-1	4	2
7037	2526	-1	2	3
7038	2526	-1	0	4
26001	2526	-3	8	11
26002	2526	-3	2	2
5001	2627	2	1	12
5002	2627	3	1	12
5009	2627	2	6	12
5010	2627	2	5	12
5068	2627	-1	1	12

Table D.2 Summary of Grove-Control Thermometer Data

Grove	Control Thermometer	Shift Temperature, °F	Fruit Type	Month of Harvest
5105	2827	-1	1	1
5043	2827-C	2	6	12
5044	2827-C	2	8	5
5046	2827-C	2	6	1
5051	2827-C	2	3	5
5062	2827-C	2	3	4
5033	3026	2	3	5
5055	3026	4	3	6
5108	3026	1	3	6
5109	3026	1	1	2
5092	3328	-2	3	5
5093	3328	-2	2	2
5094	3328	-2	2	2
5095	3328	-2	2	2
5096	3328	-2	2	2
5097	3328	-2	3	6
5098	3328	-2	3	6
5099	3328	-2	3	6
5100	3328	-2	2	2
5101	3328	-2	3	6
5102	3328	-2	3	6
5103	3328	-2	3	6
5104	3328	-2	2	2
27004	3328	-2	2	17
27005	3328	0	5	11
27006	3328	-2	6	10
30004	3328	-2	1	12
30005	3328	-2	3	4
5073	2924-A	2	1	12
5074	2924-A	3	9	12
5075	2924-A	2	7	3
5076	2924-A	2	6	3
5077	2924-A	2	3	5
5078	2924-A	2	8	3
5079	2924-A	2	7	3
5080	2924-A	2	2	2
5081	2924-A	2	7	2
5070	3426	-3	2	2
5071	3426	-3	3	5
30002	3426	-2	5	3
5088	3023	0	3	3
3007	2717	-2	6	4
3008	2717	-3	4	2
3009	2717	-2	5	11
3010	2717	0	6	10
5006	2928	2	8	4
5007	2928	2	3	6
5025	2928	2	3	5
5029	2928	2	3	5
5030	2928	2	3	5
5047	2928	2	3	5
5048	2928	2	3	5
5050	2928	2	3	5
5059	2928	-1	3	6
5060	2928	-1	4	2

Table D.2 Summary of Grove-Control Thermometer Data

Grove	Control Thermometer	Shift Temperature, °F	Fruit Type	Month of Harvest
5032	2928	6	2	1
5083	2928	6	3	4
5064	2928	4	3	5
5106	2928	0	3	4

From Table D.2, it can be seen that grove 14008 contains Early Oranges which are harvested in January. Recalculating the previous example to include the shift temperature of -3°F (the grove was 3°F colder on the average cold night than the NWS control thermometer 1724-A) yields the following:

Temperature	Adjusted Temperature	Adjusted Durations	Severity Fruit	Severity Tree
32°F	29	1.0	0	0
31	28	1.0	0	0
30	27	1.2	0	0
29	26	1.3	1	0
28	25	1.0	1	0
27	24	2.5	4	1.0
26	23	1.5	2.7	1.0
25	22	0.5	2.5	1.3
		Total Severity	11.2	3.3

The recomputed fruit severity is 11.2, and the tree severity is 3.3. Since the variety is Early Oranges, there is no change in the threshold of severity.

Grove 14014 contains Tangerines which requires a change in the threshhold of one degree, in addition to the one degree shift temperature. The resulting temperature profile and severity computation is as follows:

Temperature	Adjusted Temperature	Adjusted Durations	Severity Fruit	Severity Tree
32°F	30	1.0	0	0
31	29	1.0	0	0
30	28	1.2	0	0
29	27	1.3	0	0
28	26	1.0	0	0
27	25	2.5	3	0
26	24	1.0	2.4	1
25	23	0.5	2	1
		Total Severity	7.4	2

For Grove 14014 (tangerines), on December 7, 1937 a fruit severity of 7.4, and a tree severity of 2.0 are calculated.

A computer program was written to perform these calculations for the 30 years of data for each of the groves in the control group data base. The tape was read, and the groves associated with a particular thermometer were found. The minimum temperatures were corrected to reflect the fruit type, and grove location. The fruit and tree severity were then calculated. A flow chart of the program is shown in Figure D.2.

The output from the program is separated into four files by variety of citrus; early and midseason oranges comprise one output file, Valencias another, all grapefruit the third, and specialty fruit, such as temples and tangerines, the fourth. This data will, at the conclusion of the experiment, be used to establish the economic loss for a normal or standard weather pattern.

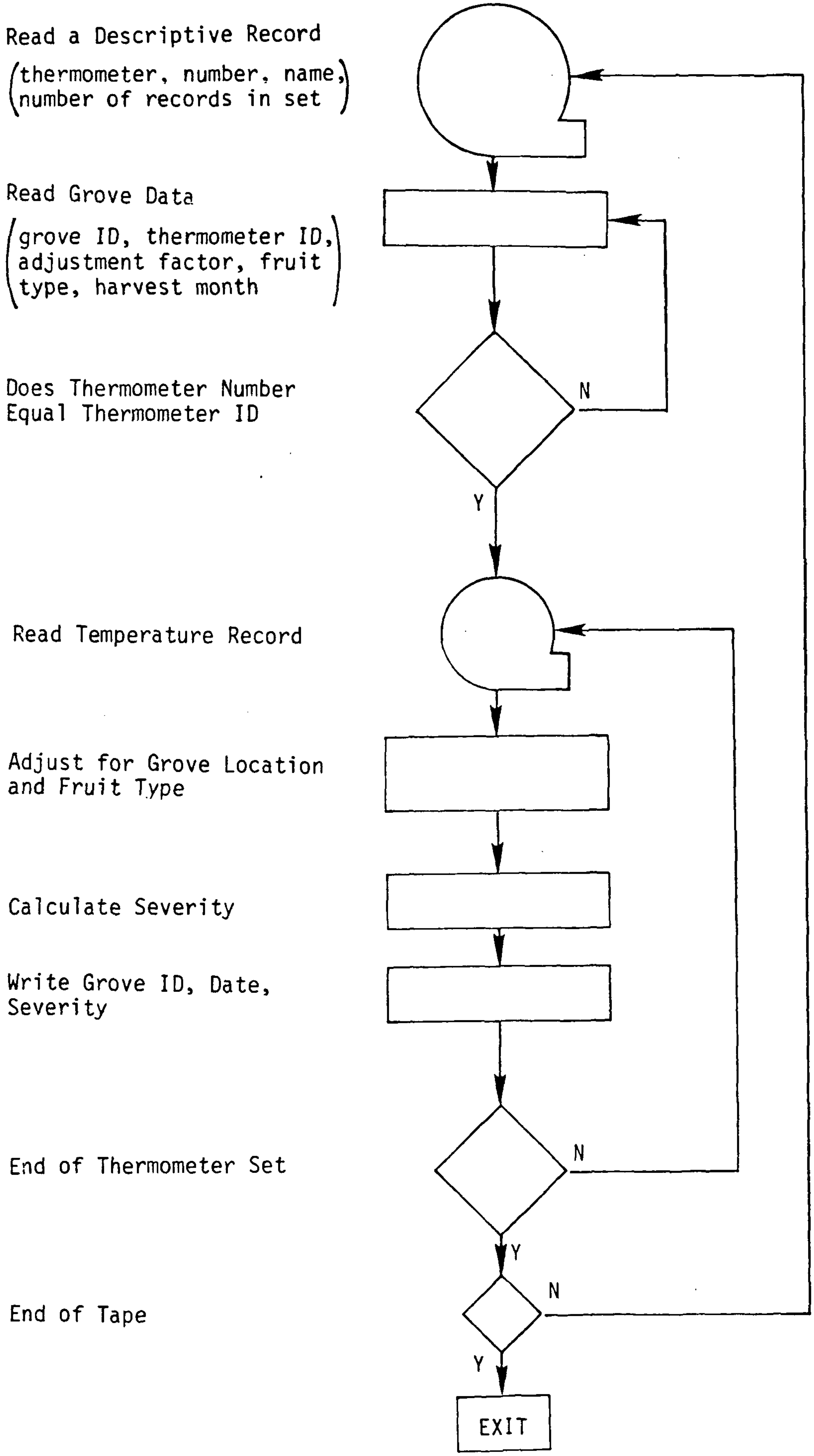

Figure D.2 Flow Chart for Computing Severity for 30 Years of Temperature Data

APPENDIX E

IMPLEMENTATION OF DATABASE PROGRAMS

APPENDIX E

IMPLEMENTATION OF DATA BASE PROGRAMS

The flow of data into ECON from the various sources in Florida has been nearly constant since the beginning of the project. The primary sources of data are:

- The green Grove Background Reports (collected between October 1976 and May 1977)
- The white grove Nightly Frost/Freeze Protection Activity Reports (collected between January and October 1977)*
- The pink Damage Reports (collected between January and October 1977)*
- Thermograph traces from the control thermometers on all cold nights (collected between November 1976 and March 1977)
- Forecasts for all nights in zones 9, 11, 13, 14 and 15 (collected between November 1976 and April 1977)
- Economic and marketing data sheets from the Florida Citrus Mutual and the Florida Canners' Association (collected weekly throughout the growing season).

As soon as the majority of a particular set of data (such as the green Grove Background Reports) had been collected, data coding and reduction were undertaken. Updates were made as needed, to correspond with corrections on existing data or new information provided.

As far as possible, data was stored with an eye to its potential uses later in the experiment, as well as data needs in the current phase. The nature of the raw data made it difficult at times to find an optimal reduced form which would be suitable for all applications. Efficiency

---

*It should be noted that the frost season extends from December through March. Thus there was a significant and unanticipated delay in obtaining much of the data from the growers--however, nearly all of the required data was provided by the growers.

of data storage and access had to be considered, as well as the need for straightforward interfaces between the various sets of data.

The data management techniques used are described in the remainder of this Appendix. Samples of the raw data inputs are included, along with detailed documentation of the coding, storage, and reduction process. Finally, the preparation of grower reports and summary statistics is discussed, with appropriate samples included.

E.1 Data Collection

E.1.1 Grower Data Forms

The distribution of the Grove Background Reports began early in the project. The bulk of the reports were completed and returned to ECON by early January, although some stragglers were received as late as June of 1977. Figure E.1 is a typical completed background report (the grove identification data has been deleted as per agreement with growers). The responses to most questions indicate that the overall design of the form was satisfactory; questions were not often misinterpreted or left blank due to undue complexity. Some difficulty was encountered with the specification of "type of wind machine" and "type of heater" with some growers providing only a brand name, rather than the hoped-for general mechnical description. Forms to be distributed in future years have been altered slightly to request more precise answers to these questions.

The first frost event which stimulated action among the sample groves occurred on the night of December 21, 1976. Soon, white activity reports began to pour in, with the intensity of the flow peaking about 3-6 weeks after the major freeze of January 17-21, 1977. White forms continued to come in throughout the spring, summer and early fall of 1977. The final

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GROVE BACKGROUND REPORT

I.D. No. X-Y

This section records some specific information about one of the groves selected for this study. Most of this information will not change from December to March. Please be as specific as possible in answering these questions.

DESCRIPTION AND CHARACTERISTICS OF THE GROVE

1. Your own grove identification: XXXXXX
2. Grove location: XX (Section) / YY (Range) / ZZ (Township)
3. Variety of Citrus grown in this grove:

   CIRCLE ONE NUMBER

   1 Early Oranges
   2 Midseason Oranges
   3 Late (Valencia) Oranges
   4 Temples
   5 Tangelos
   6 Tangerines & Honey Tangerines
   7 Seedy Grapefruit
   8 White Seedless Grapefruit
   9 Red-Pink Seedless Grapefruit
   10 Some other variety; PLEASE SPECIFY: ________

4. Type of rootstock: CIRCLE ONE NUMBER

   1 Rough Lemon
   2 Sour Orange
   3 Cleopatra Mandarin
   4 Trifoliate Orange
   5 Carrizo Citrange
   6 Other

5. Year grove was planted: 1964
6. Percentage of all trees that are resets less that 7 years of age or skips: 2 percent
7. Grove area (If possible be as specific as tenths of an acre of actual citrus bearing tree acres.): 7 acres
8. Grove terrain: CIRCLE ONE NUMBER

   1 High Ground
   2 Low Ground
   3 Other; PLEASE DESCRIBE ________

9. Grove soil type: CIRCLE ONE NUMBER

   1 Ridge
   2 Flatwoods
   3 Other; PLEASE DESCRIBE ________

10. Are there any large bodies of water which may influence your grove?

    1 Yes
    2 No

12. If you know the Federal Crop Insurance Corporation classification of this grove would you please write it down? ________

GROVE STATUS

13. Month of expected harvest: CIRCLE ONE NUMBER

    1 January
    2 February
    3 March
    4 April
    5 May
    6 June
    7 July
    8 August
    9 September
    10 October
    11 November
    12 December

14. Average yield per acre in this grove in the

    1973-74 season: 175 boxes per acre
    1974-75 season: 250 boxes per acre
    1975-76 season: 200 boxes per acre

15. Estimate of yield per acre for the 1976-77 season: 275 boxes per acre
16. Grove has experienced frost/freeze damage in the past three years which has reduced the grove's productivity or damaged the trees:

    1 Yes → When did this damage occur? Month: Dec Year 1974
    Month: ____ Year ____
    Month: ____ Year ____
    2 No

17. Did this damage prompt any additional frost/freeze protection measures for this grove?

    1 Yes
    2 No

MARKETING PLANS

18. At this time, do you intend to produce the citrus from this grove for fresh or processed market? CIRCLE ONE NUMBER

    1 Fresh
    2 Processed
    3 Don't know

19. What are the primary reasons you plan to market this fruit in this manner? CIRCLE AS MANY AS APPLY

    1 Variety or quality of fruit
    2 Expected market price
    3 Anticipated costs of freeze/frost protection
    4 Other; PLEASE EXPLAIN: ________

If you have any questions, call your county extension agent.

PLEASE CONTINUE ON NEXT PAGE

Figure E.1 Grove Background Report

FROST/FREEZE PROTECTION MEASURES

20. Wind machines used in this grove?
1 Yes
2 No...GO TO QUESTION 22

21. Wind machine data for this grove:

Type of Machines	Number of Machines	Type of Fuel	Average Fuel Consumption Rate*
FMC Tropic Breeze	2	gasoline	12 gal/hr.

*gasoline......gallons/hour
electricity...kilowatts/hour
propane.......pounds/hour

22. Heaters used in this grove?
1 Yes
2 No...GO TO QUESTION 26

23. Heater data for this grove:

Type of Heaters	Number of Heaters	Type of Fuel	Average Fuel Consumtion Rate*
George's	600	#2 diesel	1 gal/hr.
Schew Return			
Stack	50	Diesel	2 gal/hr.

*diesel fuel...gallons/hour
propane.......pounds/hour

24. Storage capacity and fuel on hand:

Type of Fuel	Storage Capacity	Fuel on Hand
diesel	11,000 gal.	11,000 gal.
propane	lbs.	lbs.
other	gasoline 2,000	200 gal

25. Average price of fuel on hand:
diesel fuel 40 ¢/gallons
propane ______ ¢/pound
other 50 gal gasoline

26. Other frost/freeze protection methods used in this grove?

1 Yes → What kind?
1 Permanent Oil Heating System
2 Sprinklers
3 Flood Irrigation
4 Other; PLEASE DESCRIBE: ________

OTHER INFORMATION

27. What other information can you provide that would be helpful in understanding the management of this particular grove?
PLEASE DESCRIBE ____________________

Figure E.1 Grove Background Report (continued) tally, as indicated in Table E 1, indicates that over 88 percent of the expected activity reports were actually received. A sample white form is given in Figure E.2. Again, the design of the questionnaire seems to have been quite good, since the growers appeared to have no major difficulties in completing it. Minor changes in the design of the activity report have been made to streamline the data collection procedure and reduce the time burden on the growers and the county extention agents (who, on the average, filled out over 10 reports per grove during the last season).

A completed pink Damage Report is given in Figure E.3. Damage reports were not returned with as great reliability as the other two survey forms. Part of the reason for this lies in the difficulty of assessing damages until the fruit is actually harvested--in some cases, several months after the cessation of cold weather. Those growers who harvested soon after the freeze were often too busy to spend any time completing the damage reports. Since many growers were not able to fill out their damage reports right after the freeze occurred, some time passed before any significant returns were received. As months passed, cold weather became a distant memory, and many growers had to be reminded that they had not yet reported their damages for this growing season. Damage reports for the 1976-77 season were received by ECON as late as November 1977, making it difficult to undertake the calculation of losses when originally planned. In addition, there are more incomplete and inaccurate pink forms than either of the other two survey forms. Still, as shown in Table E.1, the final percentage of expected damage reports received was almost 90 percent, a very satisfactory return.

Table E.1 Overall Summary of Grove Data Collection			
	Reports Received		
County	Grove Background	Nightly Protection	Damage
Hardee	4	21	2
Highlands	10	63	10
Hillsborough	15	70	7
Marion	14	154	59
Lake	51	592	12
Orange	38	456	53
Osceola	4	48	12
Polk	109	816	132
Total	245	2216	287
Completion	100%	88.5%	≈88%

Some changes have been made to the damage report to alleviate some of the problems which became apparent in this area during the first phase of the experiment. Most importantly, several of the questions were reworded to eliminate ambiguities. In addition, a question was added requesting the grower to provide a more precise harvest date for the grove. This information will aid in the determination of prices received for the harvested fruit, an important factor in the loss calculation.

Coding of the data from the grower data forms presented a major problem. It was desirable to have the data in the most reduced form possible, and yet retain all of the detail present in the raw data. A portion of a completed codesheet for the Grove Background Report is shown in Figure E.4. The coder was given a set of consistent instructions (much the same for the white and pink data forms) on the coding and placement of the data on the

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NIGHTLY FROST/FREEZE PROTECTION ACTIVITY REPORT

Please limit your answer to one grove only (see the instruction sheet for the definition of a "grove" as used in this report). Please answer the following questions only if a fruit frost bulletin by NWS predicted the lowest temperatures to be 28°F or less for the zone in which this grove is located or you had taken any frost/freeze protection during which you incurred costs regardless of predicted temperatures.

1. Your own grove identification: XXX grove I.D. number: X-Y

2. Today's date . . . . Month: JAN Day: 17

3. Which of the NWS forecasts influenced you to initiate some form of frost/freeze protection? . . . .
   CIRCLE ONE NUMBER
   1 10:15 a.m.
   2 4:15 p.m.
   3 10:15 p.m.

4. On a scale of one to ten, how much confidence do you have in the NWS forecast identified in Question 3?
   CIRCLE ONE NUMBER
   no confidence 1 2 3 4 5 6 7 8 9 10 absolute confidence

5. On this night, did you take any action which incurred costs (including calling in laborers, paying someone extra to check the equipment, starting wind machines, firing heaters, etc.)?
   1 Yes
   2 No...GO TO QUESTION 12

6. Labor costs associated with this night's frost/freeze protective action, prorated to this grove:
   1 Total direct wages of laborers called in . . . . . . $ 179.14
   2 Extra direct wages of other personnel to supervise, to monitor weather, check or operate equipment, etc. $ 5.00

7. Wind machines:

	Number of Machines	Fuel Type	Fuel Consumption Rate*	Time (hours and minutes) On	Off
Group 1					
Group 2					
Group 3					

*gasoline......gallons/hour
diesel........gallons/hour
propane.......pounds/hour
electricity...kilowatts/hour

8. Heaters:

	Number of Heaters	Fuel Type	Fuel Consumption Rate*	Time (hours and minutes) Fired	Extinguished
Group 1	445	D	1 gal/hr	2:00AM	8:30AM
Group 2			″		
Group 3					
Group 4					
Group 5					
Group 6					

*diesel........gallons/hour
propane.......pounds/hour

9. Operating costs of any other used frost/freeze protection method: $ —

10. Total approximate mileage incurred during frost/freeze protection travel, prorated to this grove: . . . Trucks: ____ miles
    Automobile ____ miles

11. Minimum temperature recorded on the control thermometer for this grove: . . . . 21 °F

12. Was there observed any damage to fruit and/or trees not previously reported? . . . . .
    1 Yes...DO NOT FORGET TO FILL OUT A DAMAGE REPORT
    2 No

13. If you took no action which incurred costs what were the reasons for not taking it?
    1 Weather conditions did not seem to warrant it
    2 Market conditions
    3 Anticipated protection costs too high
    4 Frost previously damaged
    5 Started too late—not enough time
    6 Took limited action. No additional expense incurred (alerting laborers, having checked equipment at no additional cost, etc.)
    7 Other reason; PLEASE EXPLAIN ____

If you have any questions, call your county extension agent.

Figure E.2 Nightly Frost/Freeze Protection Activity Report

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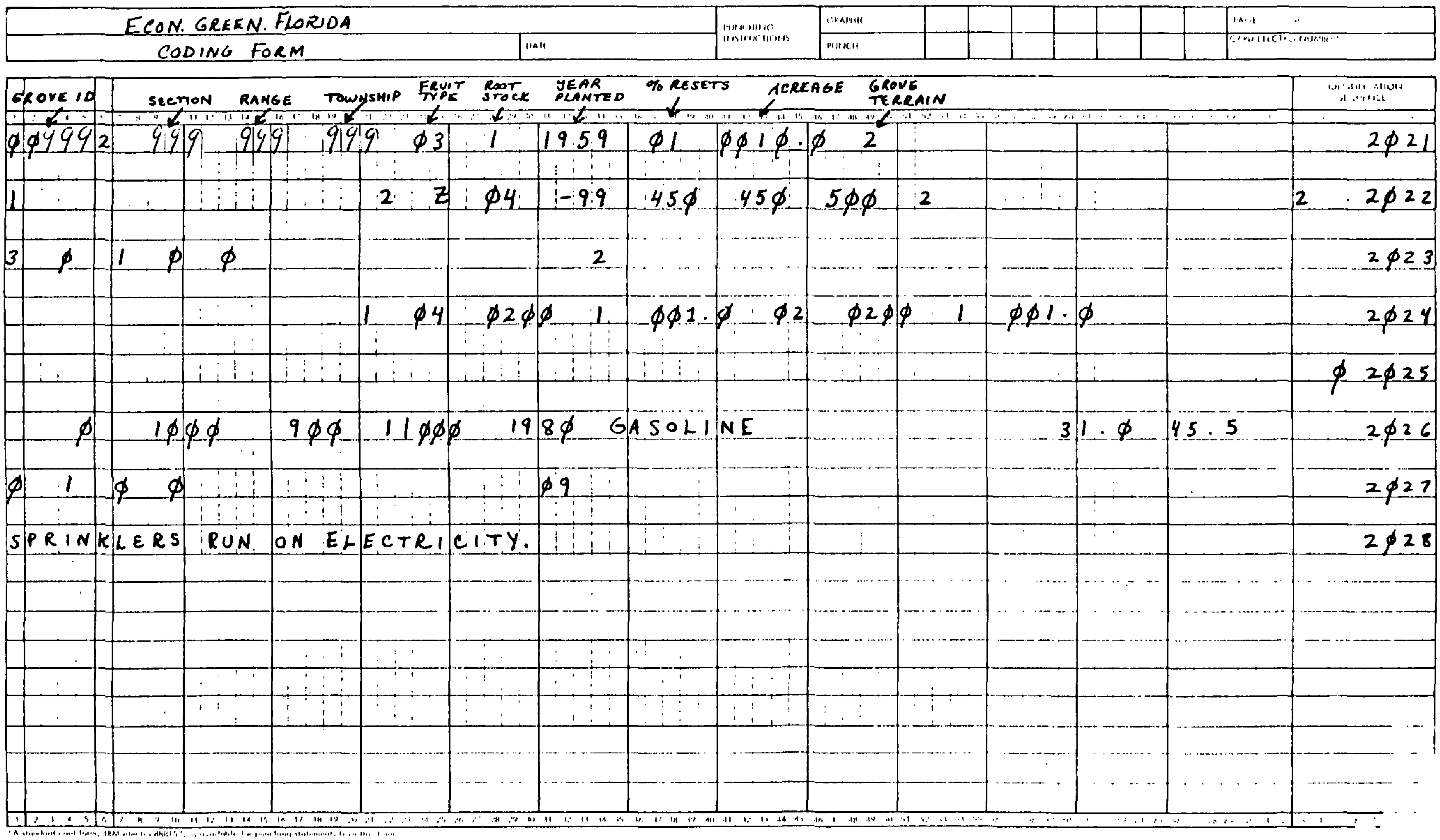
DAMAGE REPORT

Please answer the following questions when you observed damage to your fruit and/or trees. Please limit the answers for one grove to one page.

1. Your own grove identification: XXX and grove I.D. number: X-Y
2. Today's date . . . . Month: 1 Day: 19-20
3. On what night (or nights) was the damage done? . . . . . Month: 1 Day(s): 17-18 + 19-20
4. In this grove, was there any damage to the fruit? . . . . .
   1 Yes
   2 No...GO TO QUESTION 9
5. How did you intend to market the fruit before the damage? . . . . .
   1 Fresh
   2 Processed
6. How do you intend to market the fruit now? . . . . .
   1 Fresh
   2 Processed
7. How would you estimate the yield before the damage? . . . . . 500 boxes per acre
   or ______ lbs-solids per acre
8. How would you estimate the yield after the damage? . . . . . 350 boxes per acre
   or ______ lbs-solids per acre
9. Was there any damage to the trees? . . . . .
   1 Yes
   2 No...GO TO QUESTION 12
10. If there was damage to the trees, in how many years do you expect full production from this grove? . . . . . 3 years
11. What is the approximate percentage of the grove which was damaged? . . . . 100 percent
12. Would you wish to make any other comment? PLEASE DESCRIBE . . . . . too early to make a good estimate. Just guessing now—

If you have any questions, call your county extension agent.

Figure E.3 Damage Report



ECON. GREEN. FLORIDA
CODING FORM

CARD	GROVE ID / SECTION / RANGE / TOWNSHIP / FRUIT TYPE / ROOT STOCK / YEAR PLANTED / % RESETS / ACREAGE / GROVE TERRAIN	IDENTIFICATION
1	φφ999 2 999 999 999 φ3 1 1959 φ1 φφ1φ.φ 2	2φ21
2	1 2 Z φ4 -99 45φ 45φ 5φφ 2	2 2φ22
3	3 φ 1 φ φ 2	2φ23
4	1 φ4 φ2φφ 1 φφ1.φ φ2 φ2φφ 1 φφ1.φ	2φ24
5		φ 2φ25
6	φ 1φφφ 9φφ 11φφφ 198φ GASOLINE 31.φ 45.5	2φ26
7	φ 1 φ φ φ9	2φ27
8	SPRINKLERS RUN ON ELECTRICITY.	2φ28

Figure E.4 Green Florida Coding Form

computer sheet. Later, each completed sheet was scanned for errors before it was sent to be keypunched onto computer cards. In the next step, the data cards were pre-processed by a program which filled in certain codes for "not applicable" data and produced an output which again could be scanned for errors. This somewhat time-consuming procedure effectively reduced the incidence of accidental errors in coding and safeguarded the integrity of the data.

Approximately 250 Grove Background Reports, 2500 Activity Reports, and 300 Damage Reports were processed in this way, generating well over 15,000 computer cards for the first year of the experiment. The actual storage of the data on tape is discussed below, in Section E.2.

E.1.2 Weather Data

The data collected from the National Weather Service representatives in Florida consisted of

- Thermograph traces from 39 control thermometers
- Forecasts from the five zones in which groves in the ECON control group sample lie
- Thirty-year tape of historical cold weather durations
- Monthly minimum temperature records for all stations and all nights.

Thermograph Traces

Figure E.5 shows a typical weekly temperature curve for one of the NWS weather stations. Each station is tended by a local grower or other individual recruited by NWS, whose responsibility it is to change the paper on the instrument in the shelter each week and mail the completed traces to the nearby NWS office. It occasionally happens that the instrument is not reset on time, resulting in a double trace. (See (A) on Figure E.5.)

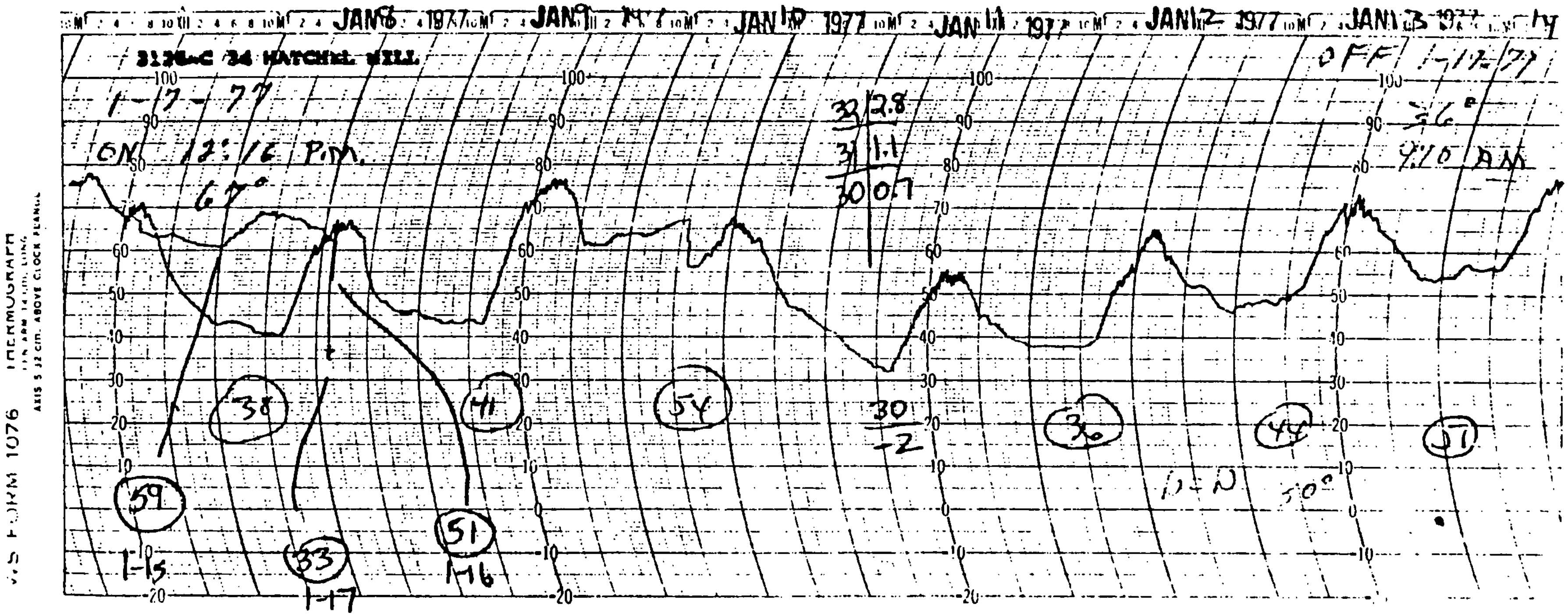


Figure E.5 Typical Thermograph Trace

Other problems are inaccurate calibration, and the overall poor quality of the reproductions received by ECON. Fortunately, before the thermographs are duplicated, a weather service employee records on the trace sheets the durations of all cold temperatures below 32°F. (See (B) on Figure E.5.) Also recorded below the week's minimum temperature is any offset due to an error in calibration (designated by (C) on Figure E.5). Thus, although the trace shows 32° as the minimum temperature for the week, the true minimum is 30°--2° colder than the temperature curve itself shows. The breakdown of durations provided by NWS made it possible for ECON to develop a set of programs to calculate grove frost severity indexes, based on these durations as input data. The WETHR programs which accomplish this are documented more extensively in Section E.2.2.

The coding of the data from the thermographs was done in a straightforward way. Thermometer number and date were recorded first, followed by the minimum temperature at the station on the given date, and the duration of all cold temperatures below 32°. After an error check, the data on the codesheets was keypunched and used as input to the weather data analysis. Figure E.6 shows a portion of a codesheet containing some recorded cold temperature data.

Forecasts

Figure E.7 consists of a set of forecasts for January 19, 1977. Three forecasts are issued on most days: at 10:15 a.m., 4:15 p.m., and 10:15 p.m. On particularly severe days, extra forecasts may be issued.

From mid-fall of 1976 to April of 1977, ECON received all forecasts issued in Florida by the NWS for zones 9, 11, 13, 14 and 15. These forecasts were used extensively to determine needed thermographs traces, and

1 of 10

ECON THERMOGRAPH CODING FORMS 3/4/77

SEQ. NO.	THERM NO.	DATE	MIN TEMP	TEMPERATURE READINGS														NO. OF TEMPS
1	2	2017	22	8.7	8.4	8.1	7.0	6.2	5.2	4.8	3.9	3.1	2.1	0.1				11
2	2	2018	28	8.0	5.0	4.4	3.1	1.0	0.4									6
3	2	2019	21	14.8	14.2	14.0	13.2	12.7	11.3	10.4	10.0	9.5	9.0	7.0	0.8			12
4	2	2020	24	11.0	10.3	10.1	9.0	8.0	7.0	3.2	1.8	0.3						9
5	2	2021	29	5.7	4.0	2.7	0.4											4
6	2	2025	28	5.4	3.5	2.0	1.2	0.3										5
7	3	2017	22	9.1	9.0	8.4	8.2	7.8	6.0	5.0	4.6	3.8	1.5	0.5				11
8	3	2018	24	13.0	10.2	7.0	6.2	5.5	5.1	2.2	2.0	1.2						9
9	3	2019	21	14.6	14.4	14.3	14.0	13.4	12.8	11.7	10.6	4.5	7.3	3.0	1.2			12
10	3	2020	26	12.0	11	10.7	9.0	7.3	3.0	0.2								7
11	3	2021	26	9.8	9.0	6.7	4.4	2.8	1.3	0.1								7
12	3	2025	26	4.6	3.2	2.4	1.8	1.0	0.5	0.2								7
13	5	2010	29	3.7	2.2	1.2	0.3											4
14	5	2017	24	8.2	7.6	6.6	6.3	4.4	3.3	2.3	2.0	0.5						9
15	5	2018	26	10.7	8.8	6.0	5.2	4.0	2.0	0.3								7
16	5	2019	23	14.8	14.0	13.5	12.8	11.4	9.7									6
17	5	2029	31	2.1	1.7													2
18	6	2017	22	11.0	8.3	8.2	8.0	7.3	6.0	5.3	3.3	3.0	1.6	0.1				11
19	6	2018	24	12.0	11.0	6.0	5.8	5.4	5.0	2.6	2.0	0.7						9
20	6	2019	19.5	14.0	13.2	12.3	11.2	10.8	7.5	6.0	5.0	4.2	4.0	3.5	3.3	2.0		13
21	7	2017	22	12.0	9.0	8.3	7.5	7.4	7.3	6.8	5.3	4.7	3.3	1.8				11
22	7	2018	24	16.5	14.3	12.0	9.0	5.5	5.0	4.0	3.3	1.0						9
23	7	2019	20	15.0	14.0	13.5	13.0	12.0	10.8	10.3	10.0	9.3	7.0	5.8	4.5	2.0		13

Figure E.6 ECON Thermograph Coding Form

NNNNATT↓AX
ZCZC
FXUS8 RWRB 192115
↑T BW
PENINSULAR FLORIDA FARM AREA MINIMUM TEMPERATURE FORECAST
NATIONAL WEATHER SERVICE TAMPA BAY AREA RUSKIN FL
4 15 PM EST WED JAN 19 1977

FREEZE WARNING ALL AREAS TONIGHT

TONIGHT..CLEAR AND COLD. NORTHWEST WINDS DIMINISHING OVERNIGHT WITH PERIODS OF CALM POSSIBLE AFTER MIDNIGHT. TEMPERATURES FALLING STEADILY THROUGH THE NIGHT WITH LOWS TO OCCUR BETWEEN 5 AM AND SUNRISE.

LOWEST TEMPERATURES

ZONES 6 7	10 TO 14
ZONE 8	12 TO 16
ZONE 9	14 TO 18
ZONES 10 12	18 TO 22 WITH 16 TO 18 COLD POCKETS
ZONE 11	16 TO 20 WITH 14 TO 16 POCKETS AND MUCKLANDS. SCATTERED FROST
ZONES 13 14 15 16	20 TO 24 WITH 16 TO 20 POCKETS. FROST
ZONE 17	22 TO 26 FROST
ZONES 18 19 INCLUDING IMMOKALEE	22 TO 26 WITH 20 TO 22 BACKLANDS. FROST
ZONES 20 21	24 TO 28 FROST
ZONE 22	26 TO 30 EXCEPT 28 TO 32 ALONG THE COAST. FROST.

TEMPERATURE OUTLOOK...CONTINUED COLD WITH FREEZING TEMPERATURES AGIN MOST FARMING AREAS FRIDAY MORNING.

VC

Figure E.7 Typical NWS Temperature Forecast to anticipate the number of activity reports for a given night which should eventually be received (according to the 28° trigger mechanism). In addition, the forecasts were used in conjunction with the monthly minimum temperature records for an analysis of forecast accuracy. The forecasts were also part of the input data for REPT, the program which prepares year-end reports for all groves. (REPT is documented in Section E.3.)

Thirty-Year Historical Weather Tape

ECON was able to obtain a copy of a magnetic tape which contained records of durations of cold temperatures, for all NWS weather stations in central Florida, for the years 1937 to 1966. This data was used to provide the numerical framework for the normalization of sample costs and losses to an "average" weather year. The tape had been prepared by Dr. Jim Georg, now retired, who headed the Lakeland, Florida NWS office. The current NWS staff was not able to provide any accompanying documentation for the tape, and it was left to ECON to decode the data on it. Eventually, the format of the data was determined, and normalization programs were set up using the historical weather records as input (see Appendix D).

Monthly Minimum Temperature Records

Monthly minimum temperature records provided by NWS for all stations were useful in determining which thermograph traces were needed, and in the measurement of forecast accuracy. They also provided a means of checking the data on the occasionally illegible, faint, or inaccurate thermograph reproductions. These records, which are really an amalgamation of data from the thermographs themselves, are prepared by hand at the end of each month in the frost season.

E.2 Data Reduction

E.2.1 Grower Data

After coding, keypunching and pre-processing, the data from the grower survey forms were entered into an SPSS database and stored on tape. SPSS (Statistical Package for the Social Sciences) is a data management/statistical analysis program package available on most large batch computer systems. SPSS provides an enormous range of statistical procedures and flexible data management facilities tailored to the particular needs of empirical researchers in the social sciences. Thus, SPSS was ideal both for the storage of the grower survey data, and for the generation of sample statistics of many kinds.

Two data files were created to hold the grower data. ECON.GREEN.FLORIDA consists of the coded data from the green Grove Background Reports. ECON. WHITE.FLORIDA, a much larger file, contains the approximately 2500 Nightly Activity Reports recieved in the first year of the experiment. Later, the data from the pink Grove Damage Reports was added to the white form database, so that all cost and loss data could be simultaneously accessed.

The structure of an SPSS is extremely simple. As shown in Figure E.8, it can be viewed as a 2-dimensional matrix divided into columns corresponding to the different variables, and rows corresponding to each case (where a case is defined as the data from one data form).

In the green database, each case is keyed on the grove identification number, while in the white-pink database, the cases are keyed on grove I.D. and date of frost/freeze. The cases can be stratified into any number of subgroups based on the values of any of the variables in the database. For example, one might wish to generate statistics based on all groves

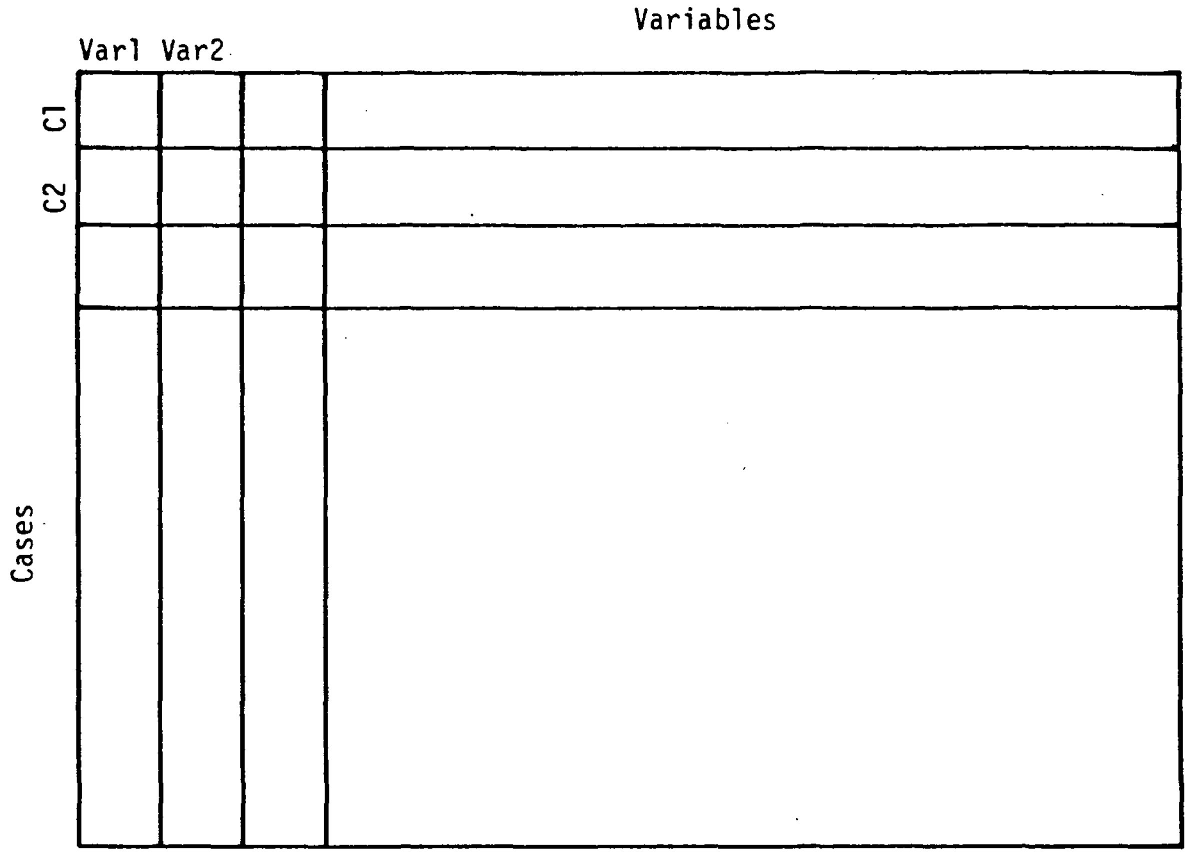


Figure E.8 Matrix Representation of an SPSS Database

with heaters in Polk county which produce valencia oranges. This is achieved by using a straightforward SPSS "SELECT" command, in conjunction with the desired statistical procedure. No sorting or data manipulation is undertaken. Data may be temporarily or permanently recoded, and new variables may be calculated from existing variables in a single statement. All, or any subset, of the data may be "dumped" onto tape, disk, cards, or paper in any desired format and in any desired order. This feature was useful in preparing data for input to the FORTRAN report writer (documented below).

SPSS maintains its own internal documentation based on data specifications given by the user, and will print out this documentation whenever requested. The two sets of "FILEINFO" which follow (for the green and white-pink databases, respectively) provide detailed information on all of the variables contained in the two ECON databases. There are 128 variables included in the green form database, and 138 in the white-pink form database.

In the FILEINFO, the number to the left side of each variable name is the relative position of the variable in the file (that is, the column number as shown in Figure E.8). "Missing values" are those values which the variable may take which have been designated as special codes for missing data. Up to three different missing values for each variable are allowable. When any statistics are requested, those cases with missing values for a particular variable are automatically excluded by the system. The final column gives the "print format" of the variable--either the number of significant digits to be printed after the decimal point, or the letter "A" indicating an alphanumeric variable.

E.2.2 WETHR Programs

Figure E.9 presents a flow chart which traces through the three major phases of the weather data analysis. The programs for analyzing the thermograph data work as a chain, each producing output necessary for input to the next step. The three main stages of the analysis are:

- Calculation of degree-hours of frost for each control thermometer on each cold night (WETHR1)
- Adjustment of the degree-hours (or durations coded directly from the thermographs) for each grove (WETHR2)
- Calculation of severity of frost indexes for fruit and trees, for each grove on each cold night (WETHR3).

The decision to code durations directly from the thermographs rather than coding actual temperatures at intervals and using WETHR1 to calculate degree-hours was based on a desire for compatibility with historical temperature records. Thus, WETHR2 was adapted to accept either durations or degree-hours as input. However, since it was expected that durations would be used throughout the remainder of the project, WETHR3 was written to calculate severity indexes from adjusted durations only.

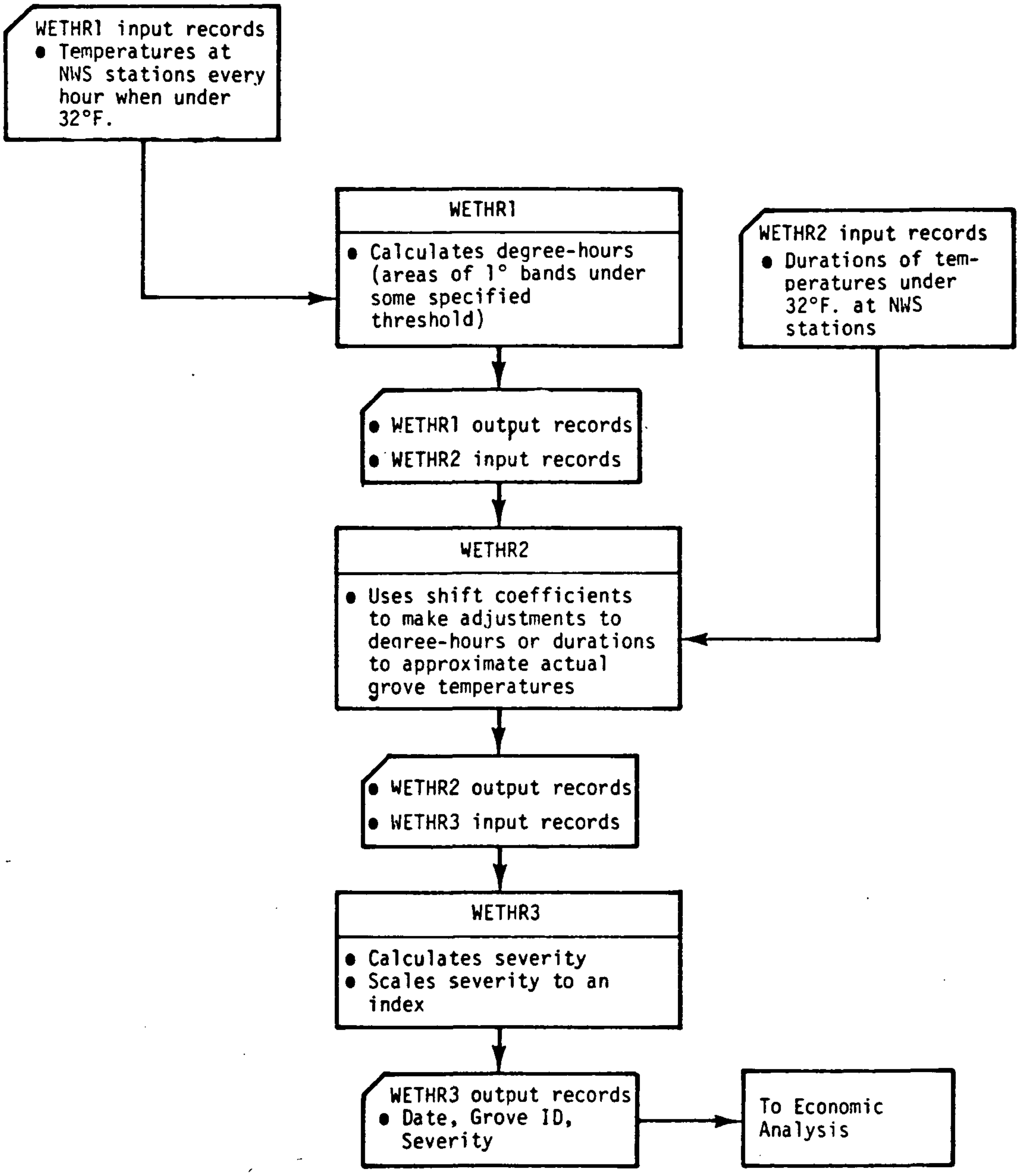


Figure E.9 Weather Data Analysis Programs--Overall Flow

FILEINFO

FILE ECON.WHI (CREATION DATE = 11/18/77)

DOCUMENTATION FOR SPSS FILE 'ECON.WHI'

LIST OF THE 1 SUBFILES COMPRISING THE FILE

ECON.WHI N= 2439

DOCUMENTATION FOR THE 138 VARIABLES IN THE FILE 'ECON.WHI'

```
REL  VARIABLE  VARIABLE LABEL                               MISSING   PRT
POS    NAME                                                 VALUES    FMT


  1  SEQNUM                                                   NONE     0

  2  SUBFILE                                                  NONE     A

  3  CASWGT                                                   NONE     4

  4  GID       GROVE ID NUMBER                              -99999.    0
               MISS        -99999. MISSING

  5  DATE      DATE FORM FILLED OUT                          -9999.    0
               MISS        -9999. MISSING

  6  FOREC     FORECAST WHICH STARTED ACTION                     0.    0
               MISS            0. MISSING
                               1. 10:15 AM
                               2. 4:15 PM
                               3. 10:15 PM

  7  CONF      CONFIDENCE IN NWS                                -9.    0
               MISS           -9. MISSING

  8  COSTS     WHETHER ANY $ ACTION TAKEN                        0.    0
               MISS            0. MISSING
                               1. YES
                               2. NO

  9  TOTLAB    TOTAL DIRECT WAGES                          -8888.00    2
               MISS      -8888.00 NOT APPLICABLE

 10  EXTLAB    EXTRA DIRECT WAGES                          -8888.00    2
               MISS      -8888.00 NOT APPLICABLE

 11  NOWM1     NO OF WM IN GROUP 1                            -9.00    2
                                                              -8.00
               MISS         -9.00 MISSING
               MISS         -8.00 NOT APPLICABLE
```

```
DOCUMENTATION FOR THE  138 VARIABLES IN THE FILE 'ECON.WHI'

 REL  VARIABLE  VARIABLE LABEL                                MISSING PRT
 POS     NAME                                                 VALUES  FMT

  12  WM1FT     FUEL USED BY WM GROUP 1                           0.    0
                                                                  8.
                MISS            0. MISSING
                MISS            8. NOT APPLICABLE
                                1. GASOLINE
                                2. LIQUID PROPANE
                                3. LIQUID BUTANE

  13  WM1FC     FUEL CONSUMPTION BY GRP 1 WM                   -9.00    2
                                                               -8.00
                MISS        -9.00 MISSING
                MISS        -8.00 NOT APPLICABLE

  14  WM1ON     TIME ON FOR GRP 1 WM                           -999.    0
                                                               -888.
                MISS        -999. MISSING
                MISS        -888. NOT APPLICABLE

  15  WM1OFF    TIME OFF FOR GRP1 WM                           NONE     0
                            -999. MISSING
                            -888. NOT APPLICABLE

  16  NOWM2     NO OF WM IN GROUP 2                            -9.00    2
                                                               -8.00

  17  WM2FT     FUEL USED BY WM GROUP 2                           0.    0
                                                                  8.
                MISS            0. MISSING
                                1. GASCLINE
                                2. LIQUID PROPANE
                                3. LIQUID BUTANE
                MISS            8. NOT APPLICABLE

  18  WM2FC     FUEL CONSUMPTION BY GRP 2 WM                   -9.00    2
                                                               -8.00
                MISS        -9.00 MISSING
                MISS        -8.00 NOT APPLICABLE

  19  WM2ON     TIME ON FOR GRP 2 WM                           -999.    0
                                                               -888.
                MISS        -999. MISSING
                MISS        -888. NOT APPLICABLE
```

DOCUMENTATION FOR THE 138 VARIABLES IN THE FILE 'ECON.WHI'

```
REL  VARIABLE  VARIABLE LABEL                                MISSING  PRT
POS  NAME                                                    VALUES   FMT

20   WM2OFF    TIME OFF FOR GRP 2 WM                         NONE     0
                           -999. MISSING
                           -888. NOT APPLICABLE

21   NOWM3     NO OF WM IN GROUP 3                           -9.00    2
                                                             -8.00
               MISS        -9.00 MISSING
               MISS        -8.00 NOT APPLICABLE

22   WM3FT     FUEL USED BY WM GROUP 3                       0.       0
                                                             8.
               MISS           0. MISSING
               MISS           8. NOT APPLICABLE
                              1. GASOLINE
                              2. LIQUID PROPANE
                              3. LIQUID BUTANE

23   WM3FC     FUEL CONSUMPTION BY GRP 3 WM                  -9.00    2
                                                             -8.00
               MISS        -9.00 MISSING
               MISS        -8.00 NOT APPLICABLE

24   WM3ON     TIME ON FOR GRP3 WM                           -999.    0
                                                             -888.
               MISS        -999. MISSING
               MISS        -888. NOT APPLICABLE

25   WM3OFF    TIME OFF FOR GRP 3 WM                         NONE     0
                           -999. MISSING
                           -888. NOT APPLICABLE

26   NOH1      NO OF HEATERS IN GROUP 1                      -9999.   0
                                                             -8888.
               MISS       -9999. MISSING
               MISS       -8888. NOT APPLICABLE

27   H1FT      FUEL USED BY HTR GRP 1                        0.       0
                                                             8.
               MISS           0. MISSING
               MISS           8. NOT APPLICABLE
                              1. #2 DIESEL

28   H1FC      FUEL CONSUMPTION BY HTR GRP 1                 -9.00    2
                                                             -8.00
               MISS        -9.00 MISSING
```

```
DOCUMENTATION FOR THE  138 VARIABLES IN THE FILE 'ECON.WHI'

REL  VARIABLE  VARIABLE LABEL                                MISSING PRT
POS      NAME                                                 VALUES FMT


 28  H1FC       CONT
                MISS          -8.00 NOT APPLICABLE

 29  H1ON       TIME ON FOR HTR GRP 1                           -999.   0
                                                                -888.
                MISS          -999. MISSING
                MISS          -888. NOT APPLICABLE

 30  H1OFF      TIME OFF FOR HTR GRP1                           -999.   0
                                                                -888.
                MISS          -999. MISSING
                MISS          -888. NOT APPLICABLE

 31  NOH2       NO OF HEATERS IN GROUP 2                       -9999.   0
                                                               -8888.
                MISS         -9999. MISSING
                MISS         -8888. NOT APPLICABLE

 32  H2FT       FUEL USED BY HTR GRP 2                             0.   0
                                                                   8.
                MISS             0. MISSING
                MISS             8. NOT APPLICABLE
                                 1. #2 DIESEL

 33  H2FC       FUEL CONSUMPTION BY HTR GRP 2                   -9.00   2
                                                                -8.00
                MISS          -9.00 MISSING
                MISS          -8.00 NOT APPLICABLE

 34  H2ON       TIME ON FOR HTR GRP 2                           -999.   0
                                                                -888.
                MISS          -999. MISSING
                MISS          -888. NOT APPLICABLE

 35  H2OFF      TIME OFF FOR HTR GRP 2                          -999.   0
                                                                -888.
                MISS          -999. MISSING
                MISS          -888. NOT APPLICABLE

 36  NOH3       NO OF HEATERS IN GROUP 3                       -9999.   0
                                                               -8888.
                MISS         -9999. MISSING
                MISS         -8888. NOT APPLICABLE
```

DOCUMENTATION FOR THE 138 VARIABLES IN THE FILE 'ECON.WHI'

```
REL  VARIABLE  VARIABLE LABEL                                  MISSING  PRT
POS      NAME                                                  VALUES   FMT

 37  H3FT      FUEL USED BY HTR GRP 3                               0.    0
                                                                    8.
               MISS          0. MISSING
               MISS          8. NOT APPLICABLE
                             1. #2 DIESEL

 38  H3FC      FUEL CONSUMPTION BY HTR GRP 3                     -9.00    2
                                                                 -8.00
               MISS      -9.00 MISSING
               MISS      -8.00 NOT APPLICABLE

 39  H3ON      TIME ON FOR HTR GRP 3                             -999.    0
                                                                 -888.
               MISS       -999. MISSING
               MISS       -888. NOT APPLICABLE

 40  H3OFF     TIME OFF FOR HTR GRP 3                            -999.    0
                                                                 -888.
               MISS       -999. MISSING
               MISS       -888. NOT APPLICABLE

 41  NOH4      NO OF HEATERS IN GROUP 4                         -9999.    0
                                                                -8888.
               MISS      -9999. MISSING
               MISS      -8888. NOT APPLICABLE

 42  H4FT      FUEL USED BY HTR GRP 4                               0.    0
                                                                    8.
               MISS          0. MISSING
               MISS          8. NOT APPLICABLE
                             1. #2 DIESEL

 43  H4FC      FUEL CONSUMPTION BY HTR GRP 4                     -9.00    2
                                                                 -8.00
               MISS      -9.00 MISSING
               MISS      -8.00 NOT APPLICABLE

 44  H4ON      TIME ON FOR HTR GRP4                              -999.    0
                                                                 -888.
               MISS       -999. MISSING
               MISS       -888. NOT APPLICABLE

 45  H4OFF     TIME OFF FOR HTR GRP4                             -999.    0
                                                                 -888.
               MISS       -999. MISSING
```

DOCUMENTATION FOR THE 138 VARIABLES IN THE FILE 'FCON.WHI'

```
REL  VARIABLE  VARIABLE LABEL                               MISSING  PRT
POS    NAME                                                 VALUES   FMT

 45  H4OFF     CONT
               MISS        -888. NOT APPLICABLE

 46  NOH5      NO OF HEATERS IN GROUP 5                     -9999.    0
                                                            -8888.
               MISS       -9999. MISSING
               MISS       -8888. NOT APPLICABLE

 47  H5FT      FUEL USED BY HTR GRP 5                           0.    0
                                                                8.
               MISS           0. MISSING
               MISS           8. NOT APPLICABLE
                              1. #2 DIESEL

 48  H5FC      FUEL CONSUMPTION BY HTR GRP 5                 -9.00    2
                                                             -8.00
               MISS        -9.00 MISSING
               MISS        -8.00 NOT APPLICABLE

 49  H5ON      TIME ON FOR HTR GRP 5                         -999.    0
                                                             -888.
               MISS        -999. MISSING
               MISS        -888. NOT APPLICABLE

 50  H5OFF     TIME OFF FOR HTR GRP5                         -999.    0
                                                             -888.
               MISS        -999. MISSING
               MISS        -888. NOT APPLICABLE

 51  NOH6      NO OF HEATERS IN GROUP 6                     -9999.    0
                                                            -8888.
               MISS       -9999. MISSING
               MISS       -8888. NOT APPLICABLE

 52  H6FT      FUEL USED BY HTR GRP 6                           0.    0
                                                                8.
               MISS           0. MISSING
               MISS           8. NOT APPLICABLE
                              1. #2 DIESEL

 53  H6FC      FUEL CONSUMPTION BY HTR GRP 6                 -9.00    2
                                                             -8.00
               MISS        -9.00 MISSING
               MISS        -8.00 NOT APPLICABLE
```

DOCUMENTATION FOR THE 138 VARIABLES IN THE FILE 'ECON.WHI'

```
REL  VARIABLE  VARIABLE LABEL                                  MISSING  PRT
POS    NAME                                                     VALUES  FMT

 53  H6FC      CONT

 54  H6ON      TIME ON FOR HTR GRP6                              -999.    0
                                                                 -888.
               MISS           -999. MISSING
               MISS           -888. NOT APPLICABLE

 55  H6OFF     TIME OFF FOR HTR GRP 6                            -999.    0
                                                                 -888.
               MISS           -999. MISSING
               MISS           -888. NOT APPLICABLE

 56  COSTOM    COST OF OTHER PROT. METHODS                    -8888.00    2
               MISS        -8888.00 NOT APPLICABLE

 57  TRUCKM    TOTAL TRUCK MILEAGE                              -888.0    1
               MISS          -888.0 NOT APPLICABLE

 58  AUTOM     TOTAL CAR MILEAGE                                -888.0    1
               MISS          -888.0 NOT APPLICABLE

 59  MNTEMP    MIN TEMP ON CONTROL THERMOMETER                     -8.    0
               MISS             -8. NOT APPLICABLE

 60  DAMGE     WHETHER NEW DAMAGE FROM FROST                        0.    0
               MISS              0. MISSING
                                 1. YES
                                 2. NO

 61  RNA1      NO ACTION:WEATHER                                  NONE    0
                                 0. REASON 1 NOT MARKED
                                 1. REASON 1 MARKED

 62  RNA2      NO ACTION:MARKET                                   NONE    0
                                 0. REASON 2 NOT MARKED
                                 1. REASON 2 MARKED

 63  RNA3      NO ACTION:EXPENSE                                  NONE    0
                                 0. REASON 3 NOT MARKED
                                 1. REASON 3 MARKED

 64  RNA4      NO ACTION:PREVIOUS DAMAGE                          NONE    0
                                 0. REASON 4 NOT MARKED
                                 1. REASON 4 MARKED
```

DOCUMENTATION FOR THE 138 VARIABLES IN THE FILE 'ECON.RHI'

REL POS	VARIABLE NAME	VARIABLE LABEL	MISSING VALUES	PRT FMT
64	RNA4	CONT		
65	RNA5	NO ACTION:NOT ENOUGH TIME 0. REASON 5 NOT MARKED 1. REASON 5 MARKED	NONE	0
66	RNA6	NO ACTION:NO EXPENSE INCURRED 0. REASON 6 NOT MARKED 1. REASON 6 MARKED	NONE	0
67	RNA7	NO ACTION:OTHER REASON 0. REASON 7 NOT MARKED 1. REASON 7 MARKED	NONE	0
68	RNAC1		NONE	A
69	RNAC2		NONE	A
70	RNAC3		NONE	A
71	RNAC4		NONE	A
72	VC	VARIETY OF CITRUS 1. EARLY ORANGES 2. MIDSEASON ORANGES 3. VALENCIA ORANGES 4. TEMPLES 5. TANGELOS 6. TANGERINES 7. SEEDY GRAPEFRUIT 8. WHT SEEDLESS GRAPEFT 9. RED SEEDLESS GRAPEFT 10. OTHER MISS -9. MISSING	-9.	0
73	PYEAR	PROJECT YEAR 1. '76-'77 2. '77-'78 3. '78-'79 4. '79-'80	NONE	0
74	WDATE	RECODED DATE FOR WETHR PROGRAMS	NONE	0

DOCUMENTATION FOR THE 139 VARIABLES IN THE FILE 'ECON.WHI'

REL POS	VARIABLE NAME	VARIABLE LABEL	MISSING VALUES	PRT FMT
75	LABOR	TOTAL LABOR COSTS MISS -8888.00 NOT APPLICABLE	-8888.00	2
76	CNTY	COUNTY	NONE	0
77	FUELWM1		NONE	0
78	FUELWM2		NONE	0
79	FUELWM3		NONE	0
80	FUELH1		NONE	0
81	FUELH2		NONE	0
82	FUELH3		NONE	0
83	FUELH4		NONE	0
84	FUELH5		NONE	0
85	FUELH6		NONE	0
86	FRUITSEV	FROST SEVERITY COEFFICIENT FOR FRUIT	-9.00	2
87	TREESEV	FROST SEVERITY COEFFICIENT FOR TREES	-9.00	2
88	ACRES	GROVE ACREAGE	-99.0	1
89	FCIC	FCIC CODE	Z	A
90	FZONE	FORECAST ZONE	0.	0
91	PROT	PROTECTION TECHNOLOGY AVAILABLE	0.	0
92	FTDAM	WHETHER GROVE HAD FRUIT DAMAGE 1. YES 2. NO MISS 9. MISSING 0. N.A.	9.	0
93	MPBEF	MARKETING PLANS BEFORE DAMAGE 0. N.A. 1. FRESH	9.	0

DOCUMENTATION FOR THE 138 VARIABLES IN THE FILE 'ECON.WHI'

```
REL  VARIABLE  VARIABLE LABEL                                MISSING  PRT
POS      NAME                                                 VALUES  FMT

 93  MPBEF     CONT
                              2. PROCESSED
                              3. FRESH & PROC.
               MISS           9. MISSING

 94  MPAFT     MARKETING PLANS AFTER DAMAGE                       9.    0
                              0. N.A.
                              1. FRESH
                              2. PROCESSED
                              3. FRESH & PROC.
               MISS           9. MISSING

 95  DFRESH    CHANGE IN P.A. FRESH FT. YIELD                -99999.    0
               MISS      -99999. MISSING

 96  DPROC     CHANGE IN P.A. PROC. FT. YIELD                -99999.    0
               MISS      -99999. MISSING

 97  TREEDAM   WHETHER GROVE HAD TREE DAMAGE                      9.    0
                              1. YES
                              2. NO
               MISS           9. MISSING
                              0. N.A.

 98  FULPRO    YEARS UNTIL FULL PRODUCTION                       -9.    0
               MISS          -9. MISSING

 99  PCTDAM    % OF GROVE DAMAGED                               -99.    0
               MISS         -99. MISSING

100  MSLOSS    MISSING DATA INDICATOR                           NONE    0
                              0. DATA OK WITH WHITE F
                              1. PINK FORM DATA MISSI

101  DAM1                                                       NONE    A

102  DAM2                                                       NONE    A

103  DAM3                                                       NONE    A

104  DAM4                                                       NONE    A

105  DAM5                                                       NONE    A
```

DOCUMENTATION FOR THE 138 VARIABLES IN THE FILE 'ECON.WHI'

REL POS	VARIABLE NAME	VARIABLE LABEL	MISSING VALUES	PRT FMT
106	DAM6		NONE	A
107	DAM7		NONE	A
108	DAM8		NONE	A
109	DAM9		NONE	A
110	DAM10		NONE	A
111	DAM11		NONE	A
112	DAM12		NONE	A
113	DAM13		NONE	A
114	DAM14		NONE	A
115	DAM15		NONE	A
116	DAM16		NONE	A
117	DAM17		NONE	A
118	DAM18		NONE	A
119	DAM19		NONE	A
120	PFRESH	F.O.B. PRICE FOR FRESH FRUIT	NONE	3
121	PPROC	DELIVERED PRICE, GALS OR LBS-SOLIDS	NONE	3
122	LOSSPA	GROVE LOSS PER ACRE	99999.0	1
123	TLOSS	TOTAL GROVE LOSS	999999.0	1
124	CWM1	COST OF WM GROUP 1	NONE	2
125	CWM2	COST OF WM GROUP 2	NONE	2
126	CWM3	COST OF WM GROUP 3	NONE	2
127	CH1	COST OF HTR GROUP 1	NONE	2

DOCUMENTATION FOR THE 138 VARIABLES IN THE FILE 'ECON.WHI'

REL POS	VARIABLE NAME	VARIABLE LABEL	MISSING VALUES	PRT FMT
128	CH2	COST OF HTR GROUP 2	NONE	2
129	CH3	COST OF HTR GROUP 3	NONE	2
130	CH4	COST OF HTR GROUP 4	NONE	2
131	CH5	COST OF HTR GROUP 5	NONE	2
132	CH6	COST OF HTR GROUP 6	NONE	2
133	TCOST	TOTAL GROVE PROTECTION COST	NONE	2
134	COSTPA	COST OF PROTECTION PER ACRE	-9999.00	2
135	WMHRS	TOTAL WIND MACHINE HOURS	NONE	1
136	HTHRS	TOTAL HEATER HOURS	NONE	1
137	WMS	TOTAL NO. OF WIND MACHINES USED	NONE	1
138	HTS	TOTAL NO. OF HEATERS USED	NONE	0

FILEINFO

FILE ECON.GRE (CREATION DATE = 11/18/77) 1976 FLORIDA ASVT GREEN FORM DATABASE

DOCUMENTATION FOR SPSS FILE 'ECON.GRE' 1976 FLORIDA ASVT GREEN FORM DAT

LIST OF THE 1 SUBFILES COMPRISING THE FILE

ECON.GRE N= 245

DOCUMENTATION FOR THE 128 VARIABLES IN THE FILE 'ECON.GRE'

REL POS	VARIABLE NAME	VARIABLE LABEL		MISSING VALUES	PRT FMT
1	SEQNUM			NONE	0
2	SUBFILE			NONE	A
3	CASWGT			NONE	4
4	ID	ID NUMBER OF GROVE		-99999.	0
5	SN	SECTION OF GROVE		-99.	0
6	RG	RANGE OF GROVE		-99.	0
7	TS	TOWNSHIP OF GROVE		-99.	0
8	VC	VARIETY OF CITRUS		0.	0
		MISS	0. MISSING		
			1. EARLY ORANGES		
			2. MIDSEASON ORANGES		
			3. LATE ORANGES		
			4. TEMPLES		
			5. TANGELOS		
			6. TANGERINES		
			7. SEEDY GRAPEFRUIT		
			8. WT. SEEDLESS GRAPEFT		
			9. RD. SEEDLESS GRAPEFT		
			10. OTHER		
9	TR	TYPE OF ROOTSTOCK		0.	0
		MISS	0. MISSING		
			1. ROUGH LEMON		
			2. SOUR ORANGE		
			3. CLEOPATRA MANDARIN		
			4. TRIFOLIATE ORANGE		
			5. CARRIZO CITRANGE		
			6. OTHER		
10	YP	YEAR GROVE PLANTED		-999.	0

DOCUMENTATION FOR THE 128 VARIABLES IN THE FILE 'ECON.GRE'

REL POS	VARIABLE NAME	VARIABLE LABEL		MISSING VALUES	PRT FMT
11	PR	PERCENT OF RESETS AND SKIPS		-9.	0
12	GA	GROVE AREA		-999.0	1
13	GRT	GROVE TERRAIN		0.	0
		MISS	0. MISSING		
			1. HIGH GROUND		
			2. LOW GROUND		
			3. OTHER		
14	GTC1			NONE	A
15	GTC2			NONE	A
16	GTC3			NONE	A
17	GTC4			NONE	A
18	ST	SOIL TYPE		0.	0
		MISS	0. MISSING		
			1. RIDGE		
			2. FLATWOODS		
			3. OTHER		
19	STC1			NONE	A
20	STC2			NONE	A
21	STC3			NONE	A
22	STC4			NONE	A
23	BW	WHETHER BODIES OF WATER NEARBY		0.	0
		MISS	0. MISSING		
			1. YES		
			2. NO		
24	FCIC	FEDERAL CROP INSURANCE CLASSIFICATION		Z	A
25	MH	MONTH OF EXPECTED HARVEST		0.	0
		MISS	0. MISSING		
			1. JANUARY		
			2. FEBRUARY		
			3. MARCH		

FILEINFO

DOCUMENTATION FOR THE 128 VARIABLES IN THE FILE 'ECON.GRF'

```
REL  VARIABLE  VARIABLE LABEL                              MISSING  PRT
POS    NAME                                                VALUES   FMT

 25  MH        CONT
                             4. APRIL
                             5. MAY
                             6. JUNE
                             7. JULY
                             8. AUGUST
                             9. SEPTEMBER
                            10. OCTOBER
                            11. NOVEMBER
                            12. DECEMBER

 26  Y7374     YIELD PER ACRE 73-74,BOXES                     -99.    0

 27  Y7475     YIELD PER ACRE 74-75,BOXES                     -99.    0

 28  Y7576     YIELD PER ACRE 75-76,BOXES                     -99.    0

 29  Y7677     EXPECTED YIELD THIS YEAR,BOXES PER ACRE        -99.    0

 30  DR        WHETHER FROST DAMAGE LAST 3 YEARS                0.    0
               MISS          0. MISSING
                             1. YES
                             2. NO

 31  FD1       FIRST MONTH-YEAR OF RECENT FROST DAMAGE       -888.    0
                                                             -999.
               MISS       -888. NOT APPLICABLE
               MISS       -999. MISSING

 32  FD2       2ND MONTH-YEAR OF RECENT FROST DAMAGE         -888.    0
                                                             -999.
               MISS       -888. NOT APPLICABLE
               MISS       -999. MISSING

 33  FD3       3RD MONTH-YEAR OF RECENT FROST DAMAGE         -888.    0
                                                             -999.
               MISS       -888. NOT APPLICABLE
               MISS       -999. MISSING

 34  APM       WHETHER MORE PROTECTION DUE TO DAMAGE            0.    0
                                                                9.
               MISS          0. MISSING
                             1. YES
                             2. NO
```

```
DOCUMENTATION FOR THE  128 VARIABLES IN THE FILE 'ECON.GRE'

REL  VARIABLE  VARIABLE LABEL                                   MISSING PRT
POS      NAME                                                   VALUES  FMT

 34  APM        CONT
                              8. NOT APPLICABLE

 35  MP         MARKETING PLANS                                     0.    0
                MISS          0. MISSING
                              1. FRESH
                              2. PROCESSED
                              3. DON'T KNOW

 36  RMP1       WHY MARKETING PLANS-TYPE OF FRUIT?                NONE    0
                              0. QUALITY OF FRUIT-NO
                              1. QUALITY OF FRUIT-YES

 37  RMP2       WHY MARKETING PLANS-PREVAILING PRICES?            NONE    0
                              0. MARKET PRICE-NO
                              1. MARKET PRICE-YES

 38  RMP3       WHY MARKETING PLANS-PROTECTION COSTS?             NONE    0
                              0. PROTECT COST-NO
                              1. PROTECT COST-YES

 39  RMP4       OTHER REASON FOR MARKETING PLANS?                 NONE    0
                              0. OTHER REASON-NO
                              1. OTHER REASON-YES

 40  MPC1                                                         NONE    A

 41  MPC2                                                         NONE    A

 42  MPC3                                                         NONE    A

 43  MPC4                                                         NONE    A

 44  WMU        WHETHER WIND MACHINES USED                          0.    0
                              1. YES
                              2. NO
                MISS          0. MISSING

 45  WMT1       1ST TYPE OF WIND MACHINE USED                       0.    0
                                                                   -8.
                MISS          0. MISSING
                MISS         -8. NOT APPLICABLE
                              1. FMC TROPIC BREEZE
                              2. FMC SINGLE PROP GRND
```

DOCUMENTATION FOR THE 128 VARIABLES IN THE FILE 'ECON.GRF'

```
REL  VARIABLE  VARIABLE LABEL                                  MISSING  PRT
POS      NAME                                                   VALUES  FMT

45   WMT1      CONT
                               3. FMC-BENDIX DUAL GRND
                               4. SINGLE PROP TOP MOUN
                               5. FMC ONLY
                               6. BROGDEX
                               7. KILLEBREW
                               8. FMC DUAL TOP MOUNTED
                               9. DOUBLE PROP TOP MOUN
                              10. FMC-GP 125

46   NWM1      NO. OF WIND MACHINES OF TYPE 1 IN GROVE            -8.0    1
                                                                  -9.0
               MISS          -9.0 MISSING
               MISS          -8.0 NOT APPLICABLE

47   FTWM1     FUEL USED BY WIND MACHINE TYPE 1                     0.    0
                                                                    8.
               MISS            0. MISSING
               MISS            8. NOT APPLICABLE
                               1. GASOLINE
                               2. LIQUID PROPANE
                               3. LIQUID BUTANE

48   FCWM1     FUEL CONSUMPTION RATE OF TYPE 1 WM                 -99.0   1
                                                                  -88.0
               MISS         -99.0 MISSING
               MISS         -88.0 NOT APPLICABLE

49   WMT2      2ND TYPE OF WIND MACHINE USED                        0.    0
                                                                   -8.
               MISS            0. MISSING
               MISS           -8. NOT APPLICABLE
                               1. FMC TROPIC BREEZE
                               2. FMC SINGLE PROP GRND
                               3. FMC-BENDIX DUAL GRND
                               4. SINGLE PROP TOP MOUN
                               5. FMC ONLY
                               6. BROGDEX
                               7. KILLEBREW
                               8. FMC DUAL TOP MOUNTED
                               9. DOUBLE PROP TOP MOUN
                              10. FMC-GP 125
```

DOCUMENTATION FOR THE 128 VARIABLES IN THE FILE 'ECON.GRE'

```
REL  VARIABLE  VARIABLE LABEL                                 MISSING  PRT
POS  NAME                                                     VALUES   FMT

 50  NWM2      NO. OF WIND MACHINES OF TYPE 2 IN GROVE           -8.0   1
                                                                  -9.0
               MISS      -9.0 MISSING
               MISS      -8.0 NOT APPLICABLE

 51  FTWM2     FUEL USED BY WIND MACHINE TYPE 2                   0.    0
                                                                  8.
               MISS         0. MISSING
               MISS         8. NOT APPLICABLE
                            1. GASOLINE
                            2. LIQUID PROPANE
                            3. LIQUID BUTANE

 52  FCWM2     FUEL CONSUMPTION RATE OF TYPE 2 WM               -99.0   1
                                                                -88.0
               MISS     -99.0 MISSING
               MISS     -88.0 NOT APPLICABLE

 53  WMT3      3RD TYPE OF WIND MACHINE USED                      0.    0
                                                                 -8.
               MISS         0. MISSING
               MISS        -8. NOT APPLICABLE
                            1. FMC-TROPIC BREEZE
                            2. FMC SINGLE PROP GRND
                            3. FMC-BENDIX DUAL GRND
                            4. SINGLE PROP TOP MOUN
                            5. FMC ONLY
                            6. BROGDEX
                            7. KILLEBREW
                            8. FMC DUAL TOP MOUNTED
                            9. DOUBLE PROP TOP MOUN
                           10. FMC-GP 125

 54  NWM3      NO. OF WIND MACHINES OF TYPE 3 IN GROVE           -8.0   1
                                                                  -9.0
               MISS      -9.0 MISSING
               MISS      -8.0 NOT APPLICABLE

 55  FTWM3     FUEL USED BY WIND MACHINE TYPE 3                   0.    0
                                                                  8.
               MISS         0. MISSING
               MISS         8. NOT APPLICABLE
                            1. GASOLINE
                            2. LIQUID PROPANE
```

DOCUMENTATION FOR THE 128 VARIABLES IN THE FILE 'ECON.GRE'

```
REL  VARIABLE  VARIABLE LABEL                              MISSING  PRT
POS    NAME                                                VALUES   FMT

 55  PTWM3     CONT
                         3. LIQUID BUTANE

 56  PCWM3     FUEL CONSUMPTION RATE OF TYPE 3 WM          -99.0     1
                                                           -88.0

               MISS      -99.0 MISSING
               MISS      -88.0 NOT APPLICABLE

 57  HU        WHETHER HEATERS USED                          0.      0
               MISS          0. MISSING
                             1. YES
                             2. NO

 58  HT1       1ST TYPE OF HEATER USED                       0.      0
                                                            -8.
               MISS          0. MISSING
               MISS         -8. NOT APPLICABLE
                             1. JUMBO CONE
                             2. LAZY FLAME
                             3. SPOT
                             4. RETURN STACK
                             5. SCHEV
                             6. GEORGES
                             7. SUPER HEATER
                             8. RADIANT
                             9. BRADER CENTRAL

 59  NH1       NO. OF TYPE 1 HEATER IN GROVE               -888.     0
                                                           -999.

               MISS      -999. MISSING
               MISS      -888. NOT APPLICABLE

 60  PTH1      FUEL USED BY TYPE 1 HEATER                    0.      0
                                                             8.
               MISS          0. MISSING
               MISS          8. NOT APPLICABLE
                             1. #2 DIESEL

 61  PCH1      FUEL CONSUMPTION RATE OF TYPE 1 HEATER      -99.0     1
                                                           -88.0
               MISS      -99.0 MISSING
               MISS      -88.0 NOT APPLICABLE
```

DOCUMENTATION FOR THE 128 VARIABLES IN THE FILE 'ECON.GRE'

REL POS	VARIABLE NAME	VARIABLE LABEL			MISSING VALUES	PRT FMT
62	HT2	2ND TYPE OF HEATER USED			0. -8.	0
		MISS	0.	MISSING		
		MISS	-8.	NOT APPLICABLE		
			1.	JUMBO CONE		
			2.	LAZY FLAME		
			3.	SPOT		
			4.	RETURN STACK		
			5.	SCHEV		
			6.	GEORGES		
			7.	SUPER HEATER		
			8.	RADIANT		
			9.	BRADER CENTRAL		
63	NH2	NO. OF TYPE 2 HEATER IN GROVE			-888. -999.	0
		MISS	-999.	MISSING		
		MISS	-888.	NOT APPLICABLE		
64	FTH2	FUEL USED BY TYPE 2 HEATER			0. 8.	0
		MISS	0.	MISSING		
		MISS	8.	NOT APPLICABLE		
			1.	#2 DIESEL		
65	FCH2	FUEL CONSUMPTION RATE OF TYPE 2 HEATER			-99.0 -88.0	1
		MISS	-99.0	MISSING		
		MISS	-88.0	NOT APPLICABLE		
66	HT3	3RD TYPE OF HEATER USED			0. -8.	0
		MISS	0.	MISSING		
		MISS	-8.	NOT APPLICABLE		
			1.	JUMBO CONE		
			2.	LAZY FLAME		
			3.	SPOT		
			4.	RETURN STACK		
			5.	SCHEV		
			6.	GEORGES		
			7.	SUPER HEATER		
			8.	RADIANT		
			9.	BRADER CENTRAL		

```
DOCUMENTATION FOR THE  128 VARIABLES IN THE FILE 'ECON.GPE'

REL  VARIABLE  VARIABLE LABEL                              MISSING PRT
POS    NAME                                                 VALUES FMT

67   NH3       NO. OF TYPE 3 HEATER IN GROVE                 -888.   0
                                                             -999.
               MISS        -999. MISSING
               MISS        -888. NOT APPLICABLE

68   FTH3      FUEL USED BY TYPE 3 HEATER                       0.   0
                                                                8.
               MISS           0. MISSING
               MISS           8. NOT APPLICABLE
                              1. #2 DIESEL

69   FCH3      FUEL CONSUMPTION RATE OF TYPE 3 HEATER        -99.0   1
                                                             -88.0
               MISS        -99.0 MISSING
               MISS        -88.0 NOT APPLICABLE

70   HT4       4TH TYPE OF HEATER USED                          0.   0
                                                               -8.
               MISS           0. MISSING
               MISS          -8. NOT APPLICABLE
                              1. JUMBO CONE
                              2. LAZY FLAME
                              3. SPOT
                              4. RETURN STACK
                              5. SCHEV
                              6. GEORGES
                              7. SUPER HEATER
                              8. RADIANT
                              9. BRADER CENTRAL

71   NH4       NO. OF TYPE 4 HEATER IN GROVE                 -888.   0
                                                             -999.
               MISS        -999. MISSING
               MISS        -888. NOT APPLICABLE

72   FTH4      FUEL USED BY TYPE 4 HEATER                       0.   0
                                                                8.
               MISS           0. MISSING
               MISS           8. NOT APPLICABLE
                              1. #2 DIESEL

73   FCH4      FUEL CONSUMPTION RATE OF TYPE 4 HEATER        -99.0   1
                                                             -88.0
               MISS        -99.0 MISSING
```

FILEINFO

DOCUMENTATION FOR THE 128 VARIABLES IN THE FILE 'ECON.GRE'

```
REL  VARIABLE  VARIABLE LABEL                                  MISSING  PRT
POS    NAME                                                     VALUES  FMT

 73  FCH4      CONT
               MISS         -88.0 NOT APPLICABLE

 74  HT5       5TH TYPE OF HEATER IN GROVE                          0.    0
                                                                   -8.
               MISS            0. MISSING
               MISS           -8. NOT APPLICABLE
                               1. JUMBO CONE
                               2. LAZY FLAME
                               3. SPOT
                               4. RETURN STACK
                               5. SCHEV
                               6. GEORGES
                               7. SUPER HEATER
                               8. RADIANT
                               9. BRADER CENTRAL

 75  NH5       NO. OF TYPE 5 HEATER IN GROVE                     -888.    0
                                                                 -999.
               MISS          -999. MISSING
               MISS          -888. NOT APPLICABLE

 76  FTH5      FUEL USED BY TYPE 5 HEATER                           0.    0
                                                                    8.
               MISS            0. MISSING
               MISS            8. NOT APPLICABLE
                               1. #2 DIESEL

 77  FCH5      FUEL CONSUMPTION RATE OF TYPE 5 HEATER            -99.0    1
                                                                 -88.0
               MISS         -99.0 MISSING
               MISS         -88.0 NOT APPLICABLE

 78  HT6       6TH TYPE OF HEATER USED                              0.    0
                                                                   -8.
               MISS            0. MISSING
               MISS           -8. NOT APPLICABLE
                               1. JUMBO CONE
                               2. LAZY FLAME
                               3. SPOT
                               4. RETURN STACK
                               5. SCHEV
                               6. GEORGES
                               7. SUPER HEATER
```

DOCUMENTATION FOR THE 128 VARIABLES IN THE FILE 'ECON.GRE'

```
REL  VARIABLE  VARIABLE LABEL                                  MISSING PRT
POS      NAME                                                  VALUES  FMT


78  HT6        CONT
                          8. RADIANT
                          9. BRADER CENTRAL

79  NH6        NO. OF TYPE 6 HEATER IN GROVE                   -888.    0
                                                               -999.
               MISS       -999. MISSING
               MISS       -888. NOT APPLICABLE

80  FTH6       FUEL USED BY TYPE 6 HEATER                         0.    0
                                                                  8.
               MISS          0. MISSING
               MISS          8. NOT APPLICABLE
                             1. #2 DIESEL

81  FCH6       FUEL CONSUMPTION RATE OF TYPE 6 HEATER           -99.0   1
                                                               -88.0
               MISS       -99.0 MISSING
               MISS       -88.0 NOT APPLICABLE

82  DFSC       DIESEL FUEL STORAGE CAPACITY                    -9999.   0

83  DFOH       DIESEL FUEL ON HAND                             -9999.   0

84  PFSC       PROPANE FUEL STORAGE CAPACITY                   -9999.   0

85  PFOH       PROPANE FUEL ON HAND                            -9999.   0

86  SCOF       STORAGE CAPACITY OF OTHER FUEL                  -9999.   0

87  OFOH       OTHER FUEL ON HAND                              -9999.   0

88  OFC1                                                        NONE    A

89  OFC2                                                        NONE    A

90  OFC3                                                        NONE    A

91  OFC4                                                        NONE    A

92  PDF        PRICE OF DIESEL FUEL ON HAND                      -8.0   1
                                                                 -9.0
               MISS        -8.0 NOT APPLICABLE
               MISS        -9.0 MISSING
```

DOCUMENTATION FOR THE 128 VARIABLES IN THE FILE 'ECON.GRE'

REL POS	VARIABLE NAME	VARIABLE LABEL	MISSING VALUES	PRT FMT
92	PDF	CONT		
93	PPF	PRICE OF PROPANE FUEL ON HAND	-8.0 -9.0	1
		MISS -8.0 NOT APPLICABLE MISS -9.0 MISSING		
94	POF	PRICE OF OTHER FUEL ON HAND	-8.0 -9.0	1
		MISS -8.0 NOT APPLICABLE MISS -9.0 MISSING		
95	OPM1	WHETHER PERM. OIL HEAT USED	NONE	0
		0. PERM. OIL NOT USED 1. PERM. OIL USED		
96	OPM2	WHETHER SPRINKLERS USED	NONE	0
		0. SPRINKLERS NOT USED 1. SPRINKLERS USED		
97	OPM3	WHETHER FLOOD IRRIGATION USED	NONE	0
		0. FLOOD IRRIG. NOT USE 1. FLOOD IRRIG. USED		
98	OPM4	WHETHER OTHER PROTECT METHODS USED	NONE	0
		0. OTHER METHODS-NO 1. OTHER METHODS-YES		
99	OPMC1		NONE	A
100	OPMC2		NONE	A
101	OPMC3		NONE	A
102	OPMC4		NONE	A
103	CT	WHETHER CONTROL THERMOMETER	9.	0
		0. THERMOMETER-NO 1. THERMOMETER-YES MISS 9. MISSING		
104	INFO1		NONE	A

DOCUMENTATION FOR THE 128 VARIABLES IN THE FILE 'ECON.GRF'

REL POS	VARIABLE NAME	VARIABLE LABEL	MISSING VALUES	PRT FMT
105	INFO2		NONE	A
106	INFO3		NONE	A
107	INFO4		NONE	A
108	INFO5		NONE	A
109	INFO6		NONE	A
110	INFO7		NONE	A
111	INFO8		NONE	A
112	INFO9		NONE	A
113	INFO10		NONE	A
114	INFO11		NONE	A
115	INFO12		NONE	A
116	INFO13		NONE	A
117	INFO14		NONE	A
118	INFO15		NONE	A
119	INFO16		NONE	A
120	INFO17		NONE	A
121	INFO18		NONE	A
122	INFO19		NONE	A
123	CNTY	COUNTY	NONE	0

3. HILLSBOROUGH
5. POLK
7. ORANGE
12. LAKES
14. MARION
26. OSCEOLA
27. HIGHLANDS

DOCUMENTATION FOR THE 128 VARIABLES IN THE FILE 'ECON.GRE'

```
REL  VARIABLE  VARIABLE LABEL                                      MISSING  PRT
POS      NAME                                                       VALUES  FMT

123  CNTY      CONT
                         30. HARDEE
124  PROT      FROST PROTECTION METHODS USED                          0.     0
               MISS       0. MISSING
                          1. WIND MACHINES ONLY
                          2. HEATERS AND WIND
                          3. NO PROTECTION
                          4. HEATERS ONLY
125  FUEL      TYPES OF FUEL USED FOR FROST PROTECTION               NONE    0
                          0. NO FUEL USED
                          1. GASOLINE ONLY
                          2. PROPANE ONLY
                          3. DIESEL ONLY
                          4. GAS AND PROPANE
                          5. GAS AND DIESEL
                          6. DIESEL AND PROPANE
                          7. GAS,DIESEL,PROPANE
126  ECONYR    PROJECT YEAR                                          NONE    0
                          1. '76-'77 SEASON
                          2. '77-'78 SEASON
                          3. '78-'79 SEASON
                          4. '79-'80 SEASON
127  FCICCODE  CORRECT FCIC CODE                                **********   0
128  FZONE     FORECAST ZONE OF GROVE                                 -9.    0
                          1. ZONE 9
                          2. ZONE 11
                          3. ZONE 13
                          4. ZONE 14
                          5. ZONE 15
```

The WETHR1 Program

The WETHR1 program accepts as input a set of hourly temperature readings for each of N thermometers and N nights. Temperature readings are taken only for those hours when the temperature is below 32°F (or when the temperature drops to 32° or below during the course of an hour). The temperature data is packed into the array VALUES, with pointers to the beginning of each new case. Each case is further identified by an INDEX, a THERM (thermometer code), a DATE, and a MNTEMP (minimum observed temperature).

Before calculations are begun, subroutine BISORT is called to sort the cases, first by DATE and then by THERM. The efficient sort algorithm on which BISORT is based is known as a binary insertion sort. It operates on the principle of bisection, to locate the particular point at which each new piece of data should be inserted into the sorted array. In the case of the weather data, the only data which is physically sorted is the INDEX, which points to all of the other data.

In a loop over all the cases, the subroutine AREA is called to perform the degree-hour calculations. Arguments for the subroutine are a pair of consecutive hourly temperature readings (VALUE1 and VALUE2, with VALUE1 the largest), the DEGHRS array, and the THRSLD (threshold temperature for degree-hour calculation). Each time AREA is called, the degree-hours in each 1° temperature bracket below THRSLD are calculated, for the hour interval specified by VALUE1 and VALUE2. DEGHRS is a running total of the degree hours in each bracket. AREA uses the straight line between VALUE1 and VALUE2 to approximate the thermograph curve from which the temperature readings were taken.

When the degree-hour calculations are complete for each particular case, a variable-length output record of the following form is printed and punched: a header card containing THERM, DATE, MNTEMP, NDEG (the number of degree-hour brackets), and then one or several cards containing a total of NDEG degree-hour data points. When the loop over cases is complete, the program ends.

WETHR1: INPUT DATA SPECIFICATIONS

1st card: Specifies the number of cases for which degree-hours are to be calculated. This data (called by the variable name NOCARD) is punched in I4 format in columns 1-4.

Intervening cards: These cards contain the actual data needed for degree-hours calculations. There must be exactly NOCARD records of the following form:

1. Header card - contains INDEX (sequential index), THERM (thermometer code), DATE (4 digits*), NOHRS (number of temperature observations) and MNTEMP (minimum observed temperature.)

   Format: INDEX THERM DATE NOHRS MNTEMP
   (I4, 5x, I3, 5x, I4, 5x, I2, 5x, F4.0)

2. Data Card(s) - contain NOHRS temperature readings (VALUES).

   Format: (8x,9F8.2), as many cards as are needed. When the VALUES are exhausted for one case, a new header card signals the beginning of the next case.

Final card: Specifies the threshold temperature for input (THRSLD). This is punched in F4.1 format in columns 1-4.

* In the following form: 1=1976
2=1977 then 1001 is Jan. 1, 1976
3=1978 2365 is Dec. 31, 1977 etc.
4=1979

WETHR1: OUTPUT SPECIFICATIONS

The output from WETHR1 is a set of records of the following form:

1. Header card - contains J (a sequential index), THERM, DATE, MNTEMP, NDEG (number of degree-hour data points).
   Format: J THERM DATE MNTEMP NDEG
   (I4,5x, 13, 5x,I4, 5x,F4.1, 5x,I2)

2. Data card(s) - contain NDEG degree-hours data points (DEGHRS).
   Format: (8x,9F8.2), as many cards as are needed. When the DEGHRS are exhausted for one case, a new header card signals the beginning of the next case.

   There will be NOCARD of these cases.

The WETHR2 Program

The flowchart of Figure E.10 succinctly explains the workings of WETHR2, the program for adjusting the previously calculated control thermometer degree-hour data to the groves. It is also used to adjust the durations taken directly from the NWS thermographs, provided that these are punched in the appropriate format. The program is completely straightforward, except that so as to avoid a table lookup, it has been designed to expect input data in a certain sorted order. This enables it to step through the data (leaving a few pointers) rather than to do an exhaustive search each time it needs to determine whether there are any groves associated with a given thermometer (and what the adjustment factors are) or whether the DATE corresponds to one of the values of the ADVECT vector (the dates when an advective freeze took place). The program itself sorts the grove data records (GROVID, THERM, FACTOR), in ascending order by THERM. It uses the subroutine BISORT (previously described) for this purpose.

A second major set of input data, which is the weather records, is sent out from WETHR1 sorted by thermometer and date. <u>If durations are coded directly from the thermographs, this data must be sorted prior to its use as input data to WHETHR2. See output specifications for WETHR1 for details</u>.

Other inputs to WETHR2 include NGROVE (number of records containing grove data as described above) and NCASE (number of weather data records); THRIN (input threshold) and THROUT (output threshold temperature); the ADVECT vector (list of advective freeze dates.)

Output from WETHR2 is a set of records of the following form: GROVID, THERM, DATE, MNTEMP (adjusted minimum temperature), NDEG (number of adjusted data points), and finally the adjusted DEGHRS (degree-hours) or DURATS (durations) below THROUT. There will be NDEG of these data points.

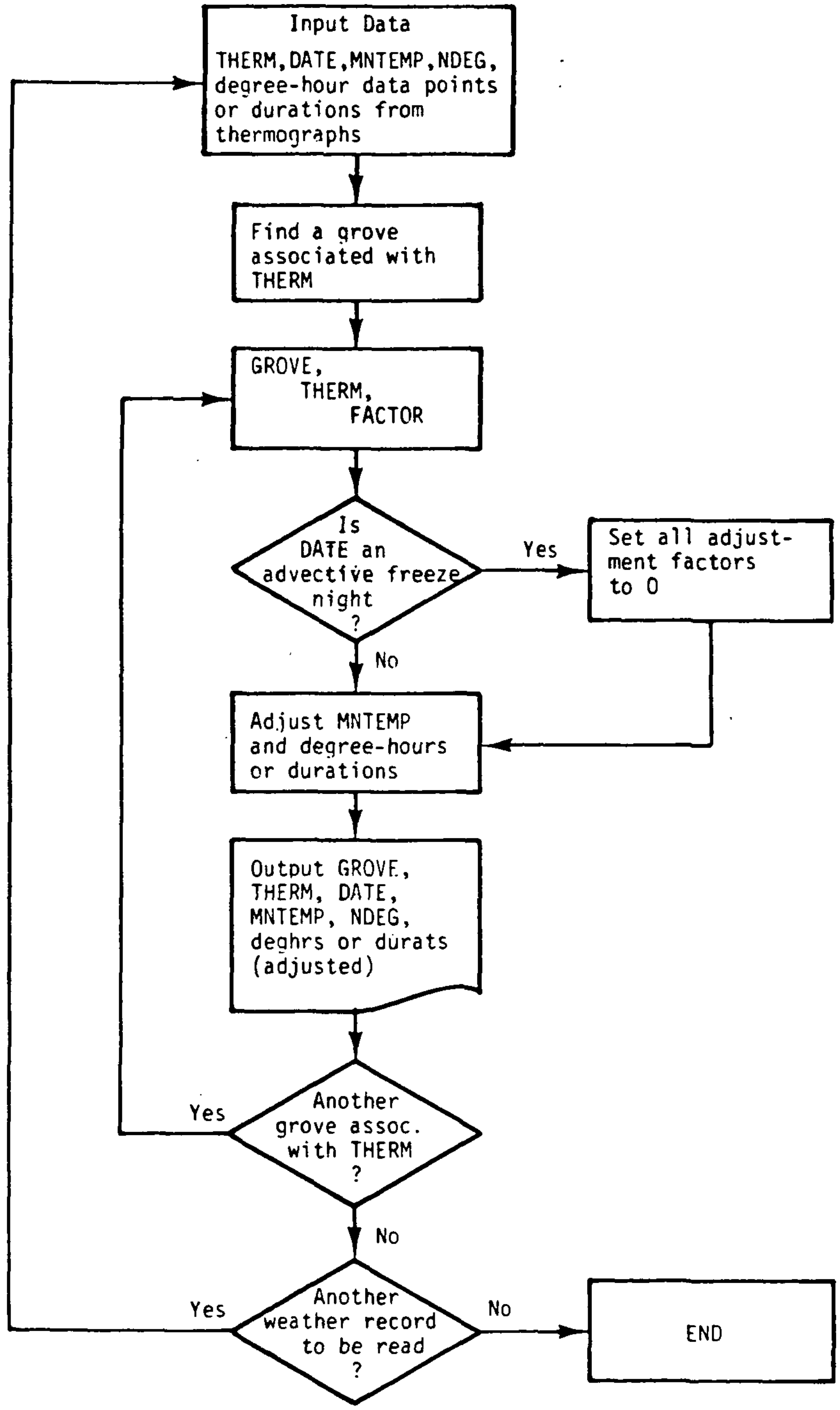


Figure E.10 The WETHR2 Program

WETHR2: INPUT DATA SPECIFICATIONS

The input data for WETHR2 can be broken down into four parts (placed back-to-back in the input data deck). They are as follows:

Set 1: Card one contains NGROVE (number of pieces of grove information) and NCASE (number of output records from WETHR1 program or duration records--this should be the same as NOCARD).
Format: NGROVE NCASE
(F4.1, 5x, F4.1)

Card two contains THRIN (input threshold--same as THRSLD from WETHR1) and THROUT (output threshold--lower than THRIN).
Format: THRIN THROUT
(F4.1,5x, F4.1)

Set 2: Grove data. Each record is one card, containing the following information: INDEX (sequential index), GROVID (six digits), CONTRL (code for control thermometer associated with grove), FACTOR (adjustment factor for grove).
Format: INDEX GROVID CONTRL FACTOR
(I4, 5x, 16, 5x, 13, 5x, 12)

Set 3: Advective frost/freeze dates. Each record is one card, with a date punched in columns 1-4 (same date code as described in WETHR1 documentation).

Set 4: Degree-hour output from WETHR1 or durations punched in the same format as the degree-hour date.

NOTE: THE VARIABLE NADV (NUMBER OF ADVECTIVE FREEZE DATES) IS SET WITHIN THE PROGRAM. THIS MUST BE CHANGED EACH YEAR TO CORRESPOND TO THE CORRECT NUMBER OF ADVECTIVE FREEZES.

WETHR2: OUTPUT SPECIFICATIONS

The output from WETHR2 is a set of records of the following form:

1. Header card - contains KWRITE (a sequential index), GROVID, THERM, DATE, LOTEMP (adjusted minimum temperature), KDEGS (number of adjusted degree-hours or durations to be output).

   Format: KWRITE GROVID THERM DATE LOTEMP KDEGS
   (I4, 5x, I6, 5x, 13, 5x, I4, 5x, F4.1, 5x, I2)

2. Data card(s) - contain KDEGS degree-hour data points (DEGS).
   Format: (9F8.2), as many cards as are needed. When the DEGS are exhausted for one case, a new header card signals the beginning of the next case.

The WETHR3 Program

The WETHR3 program requires three sets of data in order to calculate severity of frost coefficients for citrus fruit and trees for each grove and cold night. First, severity coefficients obtained from NWS are read into the arrays CHART1 through CHART4. CHART1 contains coefficients for early oranges, midseason oranges, and valencias. CHART2 contains coefficients for specialty fruit, and CHART3 holds those for grapefruit. CHART4 applies for all types of citrus trees.

The next set of data to be read in is a set of records giving GROVID, variety of citrus, month of harvest, and control thermometer for each grove in the sample. The variety of citrus is used to determine which chart to select coefficients from for calculating severity of frost. The harvest date information acts as a flag: for any date after a grove's designated harvest date, the severity of frost is naturally set to 0. The control thermometer (GTHERM) for each grove is used as a sort key only; after the grove information is read in, it is sorted using BISORT, first on GROVID and then on GTHERM. This makes it possible for the program to step through this data rather than making an exhaustive search each time it needs to determine a variety of citrus or month of harvest for a particular grove.

The third and final set of input data consists of the output records from WETHR2 (that is, the adjusted durations for each grove and cold night). As each of these records is read, the correct grove information is found and it is determined which set of severity coefficients to use in calculating severity of frost for fruit. Subroutine FRUIT is called, returning the severity of frost for fruit (SUMFT). Subsequently, subroutine TREES is called to calculate the severity of frost for trees (SUMTRE). Output records are both printed and punched on cards, and consist of values for the variables GROVID, DATE, THERM (control thermometer for grove), LOTEMP (adjusted minimum temperature), SUMFT, and SUMTRE.

WETHR3: INPUT DATA SPECIFICATIONS

The input data for WETHR3 can be broken down into three major parts (placed back-to-back in the input data deck). They are as follows:

<u>Set 1</u>: 4 sets of 28 cards in 12F6.2 Format giving severity coefficients for three types of fruit (sets 1-3) and for trees (set 4). These cards are provided with the program deck and are printed in the program listing for WETHR3.

<u>Next card</u>: This card contains NGROVE (in I4 Format)--the number of groves for which grove information is supplied.

<u>Set 2</u>: These cards contain grove data for each grove in the sample. There must be exactly NGROVE records in the following Format:

```
INDEX   GROVID   FT   MH   GTHERM
(I4, 5x,I6,5x,I2,5x,I2,5x,I3)
```

where INDEX is a sequential index used for sorting; FT is variety of citrus; MH is month of harvest; and GTHERM is control thermometer for the grove.

<u>Next card</u>: This card contains NTHERM (in I4 Format)--the number of output records from WETHR2.

<u>Set 3</u>: Output from WETHR2. (See WETHR2 documentation for details.)

WETHR3: OUTPUT SPECIFICATIONS

The output from WETHR3 is a set of printed and punched records containing the variables ID (Grove Identification number), DATE (coded as indicated earlier), THERM (control thermometer with which grove is associated), LOTEMP (adjusted minimum temperature for grove), SUMFT (severity of frost index for fruit), and SUMTRE (severity of frost index for trees).

```
FORMAT:  ID    DATE    THERM   LOTEMP   SUMFT   SUMTRE
        (I6,5x,I4,5x,I3, 5x,F4.1,5x,F8.2,5x,F8.2)
```

These records contain all nonzero severities for every grove and night. There are no records for those nights in each grove when severity for fruit and trees was 0 according to the calculation procedure outlined throughout the WETHR documentation.

E.3 Report Generation

E.3.1 Nature of the Reports

The summary reports sent to the growers at the end of the season were designed to provide a detailed account of all of the data which ECON had collected during the season regarding the management of each individual grove. Section I of the report displays all of the information which was provided on the Grove Background Report. Section II provides, for every night for which an activity report was sent in by the grower, the forecast issued by NWS, and then some information about what type of action was undertaken in the grove and in the rest of the county. Section III is a table giving the total and per acre costs of protection for each night in the individual grove and in the county. The final line of the table gives season totals for these variables. Section IV of the report details the grove's physical losses for each cold night in the season. The final section, Section V, consists of a table giving the grower's confidence in the forecasts issued by NWS, on each night for which he filed an activity report. Countywide averages are provided for comparison. The final line gives season averages for the particular grower's confidence in the forecasts, and for the countywide confidence in NWS.

A sample season summary report in included in Appendix B.

E.3.2 The REPT Program

Figure E.11 gives an overview flowchart of REPT, the FORTRAN program which prints the season summary reports for the growers. The operation of the program is straightforward; it converts coded data into attractive, easy-to-read reports and calculates certain countywide summary statistics which are included in each report for comparative purposes.

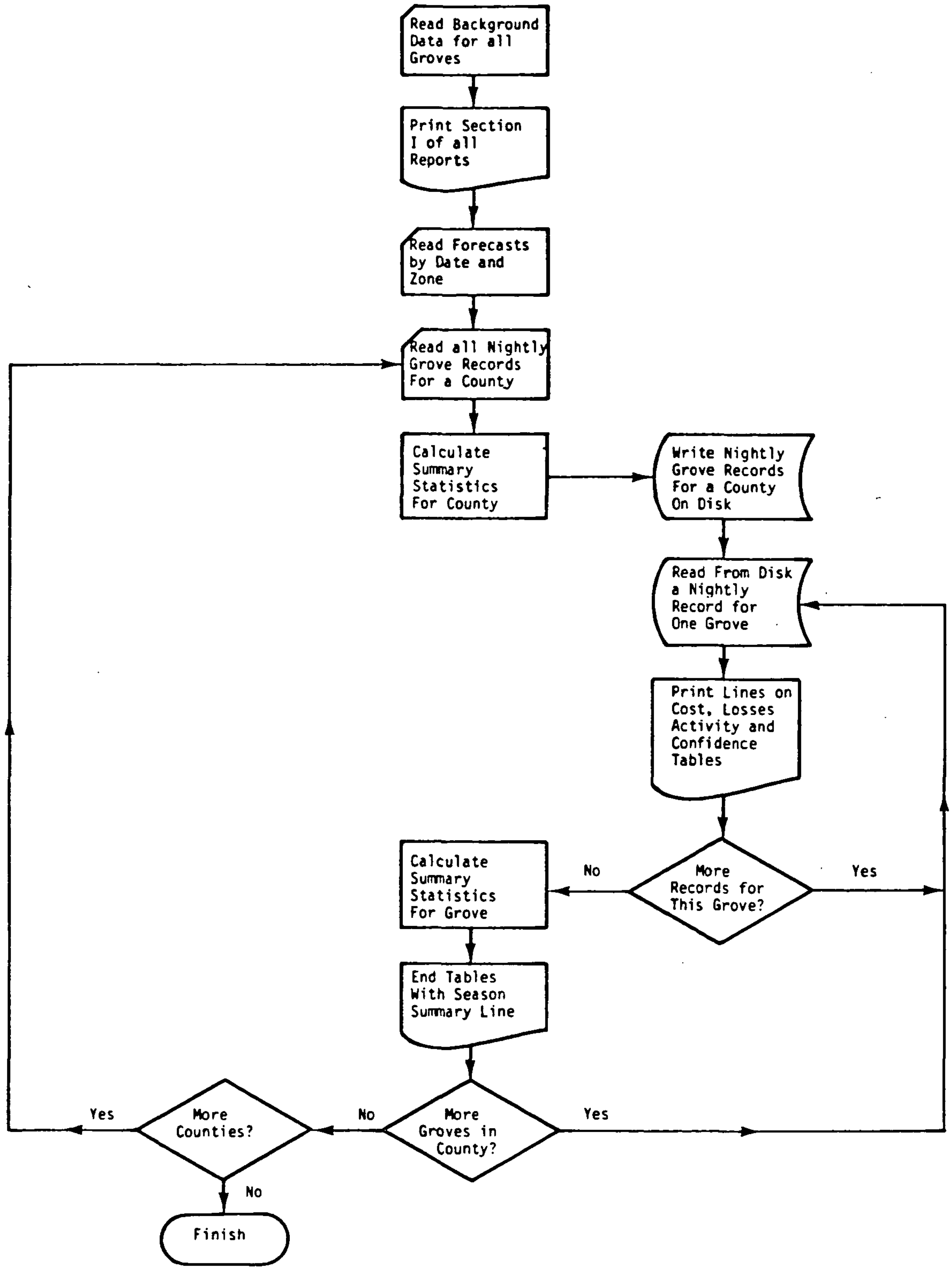


Figure E. 11 Overview Flowchart of REPT

An important set of input data for the REPT program is the nightly forecasts for all applicable zones and cold nights. These are punched onto cards directly from the forecast sheets sent to ECON by the Florida NWS representatives, and are used in preparing the nightly activity tables in Section II of the grower reports.

The grove background information from the green form database and the grove activity, cost and loss records from the white-pink database make up the bulk of the input data. These records are dumped from the SPSS databases onto cards for input into the report writer. The nightly records are read through twice by the program, once to calculate county summary statistics, and a second time for the actual line-by-line printing of the reports. When all of the reports for one county have been generated, the program turns its attention to the input data for the next county. When all of the counties have been exhausted, the program ends.

APPENDIX F

CONTROL GROUP FRUIT LOSSES, SOCIAL LOSSES AND REVENUE GAINS BY COUNTY

Table F.1 Hillsborough County Sample Fruit Losses, Social Losses and Revenue Gains*

Fruit Variety	Fresh Fruit				Processed Fruit				Totals and Averages			
	Production Before	Production Lost	Revenue Gain	Social Loss	Production Before	Production Lost	Revenue Gain	Social Loss	Revenue Gain	Social Loss	Revenue Gain Per Acre ($/acre)	Social Loss Per Acre ($/acre)
Early & Mid	38.4		53.8		58.1		2.9		56.7		394.	
Valencias	17.2		44.7		15.5	4.6	1.5	8.4	46.2	8.4	495.	90.
Temples	0.6		0.2						0.2		100.	
Tangelos	24.5		2.5						2.5		26.	
Tangerines	41.2	7.4	137.7	21.6		-4.5	0	0	137.7	21.6	1,306	205.
Grapefruit	3.5		4.3						4.3		119.	
							County Totals and Averages:		247.6	30.0	517.	63.

*Units are thousands of boxes or thousands of dollars, except where noted.

Table F.2 Polk County Sample Fruit Losses, Social Losses and Revenue Gains*

Fruit Variety	Fresh Fruit				Processed Fruit				Totals and Averages			
	Production Before	Production Lost	Revenue Gain	Social Loss	Production Before	Production Lost	Revenue Gain	Social Loss	Revenue Gain	Social Loss	Revenue Gain Per Acre ($/acre)	Social Loss Per Acre ($/acre)
Early & Mid	128.0	33.6	106.9	48.7	163.6	42.2	-25.6	124.5	81.3	173.2	124.	264.
Valencias	179.0	102.2	51.5	281.1	198.9	16.9	112.0	30.9	163.5	312.0	155.	296.
Temples	55.2	29.3	-60.0	76.2		-21.5	9.7	-9.7	-50.3	66.5	-422.	558.
Tangelos	7.7		0.8						0.8		60.	
Tangerines	54.7	41.5	11.2	121.2		-24.6	0	0	11.2	121.2	50.	545.
Grapefruit	17.3	5.9	4.0	13.8	9.6	- 7.9	3.9	-5.1	7.9	8.7	76.	84.
County Totals and Averages:									214.4	681.6	99.	314.

*Units are thousands of boxes or thousands of dollars, except where noted.

Table F.3 Orange County Sample Fruit Losses, Social Losses and Revenue Gains*

Fruit Variety	Fresh Fruit				Processed Fruit				Totals and Averages			
	Production Before	Production Lost	Revenue Gain	Social Loss	Production Before	Production Lost	Revenue Gain	Social Loss	Revenue Gain	Social Loss	Revenue Gain Per Acre ($/acre)	Social Loss Per Acre ($/acre)
Early & Mid	192.4	16.5	233.9	23.9	105.8	7.7	-0.9	22.7	233.0	46.6	523.	105.
Valencias	16.8	11.0	-0.9	30.3	46.9	11.3	10.3	20.7	9.4	51.0	51.	278.
Temples	115.3	44.3	-77.9	115.2		-25.4	11.4	-11.4	-66.5	103.8	-222.	347.
Tangerines	21.0		89.2						89.2		1,487.	
Grapefruit	12.0	10.8	-17.1	25.3		-10.0	6.0	-6.5	-11.1	18.8	-566.	959.
County Totals and Averages:									254.0	220.2	252.	219.

*Units are thousands of boxes or thousands of dollars, except where noted.

Table F.4 Lake County Sample Fruit Losses, Social Losses and Revenue Gains*

Fruit Variety	Fresh Fruit				Processed Fruit				Totals and Averages			
	Production Before	Production Lost	Revenue Gain	Social Loss	Production Before	Production Lost	Revenue Gain	Social Loss	Revenue Gain	Social Loss	Revenue Gain Per Acre ($/acre)	Social Loss Per Acre ($/acre)
Early & Mid					161.7	8.1	1.6	23.9	1.6	23.9	5.	69.
Valencias	7.7		20.0		585.1	77.4	268.6	141.6	288.5	141.6	212.	104.
Temples	37.5	5.6	-0.7	14.6		-3.4	1.5	-1.5	0.8	13.1	5.	88.
Tangelos	39.4		3.9						3.9		23.	
Tangerines	29.2	18.4	31.2	53.7		-23.7	0	0	31.2	53.7	185.	318.
Grapefruit	56.4		69.9						5.1		53.	
								County Totals and Averages:	331.1	232.3	150.	105.

*Units are thousands of boxes or thousands of dollars, except where noted.

Table F.5 Marion County Sample Fruit Losses, Social Losses and Revenue Gains*

Fruit Variety	Fresh Fruit				Processed Fruit				Totals and Averages			
	Production Before	Production Lost	Revenue Gain	Social Loss	Production Before	Production Lost	Revenue Gain	Social Loss	Revenue Gain	Social Loss	Revenue Gain Per Acre ($/acre)	Social Loss Per Acre ($/acre)
Early and Mid	13.5	5.6	6.9	8.1	19.5	-0.9	1.7	-0.7	8.6	7.4	67.	58.
Valencias					16.9	0.7	11.1	1.3	11.1	1.3	247.	29.
Tangerines	7.5		10.6						10.6		1,060.	
Grapefruit					0.8	0.2	-0.2	0.1	-0.2	0.1	-40.	20.
								County Totals and Averages:	30.1	8.8	160.	47.

*Units are thousands of boxes or thousands of dollars, except where noted.

Table F.6 Osceola County Sample Fruit Losses, Social Losses and Revenue Gains*

Fruit Variety	Fresh Fruit				Processed Fruit				Totals and Averages			
	Production Before	Production Lost	Revenue Gain	Social Loss	Production Before	Production Lost	Revenue Gain	Social Loss	Revenue Gain	Social Loss	Revenue Gain Per Acre ($/acre)	Social Loss Per Acre ($/acre)
Early and Mid	20.0	20.0	-15.0	29.0	9.3	-18.0	14.9	-14.0	-0.1	15.0	-1.	168.
Valencias	4.0	4.0	-5.8	11.0	61.8	-3.3	53.6	-6.0	47.8	5.0	348.	36.
Tangerines	6.9	0.7	25.8	2.0					25.8	2.0	1,137.	88.
Grapefruit	60.0		74.4						74.5		745.	
								County Totals:	148.0	22.0	423.	63.

*Units are thousands of boxes or thousands of dollars, except where noted.

*Table F.7 Highlands County Sample Fruit Losses, Social Losses and Revenue Gains**

Fruit Variety	Fresh Fruit				Processed Fruit				Totals and Averages			
	Production Before	Production Lost	Revenue Gain	Social Loss	Production Before	Production Lost	Revenue Gain	Social Loss	Revenue Gain	Social Loss	Revenue Gain Per Acre ($/acre)	Social Loss Per Acre ($/acre)
Early and Mid	27.3	27.3	-20.5	39.6	12.1	-24.2	20.0	-18.9	-0.5	10.7	6.	131.
Valencias	12.0		31.2		4.0	2.8	-3.2	5.1	28.0	5.1	532.	97.
Temples	55.0	55.0	-132.0	143.0		-37.1	16.7	-16.7	-115.3	126.3	-961.	1,053.
County Totals and Averages:									-87.8	142.1	-345.	488.

*Units are thousands of boxes or thousands of dollars, except where noted.

Table F.8 Hardee County Sample Fruit Losses, Social Losses and Revenue Gains*

Fruit Variety	Fresh Fruit				Processed Fruit				Totals and Averages			
	Production Before	Production Lost	Revenue Gain	Social Loss	Production Before	Production Lost	Revenue Gain	Social Loss	Revenue Gain	Social Loss	Revenue Gain Per Acre ($/acre)	Social Loss Per Acre ($/acre)
Early and Mid					34.0	1.3	0.7	0.5	0.7	0.5	7.	5.
Valencias	5.2		13.5		11.0		7.2		20.7		476.	
Temples	5.0		2.0						2.0		200.	
Tangelos	10.5	5.3	-9.8	10.6					-9.8	10.6	-280.	303.
Tangerines	4.0		17.0						17.0		1,889.	
								County Totals and Averages:	30.6	11.1	156.	57.

*Units are thousands of boxes or thousands of dollars, except where noted.

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