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PLANT COVER, SOIL TEMPERATURE, FREEZE, WATER STRESS, AND EVAPOTRANSPIRATION CONDITIONS

E79-10080
CR-157973

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15. Supplementary Notes

16. Abstract

We have been able to read the one data tape received without difficulty. A reprint, "Estimating Sugarcane Damage From Regional Freeze Night Temperature Measurements," Inter. Sugar J. (1978, Vol. 80, pp. 232-237), authored by P. R. Nixon, D. E. Phinney, and M. R. Gautreaux is appended. It illustrates how satellite surface temperature observations could be used to indicate the coldest areas in the agricultural landscape, and which fields of crops such as sugarcane might be harvested first after a freeze to minimize losses.

17. Key Words (Selected by Author(s))	18. Distribution Statement
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TYPE II QUARTERLY PROGRESS REPORT

September 1, 1978 to December 1, 1978

A. Problems:

Delivery of data products has been slower than anticipated.

B. Accomplishments:

1. HCMM data tapes.

Since the last report, one HCMM data tape, a "test" tape for a scene north of our test site obtained May 14, 1978, has been received. The following parts of the tape were read on our computer facilities without any difficulty: DIRECTORY, HEADER, ANNOTATION, IMAGE, ANCILLARY, and TRAILER.

2. Sugarcane damage from a regional freeze.

A reprint from The International Sugar Journal (1978, Vol. 80, pp. 232-237) entitled "Estimating Sugarcane Damage From Regional Freeze Night Temperature Measurements" authored by Paul R. Nixon, Dale E. Phinney, and Manuel R. Gautreaux is attached as Appendix A of this report. The work related NOAA-2 surface temperature observed on the night of a December, 1973, freeze to recoverable sugar in the commercial harvest of the fields. Significant correlations were obtained between crop damage, indicated by sugar content losses, and the satellite-observed surface temperature for the 45 fields studied. The data indicate that promptly-processed thermal data from satellites such as HCMM could aid in scheduling the harvest of freeze-damaged crops so as to minimize loss.

C. Significant Results:

None.

D. Publications:

See Appendix A.

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E. Recommendations:

We have studied the orbit maps and listed every coverage date from May 16, 1978, to July 9, 1979 for both day and night overpasses. We found that reference days 3, 8, 9, and 14 give us daytime coverage and reference days 1, 6, 11, and 12 yield nighttime coverage for our test site (97° to 100° W longitude, 25°50' to 26°40' N latitude). There will be 211 coverages during the May 1978 to July 1979 period. Some of them will be of high interest, and since we keep daily insolation records we usually have a good idea which overpasses may be usable. We desire to work directly with the HCMM data processing personnel at Goddard to lighten their load yet get the scenes we need by keeping them informed of the time periods we need the data for and cloud conditions that were experienced.

F. Funds Expended:

Allotment for FY 78 - - - - - - - - - - -	$45,240
Allotment for FY 79 - - - - - - - - - - -	50,000
	95,240
Location and Indirect PROGRAM Costs - -	26,673
Other costs through 12/6/78	
Salaries - - - - - - - - - - - - - - -	31,874
Travel & Trans. of Persons - - - - -	3,949
Trans. of Things - - - - - - - - - -	21
Services & Supplies - - - - - - - -	8,484
Equipment - - - - - - - - - - - - -	3,247
Total	$74,248
Balance	$20,992

G. Data Utility:

No comment.

APPENDIX A

Reprinted from The International Sugar Journal, 1978, **80**, 232-237.

Estimating sugar cane damage from regional freeze night temperature measurements

PAUL R. NIXON*, DALE E. PHINNEY† and MANUEL R. GAUTREAUX‡
(Soil, Water and Air Sciences, Southern Region, Science and Education Administration, USDA, and the Texas A & M Agricultural Research and Extension Center, Weslaco, Texas, USA)

SUGAR cane growers are greatly concerned about cold night temperatures because of the possibility of cane damage from subfreezing conditions. Damage is most likely during clear, calm nights, when a high pressure system follows cold front passage, and radiational cooling lowers plant temperatures below critical levels. Such conditions prevailed in the Lower Rio Grande Valley (LRGV) of Texas on the night of 20th-21st December 1973. Freezing temperatures were reached long before dawn at all locations and remained long enough to cause freeze damage to nearly all unharvested sugar cane.

Using data from this event, this paper addresses the question: Can the relative magnitudes of freeze damage be estimated, field by field, from temperature measurements made during the freeze night? If this is possible, a method free of human bias is available for rescheduling harvesting operations after a freeze so as to minimize loss from sugar cane deterioration.

The setting

Fig. 1 shows the sugar cane growing portion of the LRGV. The cane fields are usually not concentrated; rather they are scattered throughout the agricultural portions of the extensive flood plain of the Rio Grande River. Lack of topographical relief precludes the establishment of well-defined nocturnal cold air drainage patterns. Temperatures are influenced by the proximity of the warm water of the Gulf of Mexico and from smaller bodies of water within the area. Also contributing is surface air drift, which varies in direction and velocity depending upon prevailing conditions. Significant in local temperatures is the soil moisture status and the extent and type of vegetative cover. During the 1973 freeze, the very dry soil of the LRGV (except for a few recently irrigated fields and groves) contributed to the severity of the freeze.

Nearly all fields after the freeze had time-dependent deterioration of cane. Similar sugar content decreases after a hard freeze have been observed by many others[1]. An attempt was made to minimize sugar loss in the LRGV by rescheduling the order in which fields were harvested according to the extent of deterioration shown by laboratory analyses of sugar cane samples. This cooperative effort by the USDA, Texas A & M Agricultural Experiment Station, and the Rio Grande Valley Sugar Growers Association is credited with partially limiting the freeze loss. Difficulties with this approach are the requirements of adequate field sampling and the laboratory time involved.

Analysis approach

In this paper, mill records of recovered sugar of the harvested sugar cane are compared with temperature measurements made on the night of the freeze. These records of % recoverable sugar on an operational scale are considered to be the most practical indicator of freeze damage. Comparison of yield weights would be more confounded by management practices during the season and by other factors, such as site fertility. In this study, we examined 45 fields of 16·2 ha (40 acres) or larger of N:Co 310 cane. This variety, the most widely grown in the LRGV, is late-maturing; the freeze occurred before maturity, and maximum sugar contents had not yet been reached.

Temperature criteria

We estimated freeze-night temperatures at each of the fields using four different criteria: (1) minimum air temperature, (2) degree-hours of below-freezing air temperature, (3) surface temperature, indicated by satellite from the evening overpass (2107 CST), and (4) estimated surface temperature at dawn, determined by adjusting satellite data.

With each of the respective criteria, we divided the fields into three temperature classes (cold, tepid, warm) of 15 fields each. The temperature ranges of the fields in each classification are listed in Table I. Details of the temperature criteria are given below. Interpolated temperature determinations were computer-estimated, using the latitude and longitude locations of the sugar cane fields and the weather stations.

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† Principal Scientist, Lockheed Electronics Co., Houston, Texas.
‡ System Analyst, Texas A. & M. Agric. Expt. Sta., Weslaco, Texas.

[1] Miller & Gascho: *Proc. Amer. Soc. Sugar Cane Tech.*, 1974, 36–41.

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Table I. Range of temperatures in N:Co 310 sugar cane fields [16·2 ha (40 acres) or larger] during the night of 20th-21st December 1973, in the Lower Rio Grande Valley, Texas

	Temperature, by four criteria			
	Min.air	*Degree-hour*	*Surface (by satellite)*	*Adjusted satellite*
	°C			
Cold fields	—6·6 to —5·5	40 to 27	—4·8 to —0·8	—12·4 to —7·8
Tepid fields	—5·5 to —4·4	27 to 20	—0·7 to +0·8	—7·6 to —6·3
Warm fields	—4·4 to —3·8	20 to 17	+0·8 to +4·9	—6·3 to —1·8

Degree-hours. The summation, hour by hour throughout the freezing period, of the number of degrees Celsius that air temperature was below freezing supplied the degree-hours. This information was obtained for each field location by interpolating data from the four nearest weather stations in a manner similar to that used for

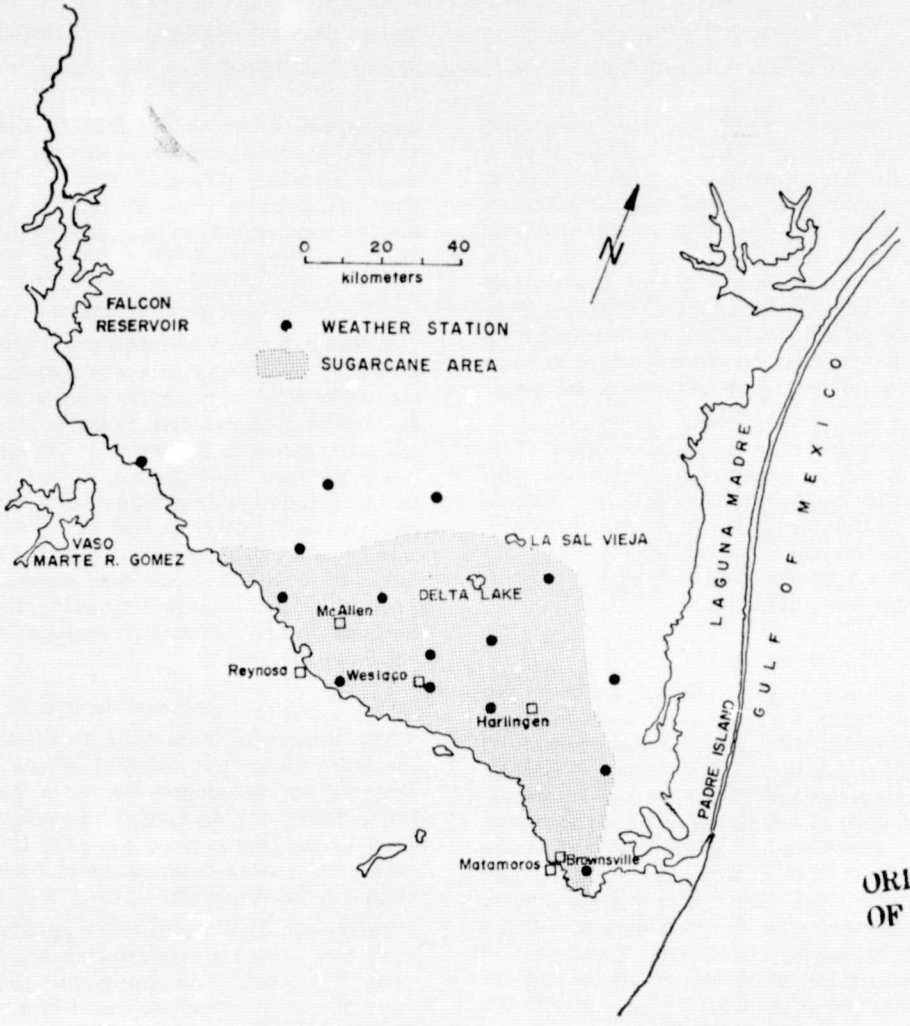

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Fig. 1. Locations of weather stations in respect to the sugar cane growing area of the Lower Rio Grande Valley, Texas.

Minimum air temperature. The minimum air temperatures in each field were estimated by interpolating data from the four weather stations operated cooperatively by the National Weather Service nearest to the field. The weather station minimum temperatures were weighted according to the inverse of their distance from the fields. Four stations were used in estimating the field temperature so as to limit using stations only on a cold (or warm) side of a field and to reduce the influence of an atypical weather station location.

This approach gave a relatively small range of minimum temperatures of 2·8 C among the sugar cane field locations (Table I). A similar temperature range (0·1 C higher) was measured at the 10 weather stations within the cane growing area (shaded area, Fig. 1). Table I shows that the temperature range of the 15 coldest fields was about twice that of the 15 warmest fields (1·1 *vs.* 0·6 C).

determining minimum air temperatures. Thermograph records from the stations showed the customary lower temperature trend throughout the night; however, some stations had periods of fluctuating temperature during the night. Since these irregularities did not fit a regional pattern, local influences were suggested. To avoid imposing local irregularities on fields some distance from the weather stations, the degree-hours determined for the fields were based on smoothed temperature decreases to the minimum values[2].

The accumulated freeze effect, expressed in degree-hours, was more than twice as great for the coldest field as for the warmest field (Table I). The degree-hours of the 15 tepid fields ranged about twice that for the 15 warm fields. Similarly, the range of degree-hours observed in the cold fields was twice that of the tepid fields, or about four times that of the warm fields.

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Estimating sugar cane damage from regional freeze night temperature measurements

Satellite-indicated surface temperatures. Current and forthcoming generations of earth-orbiting satellites, equipped with high resolution thermal scanners, are greatly increasing the practicality of obtaining land surface temperatures over large areas. In this study to estimate surface temperatures at sugar cane field locations, we used very high resolution thermal infrared (10·5 to 12·5 μm) data from the NOAA-2 satellite in polar orbit, 1450 km above the earth, that orbited the earth twice daily[3]. The night time pass at 2107 hr CST, 20th December 1973, supplied the information discussed here[4]. Fig. 2 is a representation of the variations in night time surface temperature of a part of the test area (about 90 × 140 km) shown in Fig. 1. It is a photograph of the cathode ray tube of an interpretation system upon which the satellite data image was displayed. Warm areas appear lighter and cold areas darker. On the right side of the figure, the warm water of Laguna Madre forms a "ridge" between the colder areas of Padre Island and the mainland.

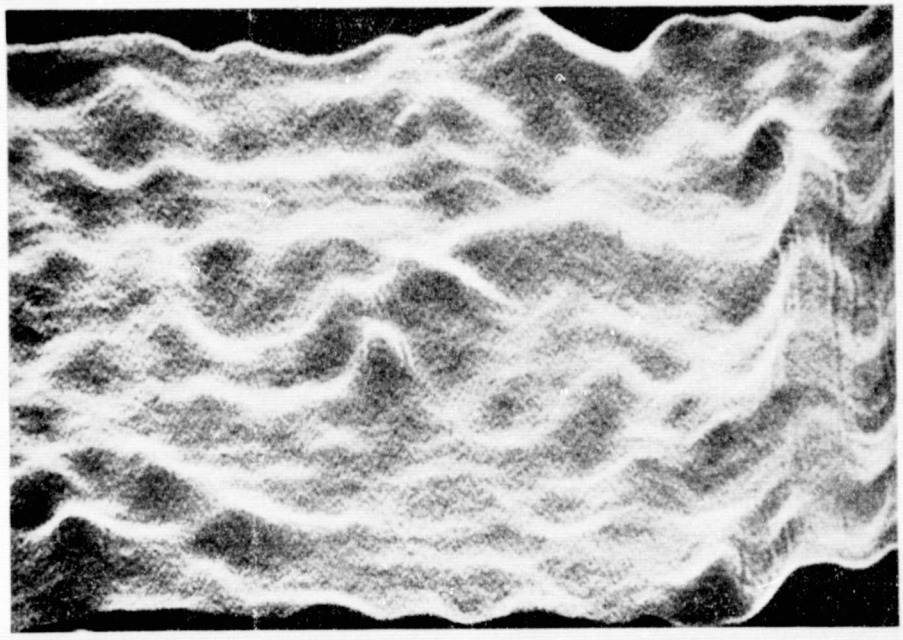

Fig. 2. Representation of surface temperatures of a portion of the Lower Rio Grande Valley at 2107 CST hours, 20th December 1973. Warm areas are represented as lighter spots and cold areas are darker. The illustration was prepared from electronic display of satellite-derived data.

Digitized satellite data registered to a 1:250,000 base map were interrogated by computer to determine the surface temperatures of cane field locations. The temperature was calculated for the centre of each field by linear interpolation from the nearest 4 pixels (satellite data points, each representing an area of about 0·8 km² at nadir).

Table I shows that the surface temperatures varied over a range of 9·7 C with the 15 tepid fields all falling within a 1·5 C range straddling zero degrees.

Adjusted satellite surface temperatures. We attempted to estimate minimum surface temperatures attained at dawn by assuming that the surface temperature decreases after the evening satellite overpass were of the same magnitude as the air temperature decreases during the same period. The satellite-determined surface temperature of each field was adjusted by interpolation of air temperature decreases from the four nearest weather stations, in the same manner previously described for minimum air temperature interpolations. The data on air temperature decrease were available through the cooperation of the weather observers who read the air temperatures at their stations at the time of the satellite overpass and also recorded the minimum air temperatures that were reached.

The interpolated decreases in air temperature were about 7 C during the approximately 10 hours after the satellite overpass. Table I shows that application of these adjustments to the satellite data compressed the temperature range of tepid fields and expanded the temperature ranges of the cold and warm fields.

Recoverable sugar

Fig. 3 shows recovered sugar of factory-milled N:Co 310 sugar cane in relation to harvest dates. The general downward trend of recoverable sugar with time after the December freeze is apparent. The decrease would have been even more bpronounced if the fields had been harvested at random, rather than by a schedule that attempted to harvest the more seriously affected fields first. Without the freeze, this late-maturing variety would have Increased in sugar content during most of the period[5].

In this study, the time-dependent change of recoverable sugar was considered when classifying the fields according to their relative amounts of recoverable sugar. The classification was made by comparing the deviation of individual fields from the second-degree polynomial curve that best fits the data from all 45 fields (Fig. 3). The 15 fields with the greatest positive deviation were designated as high sugar content; similarly the 15 fields with most negative deviation were called low sugar content. The remaining 15 fields, which occupied a narrow band along the best-fit curve, were considered to be of medium recoverable sugar.

In Fig. 3, we also show the freeze-night temperature classifications into which the fields fell according to the surface temperature criterion. Warm fields, as identified by satellite, are shown by upward pointing arrows and cold fields by downward pointing arrows. Data points without arrows were classified as tepid fields.

[2] Nixon: 1974. "Unit thermograph for minimum temperature prediction". (Agricultural Research Service, Weslaco, Texas). Unpublished report. 3 pp.

[3] Schwalb: "Modified version of the improved TIROS operational satellite (ITOS D-G)". *NOAA Tech. Mem. NESS* 35. (Nat. Oceanic and Atmos. Admin., Washington, D.C.) 1972.

[4] Nixon, Finney, Arp & Wiegand: *J. Rio Grande Valley Hort. Soc.*, 1974, **28**, 86–90.

[5] Fuchs, Gerard, Reeves & Sund: *Research Center Tech. Rpt.* (Texas A. & M. University Agricultural Research and Extension Center, Weslaco, Texas), 1973, (73–6).

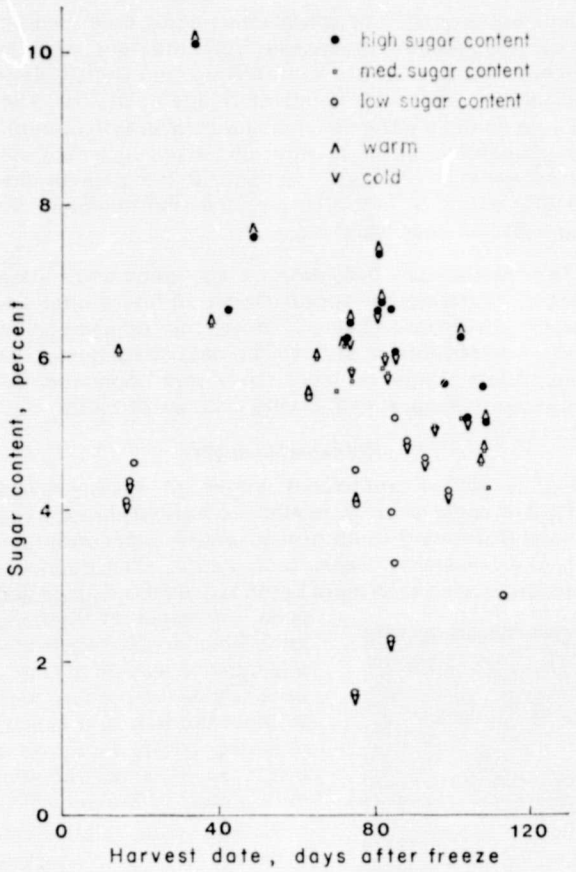

Fig. 3. Factory-recovered sugar from N:Co 310 fields of 16·2 ha or larger, with respect to time since freeze. Fields identified by satellite as warmest on the freeze night are shown by upward pointing arrows, and coldest fields by downward pointing arrows. Data points without arrows are from tepid fields.

Table II shows the relationship between post-freeze recoverable sugar and freeze-night temperatures at sugar cane field locations by showing the number of fields that fell in each combined class of sugar content and temperature. Analyses of each temperature criterion were made separately, with 15 fields in each temperature and each sugar content class. The table gives the results for each of the four temperature criteria that were investigated.

If the only factor affecting recoverable sugar had been freeze night temperatures and the temperature criteria were adequate, all 15 of the coldest fields would have had low recoverable sugar. Similarly, the medium and high-recoverable sugar fields would be perfectly matched with their respective temperature classifications. The data of Table II showed this tendency, indicating an interdependence between recoverable sugar and freeze night temperatures.

Table II shows the results were similar on a basis of minimum air temperature and degree-hour criteria; however the same fields did not aways fall within a given sugar *vs.* temperature category. Classification of individual fields by minimum air temperature and by degree-hours did not agree in 8 out of 45 cases. Similarly, classifications by surface temperature and adjusted satellite criteria differed for certain fields.

Further evidence of a relationship between post-freeze recoverable sugar and freeze-night temperatures is given in Fig. 4. This illustration, based on adjusted satellite temperatures, shows the best-fit second degree polynomial curve for the 15 fields falling into each temperature range. Fields identified as warm yielded about one-third more sugar than fields identified as cold

For a period after the freeze date, recoverable sugar increased as shown by the cold and tepid curves in Fig. 4. This trend was also present in some of the best-fit curves obtained with the other temperature criteria. This is attributable mainly to the scheduled order of field harvesting that was practised in the attempt to minimize freeze loss. However, recovery after a freeze, even if only partial and temporary, was noted by Gowing[6] and Irvine & Legendre[7]. The curve shapes were greatly

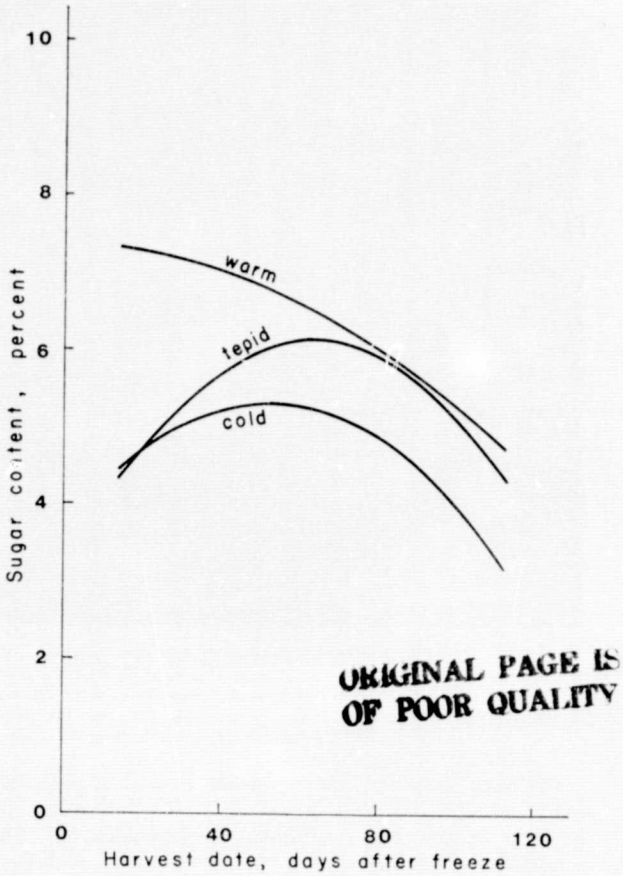

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Fig. 4. Best-fit curves of yields from fields that were classified according to temperature by adjusted satellite data.

[6] *I.S.J.*, 1975, **77,** 326–329.
[7] *Agric. Research*, 1977, **25,** (8), 15.

Table II. Relationship of post-freeze recoverable sugar to freeze-night temperatures at 45 fields of N:Co 310 of 16·2 ha (40 acres) or larger. The entries show the number of fields falling in each classification

	Temperature, by four criteria											
Sugar	*Minimum air*			*Degree-hour*			*Surface (by satellite)*			*Adjusted satellite*		
content	*Cold*	*Tepid*	*Warm*	*Cold*	*Tepid*	*Warm*	*Cold*	*Tepid*	*Warm*	*Cold*	*Tepid*	*Warm*
Low.....	6	5	4	6	5	4	7	6	2	8	4	3
Medium	7	3	5	7	3	5	4	5	6	5	4	6
High ...	2	7	6	2	7	6	4	4	7	2	7	6

influenced by the three low-sugar content fields that were harvested 16 to 18 days after the freeze (Fig. 3). Had harvesting of these seriously damaged fields been delayed, the yield would have been very low, probably uneconomical to harvest. The result would have been curves that sloped continuously downward to the right.

The average mill-processed recoverable sugar of each temperature range is shown in Table III for the four temperature criteria investigated in this study. These average values for the post-freeze harvest period were obtained from best-fit curves, like those in Fig. 4 for the adjusted satellite criterion. The data of the table are further indication of the possibility of separating sugar cane fields according to degree of freeze damage using freeze-night temperature measurements.

Table III. Average recoverable sugar of N:Co 310 fields determined by best-fit curves representing three temperature classifications for each of four temperature criteria. The average sugar contents are for the period of 14–113 days after the December 1973 freeze

	Temperature criteria			
	Min. air	*Degree-hour*	*Surface (by satellite)*	*Adjusted satellite*
	% sugar			
Cold fields	5·3	5·3	4·8	4·7
Tepid fields	5·0	6·0	5·2	5·5
Warm fields	6·3	6·2	6·4	6·3

According to the t-test made on data from the individual fields, the correlations between freeze-night temperature and recoverable sugar were significant at the following levels:

Minimum air temperature	30%
Degree-hour	50%
Satellite-indicated surface temperature...	10%
Adjusted satellite surface temperature	1%

The F-ratio was significant at the 5% level for the multiple correlation of harvest dates and satellite-sensed temperatures with recoverable sugar; and 1% when adjusted satellite temperatures were used.

The latter low probabilities that the results were due to chance variations alone support the applicability of the satellite approach. It was likely that the higher probabilities of chance associated with the air temperature measurements were related to inadequate sampling of air temperatures—an indication that the weather station network was too sparse for this application.

Discussion and conclusions

The analysis made here is a rigorous test of the use of freeze-night temperatures for estimating sugar cane freeze damage. The following factors worked against obtaining good results: (1) the deliberate attempt to offset freeze effects by rescheduling the harvesting order of the fields masked more pronounced results that would have come from randomized harvesting order, (2) weather stations were too few and too poorly distributed geographically with respect to the sugar cane fields, (3) the satellite overpass occurred about 10 hours before the minimum temperature which was too early for observation of fully-established nocturnal temperature patterns, (4) most of the sugar cane fields were smaller in size than the satellite resolution elements, and (5) other factors not related to the freeze (such as management during the growing season) also influenced recoverable sugar, the basis of these comparisons.

Despite these limiting conditions, good relationships existed between the regional freeze-night temperature measurements and the recovered sugar of the subsequent harvest. The nature of these conditions obscured, or worked counter to, the temperature relationship. However, that these relationships did persist under the circumstances suggests that temperature measurements on a freeze night can be useful in estimating the relative degree of freeze damage in individual fields and serve as a guide in rescheduling harvest operations so as to minimize loss from post-freeze deterioration.

From the data presented here the application of satellite data seems to be especially promising because of the statistically significant relationship with recoverable sugar. Better estimates of surface temperatures will be possible with future satellites that have overpasses timed closer to the occurrence of minimum temperatures and have better resolution (e.g. The Heat Capacity Mapping Mission satellite scheduled for launch in 1978 will overpass at about 0230 local time with a nadir resolution of 0·6 × 0·6 km). Thermal data from the NOAA satellite is presently available as magnetic tape from the National Climatic Center within a few days of the overpass. It is hoped that data from future thermal satellites will be available even more promptly

A presently available alternative source of surface temperature information that could be explored is the use of an aircraft-mounted thermal scanner. The resulting thermal images or digital data would contain more detail than the best satellite data. Sutherland & Bartholic[8] have demonstrated the possibility of using a thermal scanner in freeze studies in a citrus-growing area of Florida. A drawback of the thermal scanner is that essentially instantaneous coverage of a large agricultural area is not possible. However, conditions are ideal on clear cold winter nights for high altitiude thermal scanner flights covering swaths of land many kilometres wide.

Possibly the most important contribution of satellite-derived surface temperature information will be in identifying areas of repeatedly low freeze hazard for planting temperature-sensitive crops. Surface temperature maps can be routinely prepared from digital satellite data using computer facilities. Computer programmes are available to register satellite data to a base map scale. Using symbols the computer can show areas of warmest and coldest temperatures (correcting if necessary for differences in surface emissivity). The authors are currently studying such maps from several cold nights for recurrence of warm and cold locations.

Acknowledgment

We gratefully acknowledge the help of Kenneth A. Sund during the development stage of this investigation. Thanks are also due to the Rio Grande Valley Sugar Growers Inc. and to the U.S. Weather Service for making their records available, to C. M. Barnes of the National Aeronautics and Space Administration for help in acquiring and processing of satellite radiometric data; and to the 16 cooperative weather observers, who gratuitously made air temperature measurements at the time of the satellite overpass.

Summary

A computer-based statistical study was made of the effects of minimum air temperatures, degree-hours of below freezing air temperatures, evening surface temperatures measured by orbiting satellite, and dawn

[8] *Proc. Florida State Hort. Soc.*, 1974, **87**, 65–69.

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surface temperature obtained by adjustment of the satellite data. The measurements and estimations were compared for a period of freezing temperatures in December 1973 with the damage to cane recorded during the subsequent three months. Significant correlations were obtained between damage and satellite-indicated surface temperatures; satellite data may thus be used to identify fields which are likely to have suffered damage and so permit re-scheduling of harvest to minimize sugar loss. Satellite-derived temperature data can be used to identify areas down to 600 m × 600 m which are particularly vulnerable to low temperatures and should not be used for sensitive crops.

L'estimation des dégâts occasionnés à la canne par les gelées nocturnes régionales

Une étude statistique a été effectuée sur ordinateur concernant les effets des températures minimales de l'air, les degrés-heures des températures de l'air inférieures à zéro, les températures de surface le soir, mesurées par satellite sur orbite et les températures de surface au matin par ajustage des données fournies par la satellite. Les mesures et estimations ont été comparées, pour une période de gel en décembre 1973, avec les dégâts à la canne enregistrés au cours des trois mois suivants. Des corrélations significatives ont été obtenues entre les dégâts à la canne et les températures de surface mesurées par la satellite; des données fournies par satellite peuvent ainsi être utilisées pour identifier les champs qui sont susceptibles d'avoir subi des dégâts et permettre une autre programmation de la récolte pour minimiser la perte en sucre. Les données de température obtenues par satellite peuvent être utilisées pour identifier des superficies aussi petites que 600 m × 600 m qui sont particulièrement vulnérables aux basses températures et qui ne devraient pas être destinées à des cultures sensibles.

Schätzung der Schäden an Zuckerrohr durch lokale Nachtfröste

Mit EDV wurde eine statistische Studie durchgeführt über die Wirkung von Minimum-Lufttemperaturen, Frostst unden, Abend-Oberflächentemperaturen, gemessen von einem Umlauf-Satelliten, und Tagesanbruch-Temperaturen, erstellt nach Satelitten-Unterlagen. Die Messungen und Schätzungen wurden während einer Periode mit Frost-Temperaturen im Dezember 1973 mit den am Rohr in den folgenden drei Monaten festgestellten Schäden verglichen. Man erhielt signifikante Korrelationen zwischen Rohr-Schädigung und vom Satelliten stammenden Oberflächentemperatur-Unterlagen; Satelliten-Unterlagen können also benutzt werden, um Felder zu identifizieren, die wahrscheinlich Schäden erlitten haben, so dass die Ernte neu geplant und die Zuckerverluste minimiert werden können. Vom Satelliten stammende Temperatur-Unterlagen können benutzt werden, um Anbaugebiete ab 600 m × 600 m zu identifizieren, in denen besonders niedrige Temperaturen auftreten, und auf denen empfindliche Rohrsorten nicht angebaut werden sollten.

Estimación de daño a caña de azúcar de temperaturas regionales de noches de helado

Se ha hecho por computador un estudio estatístico sobre los efectos de temperaturas ambientes mínimas, grado-horas de temperaturas ambientes abajo del punto, de congelación, temperaturas del sobreficie en la tarde medido por satélite orbital, y temperaturas del sobreficie al alba obtenido por ajuste de los dados del satélite. Se han comparado las medidas y estimaciones para un periodo de temperaturas abajo de 0 C en diciembre de 1973 con el daño a caña registrado durante los tres meses después. Corelaciones significativas se han obtenido entre el daño y las temperaturas superficiales indicado por satélite; dados obtenido por uso del satélite pueden usarse para identificar campos donde es probable que daño ocurrirá y por éste permitirán re-proyectar el corte para reducir les pérdidas al mínimo. Temperaturas derivado de un satélite pueden usarse para identificar áreas hasta 600 m × 600 m que estan especialmente vulnerables a temperaturas bajas y no deben usarse para cosechas sensitivas. □