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TECHNICAL MEMORANDUM

EVALUATION OF THE LACIE TRANSITION YEAR CROP CALENDAR MODEL

By

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CONTENTS

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TABLES

FIGURES

1. INTRODUCTION

The Large Area Crop Inventory Experiment (LACIE) Transition Project uses a crop development or adjustable crop calendar (ACC) model to provide estimates of the crop developmental stage dates to assist in the identification of wheat in Land Satellite (Landsat) imagery. The analyst-interpreter (AI) uses crop development information during the early part of the growing season to determine whether the wheat is sufficiently emerged to be detectable on Landsat imagery. Between dormancy and heading, the AI relies on the estimated development stage dates to ascertain the approximate expected intensity of the wheat vegetation signature in comparison to the signatures of other spring-planted crops. Heading to senescence or maturity is a key stage in the separation of wheat from other vegetation. During this period of growth, the appearance of the wheat is significantly different from other vegetation types. The crop calendar model also serves to provide estimates of developmental stage dates for some of the recent, second-generation yield models. Although not currently implemented in LACIE Transition Project operations, these yield models are developed to explain the change in response of wheat yield to meteorological conditions as the plant progresses toward maturity. By providing estimates of the developmental stage dates, the crop calendar model determines when the yield model goes from one set of coefficients or response functions to another. Thus, errors in the ACC model can strongly influence both errors in the AI classification of wheat from Landsat imagery and yield estimates derived from second-generation yield models.

In this study, the estimated and the observed crop development dates were compared to determine the ACC model's accuracy in the LACIE Transition Project.

2. BACKGROUND

The crop calendar model developed by Robertson (ref. 1) describes the progress of spring wheat development from planting to ripening as a function of daily maximum and minimum temperatures and daylength. The principal output of the model is a daily increment of development (DID) through six physiological stages of growth (fig. 1). The biometeorological time scale (BMTS) implemented by the LACIE project is as follows:

Developmental stage	ACC stage
Planting	1.0
Emergence	2.0
Jointing	3.0
Heading	4.0
Soft dough	5.0
Ripening	6.0

The estimated crop calendar date corresponding to one of the above stages of development indicates that at least 50 percent of the crop has reached that developmental stage by the given date.

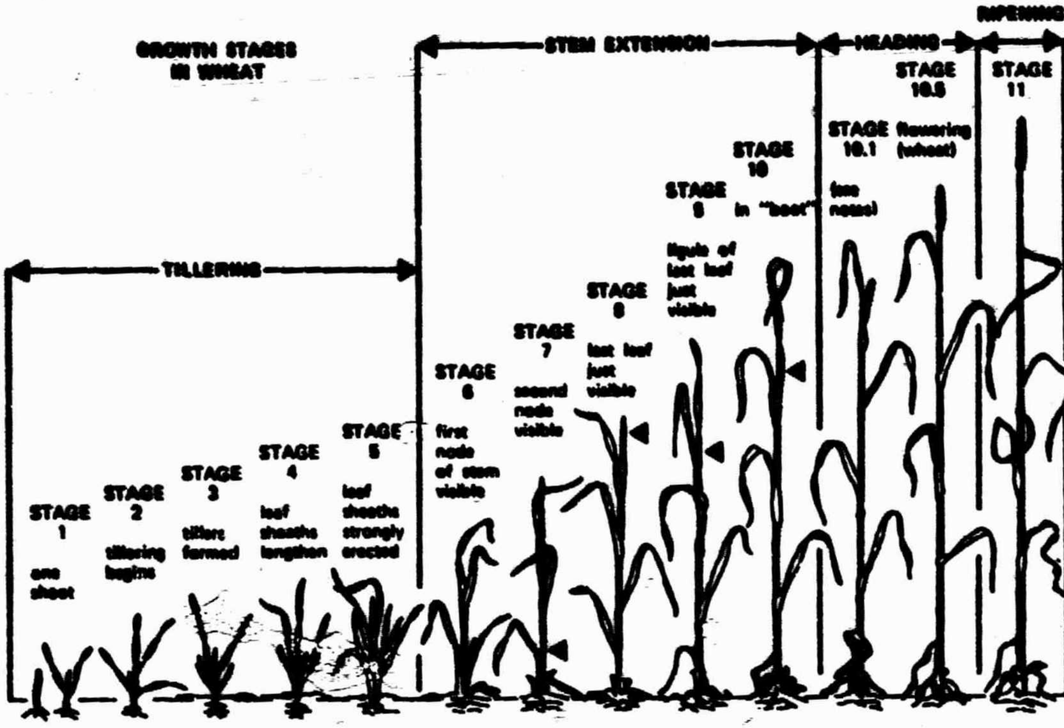
Since the Robertson model consists of the product of quadratic expressions involving the three input variables (daily maximum temperature, daily minimum temperature, and daylength), it is referred to as a triquadratic model. A quadratic equation is used to calculate the DID within each of the six physiological stages. The increments are accumulated from stage to stage since wheat responds differently to the meteorological conditions during each of these six stages of growth. Thus, five different rate equations are required. These rate equations for each stage of development may be written as follows:

$$\mathrm{DID} = \left[a_{1j}(L - a_{0j}) + a_{2j}(L - a_{0j})^2\right]\left[b_{1j}(T_X - b_{0j}) + b_{2j}(T_X - b_{0j})^2 + c_{1j}(T_N - b_{0j}) + c_{2j}(T_N - b_{0j})^2\right] \quad \text{for } j = 1, \cdots, 5$$

where

L = daylength in hours.

T_X = daily maximum air temperature (°F).



Robertson BMTS	Fusion stage	Description	
2.0	1	One shoot (number of leaves can be added) = "braiding."	TILLERING
2.2	2	Beginning of tillering.	
2.4	3	Tillers formed, leaves often twisted spirally. In some varieties of winter wheats, plants may be "creeping" or prostrate.	
2.6	4	Beginning of the erection of the pseudostem; leaf sheaths beginning to lengthen.	
2.8	5	Pseudostem (formed by sheaths of leaves) strongly erected.	
3.0	6	First node of stem visible at base of shoot.	STEM EXTENSION
3.2	7	Second node of stem formed; next-to-last leaf just visible.	
3.4	8	Last leaf visible, but still rolled up; ear beginning to swell.	
3.6	9	Ligule of last leaf just visible.	
3.8	10	Sheath of last leaf completely grown out; ear swollen but not yet visible.	
4.0	10.1	First ears just visible (awns just showing in barley; ear escaping through split of sheath in wheat or oats).	HEADING
4.13	10.2	Quarter of heading process completed.	
4.25	10.3	Half of heading process completed.	
4.37	10.4	Three-quarters of heading process completed.	
4.5	10.5	All ears out of sheath.	
4.6	10.5.1	Beginning of flowering (wheat).	FLOWERING (WHEAT)
4.7	10.5.2	Flowering complete to top of ear.	
4.8	10.5.3	Flowering over at base of ear.	
4.9	10.5.4	Flowering over; kernel watery ripe.	
5.0	11.1	Milky ripe.	RIPENING
5.33	11.2	Mealy ripe; contents of kernel soft but dry.	
5.67	11.3	Kernel hard (difficult to divide by thumb-nail).	
6.0	11.4	Ripe for cutting. Straw dead.	

Figure 1.— Robertson BMTS and observed phenological stages.

T_N = daily minimum air temperature (°F).

a_{ij}, b_{ij}, c_{ij} = characteristic coefficients, for $i = 0, 1, 2$ and $j = 1, \cdots, 5$.

This equation may be written in a more simplified form as follows:

$$DID = (G1)(G2 + G3)$$

If any one of the terms G1, G2, or G3 is negative, the value of the term is set to zero.

To apply the ACC to winter wheat, Feyerherm (ref. 2) developed an equation by which a scalar multiplier was calculated for each winter wheat crop calendar station. This factor was applied to each DID between emergence and heading to reflect the effect of dormancy on winter wheat. The equation is as follows:

$$M = 0.5684 + 0.025081\ (ADTJ) - 0.006139\ (AAPR)$$

where

M = Feyerherm's multiplier.

ADTJ = normal average daily temperature for January.

AAPR = normal average annual precipitation.

3. EVALUATION PROCEDURE AND DATA

The accuracy of the ACC model used in the LACIE Transition Year (TY) was evaluated by comparing the crop's developmental stage dates predicted by the model with those obtained from ground observations. The historical crop calendar was compared with the ground observations to ascertain whether the ACC was more reliable than the historical crop calendar. The following statistics were used to compare the two crop calendar developmental stage dates with the ground observations.

$$D_A = N_{GT} - N_A$$

$$D_H = N_{GT} - N_H$$

where

N_{GT} = date that the ground observations indicated that the wheat had reached the given developmental stage.

N_A = date that the ACC indicated that the wheat had reached the given developmental stage.

N_H = date that the historical crop calendar indicated that 50 percent of the wheat in the crop reporting district had reached the given developmental stage.

During LACIE Phases I through III, the evaluation of the LACIE ACC model was limited to data from the intensive test sites (ITS's) because drop calendar ground-observed data were collected only for those sites (ref. 3). The number of U.S. sample segments used for collecting ground-observed wheat development stage data was increased for the LACIE TY to include not only the ITS's but also the blind sites. Thus, this study includes an evaluation of the crop calendars over the 145 LACIE TY blind sites and the 23 LACIE TY ITS's in the United States. Field observers reported data from 95 of the blind sites and 14 of the ITS's to monitor winter wheat development; the remaining sites reported spring wheat development.

Within each site, the average ground-observed wheat growth stage was calculated from periodic field-by-field observations obtained by personnel of the Agricultural Stabilization and Conservation Service of the U.S. Department of Agriculture (USDA/ASCS). A numerical development scale, which is a modification of the Feekes scale, was used by USDA/ASCS personnel to record the ground-observed data from the LACIE TY sites (see fig. 1). This scale allowed the field observer more flexibility in recording crop development stages because it has 23 increments, whereas the one used during LACIE Phases I through III contained only 9 increments of development. The Feekes ground-observed developmental stages were converted to the Robertson BMTS for comparison since the LACIE ACC model and the historical crop calendar utilize the Robertson scale.

4. RESULTS

The data for both winter and spring wheat generated by the Gridded Crop Calendar Report Writer Program were reviewed, and some errors were found in the ACC's developmental stages at soft dough and ripening. This program was used to provide ACC stages of development for the wheat at each site by extrapolating between the ACC stages at the weather stations in the area nearest the site. When errors were found in the computer-extrapolated wheat development stages, the extrapolation was performed manually.

Although comparison statistics are given for the stages of jointing through ripening, the results at the stages after jointing are expected to be more valid for evaluating the ACC because jointing is defined differently from one locality to another and even from one observer to another. Furthermore, jointing on the Robertson scale is not visible for approximately 2 weeks after it has occurred. During this 2-week time period, the plant must be dissected to determine whether jointing has occurred; therefore, it is difficult for ground observers to detect when this stage of development actually occurs. For winter wheat, scalar multipliers were applied to the model's development equations between emergence and heading to account for dormancy. This makes the ACC estimates of developmental stage dates even more questionable at jointing for winter wheat. Thus, the ACC model was expected to show greater accuracy at the developmental stages after jointing.

4.1 WINTER WHEAT

Table 1 contains the results of evaluating the LACIE ACC using the blind sites only. The table contains values of $\overline{D}_A$ and $\overline{D}_H$, the average values of D_A and D_H, respectively. The standard error of the average differences, paired t-test statistics, and root mean-squared errors (RMSE's) are also given in the table.

For the seven winter wheat states of the U.S. Great Plains (USGP-7), the paired t-test indicated that the average developmental stage dates from both crop

TABLE 1.— COMPARISON OF WINTER WHEAT CROP CALENDAR DEVELOPMENTAL STAGES AND GROUND OBSERVATIONS USING THE BLIND SITES

Statistic	Jointing (3.0)		Heading (4.0)		Soft dough (5.0)		Ripening (6.0)	
	$\bar{D}_A$	$\bar{D}_H$	$\bar{D}_A$	$\bar{D}_H$	$\bar{D}_A$	$\bar{D}_H$	$\bar{D}_A$	$\bar{D}_H$
Colorado								
Average difference	26.5	3.6	-2.8	-1.3	-2.7	2.4	2.1	6.9
Standard error	3.9	2.4	1.3	1.9	1.3	1.4	2.6	3.0
Paired t-test statistics	[a]6.8	[b]1.5	[a]-2.2	[b]-0.7	[a]-2.1	[a]1.7	[b]0.8	[a]2.3
RMSE	29.2	8.4	4.9	6.1	5.2	5.5	7.6	10.6
No. of blind sites used	8	8	8	8	9	9	7	7
Kansas								
Average difference	16.9	2.5	-3.2	4.8	-4.8	5.2	0.4	5.6
Standard error	1.2	1.4	0.6	0.7	0.7	0.8	0.4	0.6
Paired t-test statistics	[a]14.1	[a]1.8	[a]-5.3	[a]6.9	[a]-6.9	[a]6.5	[b]1.0	[a]9.3
RMSE	18.5	8.7	4.8	6.5	6.6	7.2	2.2	6.5
No. of blind sites used	30	30	32	32	32	32	27	27

[a]Average difference was significant at the 10-percent level.
[b]Average difference was not significant at the 10-percent level.

TABLE 1.— Continued.

Statistic	Jointing (3.0)		Heading (4.0)		Soft dough (5.0)		Ripening (6.0)	
	$\bar{D}_A$	$\bar{D}_H$	$\bar{D}_A$	$\bar{D}_H$	$\bar{D}_A$	$\bar{D}_H$	$\bar{D}_A$	$\bar{D}_H$
Nebraska								
Average difference	21.6	4.2	-3.5	-4.3	-1.4	-0.5	1.5	2.1
Standard error	2.9	2.2	1.0	1.2	0.7	0.5	0.9	0.8
Paired t-test statistics	[a]7.4	[a]1.9	[a]-3.5	[a]-3.6	[a]-2.0	[b]-1.0	[a]1.7	[a]2.6
RMSE	24.8	10.1	5.4	6.7	3.3	2.1	3.8	3.7
No. of blind sites used	13	13	13	13	14	14	12	12
Oklahoma								
Average difference	13.0	2.0	-2.0	-1.6	-3.2	6.4	0.4	7.2
Standard error	1.6	2.8	0.9	1.9	1.2	1.4	1.2	1.7
Paired t-test statistics	[a]8.1	[b]0.7	[a]-2.2	[b]-0.8	[a]-2.7	[a]4.6	[a]3.0	[a]4.2
RMSE	13.6	7.6	4.1	7.6	6.3	9.1	4.2	8.8
No. of blind sites used	7	7	13	13	16	16	12	12
Texas								
Average difference	15.0	2.3	0.7	-3.3	-2.7	-0.3	4.1	3.1
Standard error	2.5	4.1	1.9	2.9	2.6	3.1	2.1	2.1
Paired t-test statistics	[a]6.0	[b]0.6	[b]0.4	[b]-1.1	[b]-1.0	[b]-1.0	[a]2.0	[b]1.5
RMSE	15.4	6.5	7.1	11.0	9.7	11.0	8.5	8.3
No. of blind sites used	3	3	11	11	11	11	11	11

[a]Average difference was significant at the 10-percent level.
[b]Average difference was not significant at the 10-percent level.

TABLE 1.— Concluded.

Statistic	Jointing (3.0)		Heading (4.0)		Soft dough (5.0)		Ripening (6.0)	
	$\overline{D}_A$	$\overline{D}_H$	$\overline{D}_A$	$\overline{D}_H$	$\overline{D}_A$	$\overline{D}_H$	$\overline{D}_A$	$\overline{D}_H$
Montana								
Average difference	22.8	0.9	1.6	-13.5	2.6	-6.4	8.9	2.5
Standard error	3.8	2.7	2.0	1.8	2.2	1.8	1.7	2.4
Paired t-test statistics	[a]6.0	[b]0.3	[b]0.8	[a]-7.5	[b]1.2	[a]-3.6	[a]5.2	[b]1.0
RMSE	25.9	8.7	7.1	14.9	8.5	9.3	6.6	3.2
No. of blind sites used	9	9	10	10	11	11	11	11
South Dakota								
Average difference	3.0	15	7	6	8.5	10.5	14.0	10.5
Standard error	(c)	(c)	(c)	(c)	(c)	(c)	(c)	(c)
Paired t-test statistics	(c)	(c)	(c)	(c)	(c)	(c)	(c)	(c)
RMSE	(c)	(c)	(c)	(c)	(c)	(c)	(c)	(c)
No. of blind sites used	1	1	1	1	2	2	2	2
USGP-7								
Average difference	19.3	2.9	-1.9	-1.1	-2.4	2.4	2.7	4.7
Standard error	1.1	0.9	0.5	0.8	0.5	0.7	0.6	0.5
Paired t-test statistics	[a]17.5	[a]3.2	[a]-3.8	[b]-1.4	[a]-4.8	[a]-3.4	[a]4.5	[a]9.4
RMSE	21.9	9.0	5.5	8.9	6.8	7.8	5.4	7.8
No. of blind sites used	71	71	88	88	95	95	82	82

[a]Average difference was significant at the 10-percent level.
[b]Average difference was not significant at the 10-percent level.
[c]Insufficient data were available.

calendars differed from the ground observations by significant margins (at the 10-percent level) at all stages of development, except for the historical crop calendar at heading. However, the USGP-7 level RMSE's for the ACC developmental stage dates were slightly smaller than those for the historical crop calendar at each stage of development after jointing. This indicates that the ACC was slightly more accurate than the historical crop calendar.

The RMSE's, using the blind site developmental stage dates from both crop calendars, were larger for Texas and Montana than they were for the other states in the USGP-7. The problem encountered in fitting the ACC model in Texas can be seen by studying the values of D_A and D_H given in table 2 for the ITS's. The D_A values for the two ITS's located in Texas show that the ACC wheat heading date in those two sites was at least 2 weeks ahead of the heading date observed in the field. Those two ITS's were located in the Texas Panhandle, where rainfall amounts were below normal during the fall planting season. Because of these dry soil conditions in the ITS of Oldham County, Texas, planting was delayed, and the wheat did not emerge until spring. The planting dates were not available for the wheat in the ITS of Randall County, Texas. However, the historical heading dates for both ITS's of Texas were at least 20 days ahead of the ground observations. Late planting caused the ACC model to run ahead of the actual growth stage since it started by using historical planting dates.

At soft dough, ground-observed wheat developmental stages continued to lag behind their historical averages by more than 2 weeks in the ITS's of Texas, and in some of the other sites. Reports on crop conditions in those areas indicated that the wheat development was retarded because of the drought conditions and below-normal spring temperatures. The ACC model compared much better with the ground observations in those ITS's, indicating that the model responded well to temperature.

4.2 SPRING WHEAT

The blind site statistics for assessing the accuracy of the ACC spring wheat model in the U.S. northern Great Plains (USNGP) region are found in table 3.

TABLE 2.— COMPARISON OF WINTER WHEAT CROP CALENDAR DEVELOPMENTAL STAGES AND GROUND OBSERVATIONS USING THE ITSs

Statistic	Jointing (3.0)		Heading (4.0)		Soft dough (5.0)		Ripening (6.0)	
	D_A	D_H	D_A	D_H	D_A	D_H	D_A	D_H
ITS (county, state):								
Kay, Okla.	25	18	-2	3	-1	13	(a)	(a)
Kiowa, Okla.	(a)	(a)	-1	-4	7	13	5	13
Kingfisher, Okla.	(a)	(a)	(a)	(a)	0	12	1	9
Bone, Ind.	17	1	-3	-7	6	8	0	15
Ellis, Kans.	13	8	-8	8	-9	6	-2	5
Saline, Kans.	29	4	-3	3	-2	1	-3	3
Finney, Kans.	0	-15	-9	4	3	17	3	8
Morton, Kans.	(a)	(a)	(a)	(a)	-13	0	2	7
Hayes, Nebr.	18	-6	6	0	1	6	2	1
Adams, Nebr.	(a)	(a)	(a)	(a)	3	14	3	9
Kimball, Nebr.	(a)	(a)	(a)	(a)	-4	2	-3	6
Kit Carson, Colo.	23	-3	7	6	0	7	-6	4
Randall, Tex.	36	18	16	20	7	19	6	11
Oldham, Tex.	26	6	16	23	9	22	5	10
Average difference	20.7	3.4	1.9	5.6	0.5	10	1.0	7.8
Standard error	3.5	3.6	2.8	3.0	1.8	1.8	1.0	1.1
Paired t-test statistic	[b]5.9	[c]0.9	[c]0.7	[b]1.9	[c]0.3	[b]5.6	[c]1.0	[b]7.1
RMSE	23.0	10.7	8.7	10.6	6.0	12.0	3.6	8.7

[a]Data were not available.

[b]Average difference was significant at the 10-percent level.

[c]Average difference was not significant at the 10-percent level.

TABLE 3.— COMPARISON OF SPRING WHEAT CROP CALENDAR DEVELOPMENTAL STAGES AND GROUND OBSERVATIONS USING THE BLIND SITES

Statistic	Jointing (3.0)		Heading (4.0)		Soft dough (5.0)		Ripening (6.0)	
	D_A	D_H	D_A	D_H	D_A	D_H	D_A	D_H
Minnesota								
Average difference	10.9	13.1	2.0	0.3	3.6	8.4	8.1	14.9
Standard error	1.1	1.8	0.8	0.9	1.5	2.8	2.2	5.0
Paired t-test statistics	[a]9.9	[a]7.3	[a]2.5	[b]0.3	[a]2.4	[a]3.0	[a]3.7	[a]3.0
RMSE	11.4	14.2	3.0	2.7	5.4	9.6	9.6	16.0
No. of blind sites used	8	8	8	8	7	7	7	7
North Dakota								
Average difference	15.7	18.5	6.2	5.5	5.7	3.8	7.1	4.7
Standard error	1.3	1.1	1.1	1.1	1.2	1.2	1.2	1.3
Paired t-test statistics	[a]12.1	[a]16.8	[a]5.6	[a]5.0	[a]4.8	[a]3.2	[a]5.9	[a]3.6
RMSE	17.7	19.8	9.6	8.9	9.6	8.4	10.5	9.7
No. of blind sites used	29	29	29	29	29	29	29	29
Montana								
Average difference	17.0	8.3	12.7	-5.0	13.3	5.2	16.3	12.7
Standard error	2.4	2.7	2.5	2.7	2.6	3.1	1.4	1.1
Paired t-test statistics	[a]7.1	[a]3.1	[a]5.1	[a]-1.9	[a]5.1	[b]1.68	[a]11.6	[a]11.5
RMSE	18.2	11.1	14.1	8.3	14.8	9.1	16.7	12.9
No. of blind sites used	7	7	6	6	6	6	6	6

[a]Average difference was significant at the 10-percent level.
[b]Average difference was not significant at the 10-percent level.

TABLE 3.— Concluded.

Statistic	Jointing (3.0)		Heading (4.0)		Soft dough (5.0)		Ripening (6.0)	
	D_A	D_H	D_A	D_H	D_A	D_H	D_A	D_H
South Dakota								
Average difference	15.7	14.7	7.3	-0.2	3.4	4.6	7.1	9.9
Standard error	3.0	1.5	2.4	2.0	2.7	2.4	2.7	3.1
Paired t-test statistics	[a]5.2	[a]9.8	[a]3.0	[b]-0.1	[b]1.3	[a]1.9	[a]2.6	[a]3.2
RMSE	17.4	15.1	9.4	4.9	8.1	8.1	10.3	13.1
No. of blind sites used	6	6	6	6	7	7	7	7
USNGP								
Average difference	15.1	15.7	6.5	2.6	6.0	4.8	8.4	7.8
Standard error	0.9	0.9	0.9	0.9	1.0	0.9	1.0	1.1
Paired t-test statistics	[a]16.8	[a]17.4	[a]7.2	[a]2.9	[a]6.0	[a]5.3	[a]8.4	[a]7.1
RMSE	16.9	17.5	9.5	7.7	9.7	8.6	11.4	11.9
No. of blind sites used	50	50	49	49	49	49	49	49

[a]Average difference was significant at the 10-percent level.
[b]Average difference was not significant at the 10-percent level.

These statistics are analogous to those for the winter wheat blind sites. At the USNGP level, the positive average differences indicate that the ACC model was predicting the wheat to reach the developmental stages earlier in the year than was detected by ground observations. The spring wheat starter model was the mechanism (ref. 4) by which the ACC model was started in the spring wheat regions. Naturally, the accuracy of the planting dates estimated by the starter model influences the accuracy of the ACC model estimates. In the spring of 1978, planting was delayed because of wet fields from melting snow and rain, and the starter model predicted seeding to occur 2 to 3 weeks earlier than it actually occurred. Thus, the ACC spring wheat model was started early and was ahead of the plant's actual development.

The ITS crop calendar evaluation also shows that both crop calendars tended to be ahead of the ground observation, especially in Montana and North Dakota at jointing (table 4). Jointing was the developmental stage which showed the largest differences between the crop calendars and the ground observations for the ITS's and the blind sites. After jointing, the blind site and the ITS evaluations indicated that both crop calendars were ahead of the ground observations through ripening, but the differences were not as large.

Since the accuracy of the spring wheat model is affected more by erroneous planting dates than the winter wheat model, an assessment of spring wheat seeding progress for the USNGP is given in table 5. The percentage of wheat planted in 1977 and 1978 during the three periods shown in the table (April 23, May 7, and May 14) are presented together with the average percentage of planted wheat. The percentages show that planting in 1978 lagged behind the 1977 and average rates throughout the year. By May 14, 1977, over 90 percent of the wheat had been planted in each spring wheat state, but less than half the wheat in Montana and North Dakota had been planted by May 14, 1978. Minnesota was the only state in which planting was ahead of the average rate on May 14, 1978. The percentage of wheat planted in Minnesota was behind the average on April 23, but seeding progressed at such a fast rate in Minnesota once the farmers were able to work the fields that planting was ahead of the average rate by May 14. Consequently, the blind site crop calendar investigation

TABLE 4.— COMPARISON OF SPRING WHEAT CROP CALENDAR DEVELOPMENTAL STAGES AND GROUND OBSERVATIONS

Statistic	Jointing (3.0)		Heading (4.0)		Soft dough (5.0)		Ripening (6.0)	
	D_A	D_H	D_A	D_H	D_A	D_H	D_A	D_H
ITS (county, state):								
Daniel, Mont.	24	20	21	16	29	21	23	19
Burke, N. Dak.	23	20	9	5	15	7	9	4
Williams, N. Dak.	19	15	9	5	12	4	1	-5
Rolette, N. Dak.	29	25	18	15	22	16	(a)	(a)
Ransom, N. Dak.	-3	2	3	3	1	-1	3	2
Hand, S. Dak.	1	2	-2	-7	-4	9	0	11
Roberts, S. Dak.	6	0	3	-8	6	7	5	9
West Polk, Minn.	(a)	(a)	1	-4	5	10	-1	8
Kittson, Minn.	(a)	(a)	(a)	(a)	-1	5	7	16
Average difference	14.1	12.0	7.8	3.1	9.4	8.7	5.8	8.0
Standard error	4.8	3.9	2.9	3.2	3.7	2.2	2.8	2.8
Paired t-test statistics	[b]2.9	[b]3.1	[b]2.7	[c]1.0	[a]2.5	[a]4.0	[a]2.1	[a]2.9
RMSE	18.3	13.1	10.9	9.1	14.0	10.6	9.3	10.8

[a]Data were not available.

[b]Average difference was significant at the 10-percent level.

[c]Average difference was not significant at the 10-percent level.

TABLE 5.— ASSESSMENT OF SPRING WHEAT SEEDING PROGRESS

[The table shows the percentage of wheat planted by the states given]

State	April 23			May 7			May 14		
	1977	1978	Avg	1977	1978	Avg	1977	1978	Avg
Minnesota	63	1	42	97	36	66	99	79	75
North Dakota	28	0	18	79	20	48	92	40	60
Montana	35	10	25	80	35	55	90	45	65
South Dakota	58	10	48	96	51	82	99	72	94

shows that the average ACC and the historical jointing dates were not as far ahead of the ground observations in Minnesota as they were in the other USNGP states.

5. CONCLUSIONS

Two major improvements which facilitated a more thorough evaluation of the LACIE ACC model were made in the LACIE TY ground-observed crop development data. The number of sample segments used in the LACIE TY evaluation study was increased by collecting ground-observed crop development stage data at the 145 blind sites and the 23 ITS's. In LACIE Phases II and III, ground-observed crop development data were collected for the ITS's only. In addition, field observers were able to record finer increments of wheat development for the LACIE TY crop calendar evaluation study because they used a measurement scale with 23 increments instead of the scale with only 9 increments used in the LACIE Phases II and III.

The estimates of developmental stage dates from the LACIE ACC winter wheat model had smaller RMSE's after jointing than the estimates from the historical crop calendar. This indicates that the LACIE ACC winter wheat model was somewhat more accurate than the historical crop calendar after jointing. Previous crop calendar evaluations using LACIE Phase II and III ITS data also indicated that overall, the ACC model was more accurate than the historical crop calendar.

The LACIE ACC winter wheat model was not as accurate for the Texas Panhandle as it was for other areas of the USGP-7 because dry soil conditions delayed fall planting in the Panhandle. Since the LACIE ACC winter wheat model does not contain a moisture term and it was started with historical planting dates, lengthy delays in planting mean that the ACC model will probably be started early and will estimate the developmental growth stages to occur too early in the season.

The LACIE ACC spring wheat model was also started early in most areas because of late planting due to wet fields from melting snow and rain. The LACIE spring wheat starter model used to estimate spring planting dates was not accurate under these wet soil conditions. Therefore, the LACIE ACC spring wheat model tended to predict the developmental stages to occur earlier than the dates observed in the fields. Apparently, additional research is needed to accurately determine planting dates under abnormal soil moisture conditions for both winter and spring wheat.

6. REFERENCES

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