IN-43-CR
38734
P. 44

PROJECT SUMMARY

GRANT: Using Landsat to Provide Potato Production Estimates to Columbia Basin Farmers and Processors

COOPERATIVE AGREEMENT NO. NCC 2-569

GRANTEE: Oregon State University
Department of Bioresource Engineering
(formerly Agricultural Engineering)
Corvallis, Oregon
97331

(NASA-CR-188783) USING LANDSAT TO PROVIDE POTATO PRODUCTION ESTIMATES TO COLUMBIA BASIN FARMERS AND PROCESSORS (Oregon State Univ.) 44 p CSCL 02C

N92-10209

Unclas
G3/43 0038734

Summary of Project Activities

Oregon State University's primary responsibility in this project has been estimation of potato yields in the Columbia Basin. The work was done jointly by the Agricultural Engineering Department and the Crop Science Department, with additional cooperative efforts from Washington State University, Cornell University and other institutions. The fundamental objective is to provide CROPIX with working models of potato production.

The significance of this effort is suggested by Figure 1. Annual variations in total potato production are due to variations in acreage and in yields. Approximately 22 percent of the variation from year to year in potato yields in Easter Oregon (Morrow, Umatilla, and Malheur counties) is due to variations in yield per acre. Seventy-eight percent is due to acreage fluctuations. The importance of yield estimation becomes clearer in Figure 2. A rough estimate of yields is now being obtained using satellite images to measure the acreage planted in potatoes, then multiplying by average yields from recent years. The errors that result when yield variation is ignored would range from approximately 0 to 30 percent. Ten percent errors are common. Errors of this magnitude occurring in certain critical years would seriously compromise the confidence that subscribers would have in CROPIX estimates of yields.

Oregon State University is following a two-pronged approach to yield estimation, one using simulation models and the other using purely empirical models. The simulation modeling approach has used satellite observations to determine certain key dates in the development of the crop for each field identified as potatoes. In particular these include planting dates, emergence dates and harvest dates. These critical dates are fed into simulation models of crop growth and development to derive yield forecasts. The potential for yield estimation based on these critical dates is suggested by Figures 3 and 4. Figure 3 shows the relationship observed between yields and planting dates for eight fields which were closely observed in 1988. There is a clear trend towards higher yields with later planting dates. Figure 4 shows a similar relationship between yields and harvest date. The predicted yields plotted in these two graphs were generated by an uncalibrated model early in the project. The models that have been tested so far have been in general agreement with the observed relationships between critical dates and yields.

As the season progresses and critical dates are observed for individual fields, they will be used with a simulation model which will then forecast end of season yields based on observed weather to date, forecasts of weather to the end of the season and forecasts of harvest dates in one form or another. Figure 5 shows a yield "surface" indicating the variation in yields anticipated as a function of emergence date and harvest date in 1989 (based on the CERES model prior to calibration). This kind of information will be used to calculate yields throughout the basin on a field by field basis. A surface like this will be used to estimate yields for individual fields based on the observed emergence dates and harvest dates.

The alternative to simulation modeling is the development of purely empirical models to relate yield to some spectrally derived measure of crop development. Two empirical modeling approaches are illustrated in Figures 6 and 7 as examples; one relates tuber yield to estimates of cumulative intercepted solar radiation, the other relates tuber yield to the integral under the GVI curve. Figure 6 shows an example of the observed relationship between total fresh weight of tubers and cumulative intercepted solar radiation for two fields on one farm in 1988. The method will involve estimation of canopy development based on satellite observations. These estimates will then be used to derive leaf area indices which are to be combined with solar radiation data measured at weather stations in the area. Figure 7 shows a GVI curve derived from observations of 280 fields in 1985. The integral under the GVI curve has been used for estimation of yields for other crops, and may be successfully used for estimation of yields for potatoes as well.

The approach taken by Oregon State University can be summarized in terms of Figure 8. The intent has been to combine the information derived from satellites with information that is normally and routinely collected on the ground (e.g. weather data). Algorithms are being developed to relate satellite spectral observations to crop development. The information from these observations is then augmented with information on the crop environment (weather, soils, farming practices, etc.) and experimental knowledge derived from researchers in the Pacific Northwest and other parts of the country and the world. Experimental knowledge is embodied in the potato simulation models which are being used.

The procedures at Oregon State University have involved five main steps. Step 1 was data collection, including crop phenology, weather data, spectral data from satellite observations, spectral data which were collected on the ground, farm data (farm records) and soils data. This data collection effort began before funding was finally approved. Step 2, which was conducted in parallel with the data collection effort, was a review of existing simulation models from various countries as well as other locales in the United States. Step 3 involved testing the models and refining the one that most successfully matched observations in the field. Step 4 involved development of empirical relationships, some of which are to be used to relate satellite observations to crop phenology, while others are to be used to estimate yields directly. Step 5 will be an integration of models (both simulation models and empirical models) into yield prediction algorithms used by CROPIX. The first three steps were carried out during the first two years of this research, the period covered by this report.

The data collection program involved simultaneous observations in three domains (satellite observation, field sampling, and model estimates) throughout the development of the crop. These observations were made simultaneously as the season progressed through the various critical states of development. Observations of crops include (Figure 9) leaf canopy development, total biomass, stem growth and development and tuber development. Additional spectral reflectance data were collected at ground level, as well as some limited data on intercepted solar radiation. Satellite observations included spectral observations and calculations of GVI, Red Ratio and other vegetation indices. Model determinations included interception of solar radiation (based on model estimates of leaf development and measured solar radiation), photosynthetic rates, biomass accumulation and partitioning of photosynthates among the four principal components of the plant (leaves, stems, roots, and tubers). A number of satellite images were selected for use with the observations of the specific fields in 1988 and 1989.

Field data were collected from 16 fields on three farms in two seasons. Those data are summarized in Figures 9 and 10. Thirty-four thousand pieces of data were accumulated, including plant emergence dates, dates of canopy cover, percent ground cover, leaf area, plant spacing, total weight of biomass (fresh and dry), tuber initiation dates and tuber numbers, sizes and weights. Additional data on soil structure and chemistry, use of pesticides and other chemicals, observations of pest or other problems and complete harvest weights and culling percentages were collected.

Weather data from four weather stations were used in this project, as summarized in Figure 11. Seasonal weather profiles, plotted through the growing season, are generated for maximum and minimum temperature, solar radiation, wind-run, rainfall and humidity.

Soils data were collected from SCS soil maps, as well as local sampling of soil chemistry during the season. Chemical sampling was primarily for purposes of determining nitrogen availability to the crops. Figure 12 illustrates a soils map for McNary Farms, one of the three principal farms in this project. Overlaid on the map are circles which represent the center pivots on that farm, eight of which have been sampled for purposes of this project. The extreme variability of soil type shown in this picture suggests the importance of soils data to this project.

Goals of the data collection program are summarized in Figure 13. The data are to be used <u>first</u> to calibrate and test simulation models, and <u>secondly</u> to relate satellite observations to crop development. Figure 14 is one example of the use of the data to characterize the phenologic development of the crop. This profile for one field in 1989 illustrates leaf canopy development and tuber development as the season progresses. Similar plots for these and other phenologic parameters for all fields involved in this study have been developed. Figure 15 shows the parallel development of ground cover, leaf area index and satellite observations (indicated by Red Ratio) for one field in 1989.

Figure 16 summarizes the <u>data sharing</u> program. The data collected for purposes of evaluating simulation models are being shared with this list of individuals in several locations. The objective is to get their observations and any reactions they may have either to the data or to the simulation models calibrated with those data. The data collected during the first two seasons were used in a presentation at a world potato modeling conference in Amsterdam, May 1990, by Elmer Ewing.

That brings us to the survey of simulation models, the second step in the project. The leaders of this effort were Marshall English, Dale Moss and John Bolte at Oregon State and Elmer Ewing at Cornell. Their initial efforts involved a survey of existing models and selection of two of them for testing and development in this project. The models were selected on the basis of their potential for predicting yields with reasonable accuracy. The models had to be calibrated with field data similar to what we could easily collect from local farms. It was also important that they simulate the development of the whole crop, including development of the leaf canopy in particular rather than just simulating development of the tubers. The reason for this was that canopy development and biomass might eventually be used in wholly empirical modeling of yields. Finally, the models had to be practical for large scale applications, which implied they had to have reasonable data input requirements and reasonable computer time requirements.

Two models were selected for final testing and development. One of those is the CERES model originally developed by USDA in Texas for simulation of corn development and subsequently tested and calibrated in a variety of locations around the world. It is widely accepted and has been adopted by an international coordinating committee for crop modeling (IBSNAT). The CERES model is, in fact, a "family" of models with a common format. A potato version is being developed under the auspices of IBSNAT by Dr. Tom Hodges of Washington State University. That model represents a compromise between sophistication and practicality. The other model receiving serious consideration, referred to as the Israeli model, was developed by Dr. Svetlana Fishman at the Volcani Institute in Israel. It was derived independently of the CERES model but is similar in sophistication and practicality. Dr. Fishman came to Oregon State University for a period of two weeks in February 1990 to help with installation, initial calibration and testing of the model, and she is continuing to work with us in further refinement of the model. Calibration of this model is continuing during the third year of this project; (not reported here).

Initially these two models were run in blind tests. That is, no modifications were made at all except to scale the output to roughly match the observed yields. Figure 17 shows the results of the blind tests in terms of predicted and observed yields in 1988 for the CERES model. Figure 18 shows the results for the Israeli model for both 1988 and 1989. Figure 19 shows a comparison of predicted and actual leaf development (in units of kg per 10,000 m^2) in one field in 1989. The Israeli model was originally developed using data for a completely different variety of potatoes (the Desire variety) under Israeli conditions. As a result the uncalibrated model showed an obvious consistent bias in leaf development, reflecting those different conditions. This same bias was observed in all tests of the model for all fields. Figure 20 lists a few of the parameters that can be adjusted during calibration of the model. These adjustments are made using the field data discussed above. Preliminary calibration of the Israeli model using these adjustments for our conditions has improved the ability of the model to predict leaf development, as illustrated in Figure 21. The two figures on the left represent uncalibrated model estimates for two fields; those on the right the estimates from the recalibrated model. Calibration of the Israeli model is continuing.

The empirical modeling effort was initially hampered by an insufficiency of spectral data during the critical green-up phase, approximately mid-May to mid-June. Cloud cover during that time had been such that only four good satellite observations were available in the first two seasons. Once the various models are calibrated, one or two observations during green-up will be adequate for purposes of estimating emergence dates. However the satellite data obtained so far were not adequate for the development of the empirical relationships needed to link satellite observations to crop development. That is, it is not possible to develop a curve with only two points each season, but once the curve is developed you can use it successfully with only one or two observations. This created two problems in particular. One was an inability to develop a reliable algorithm to estimate emergence dates based on satellite imagery, the other is the difficulty of recognizing sub-par fields (that is fields which are greening up slowly). Figure 22 illustrates the first problem, the determination of emergence dates. The five fields shown for 1988 were planted at decidedly different dates, and the differentiation between their planting dates is easily recognized from the observation made on Julian date 162. However there were no observations between Julian date 130 and 162, during green-up. Four of the five fields emerged after Julian Date 130 but it is impossible to say precisely when. Additionally, if we observe a field twice, and the rate of development is inconsistent with the nominal temporal profile we need to be able to recognize the delayed development. Again, the satellite data were not adequate for that purpose.

An attempt was made to overcome these problems in the third growing season of the project. We were particularly concerned with intensive collection of spectral data during the green-up phase. In addition we wanted to investigate the factors that can alter the spectral characteristics of a healthy crop. Some of these included viewing angle, sun angle, field aspect, soil type, and soil condition. Those factors which prove significant can be compensated for using appropriate algorithms. For example if the viewing angle associated with edge effect is significant then algorithms can be developed to correct for viewing angle.

The field data collection program for 1990 involved determining the spectral characteristics of six potato fields using a spectrometer mounted on a boom. Figure 23 summarizes the instrumentation used in 1990. A Spectron SE590 spectroradiometer (on loan from NASA-Ames) was used to collect the field spectral data. The field of view (FOV) used was 15°. The SE590 was attached to the end of a truck mounted boom, and couldbepositioned from 6 to 30 feet above the soil surface. The measurements were taken at 30 feet above the soil surface for this experiment. The field of view (FOV) at this height covers 49 $feet^2$ (4.6 m^2) and encompassed approximately 2.8 rows. The attachment for the SE590 was self-leveling and held the sensor in a nadir position. A camera loaded with near-infrared panchromatic film was also attached to the boom. This camera was set to have nearly the same FOV as the Spectron.

The incident solar irradiance was measured by measuring the reflected light of a 99% reflectance standard (Spectrolon reflectance panel). Figure 25 shows reference panel readings throughout one day. The variations in these reading are an indication of the variability of incident light and the effect of changing sun angles during the day.

Measurements of canopy reflectance were taken throughout 1990 the growing season in six potato fields in the central Columbia basin. Ground cover (GC) was measured in the field by placing a frame over the area of interest and taking a vertical photograph. The photographs were interpreted both digitally and visually. The reflectance data were used to calculate the values of three spectral indices; Red Ratio (RR), Normalized Difference Vegetation Index (NDVI) and a new index based on the first derivative of the reflectance curve at 750 nm. Possible sources of variability in reflectance were also investigated including moisture on the leaves, different sun angles, diverse soil reflectance, and changes in solar irradiance during measurement. The spectral indices were correlated with ground cover. NDVI was found to be most closely correlated to ground cover, followed by the first derivative of the reflectance curve at 750 nm and Red Ratio. NDVI predicted ground cover well from 20-30% ground cover until canopy closure occurred.

Ground cover was measured from photographs of a 34 inch square grid overlaid on the canopy. Four samples of ground cover were taken at each spectral sampling point. The mean of the four measurements was used as the ground cover for that position.

Typical spectral characteristics for potatoes are illustrated by Figure 26 which shows reflectance as a function of wave length at one position in a field throughout the season.

The observed relationship between Red Ratio and ground cover is shown in Figure 27. The corresponding relationship for normalized difference is shown in Figure 28.

The normalized difference index was found to be the best predictor of ground cover. Average ground cover from each field and each date are plotted against the average normalized difference values in Figure 29. These averages, encompassing six points in each field, are approximations of field-wide averages that might be observed from a satellite.

The effect of surface moisture on reflectance is indicated in Figure 30. The effect of sun angle, as indicated by time of day, and the effects of sensor viewing (nadir and ± 15 degrees off-nadir) are illustrated in Figures 31 and 32 respectively.

Figure 24 summarizes the project status, relative to the five steps outlined earlier, as of the end of the second year of the project (the end of this reporting period). The field data collection as originally planned is complete. However there will be additional spectral data collection, as described above during the 1991 season. The simulation model selection is complete. Installation, calibration, testing and documentation of the selected models are approximately 40 percent complete. There has not yet been a substantial development of empirical relationships, in part because of the need for the spectral data collected in 1990 and in part because of the intensity of effort devoted to collection and data reduction. However some preliminary work has been done in this area. This will be the primary focus of our efforts in the third project year. Integration of yield prediction algorithms into CROPIX procedures will also be completed during the coming year.

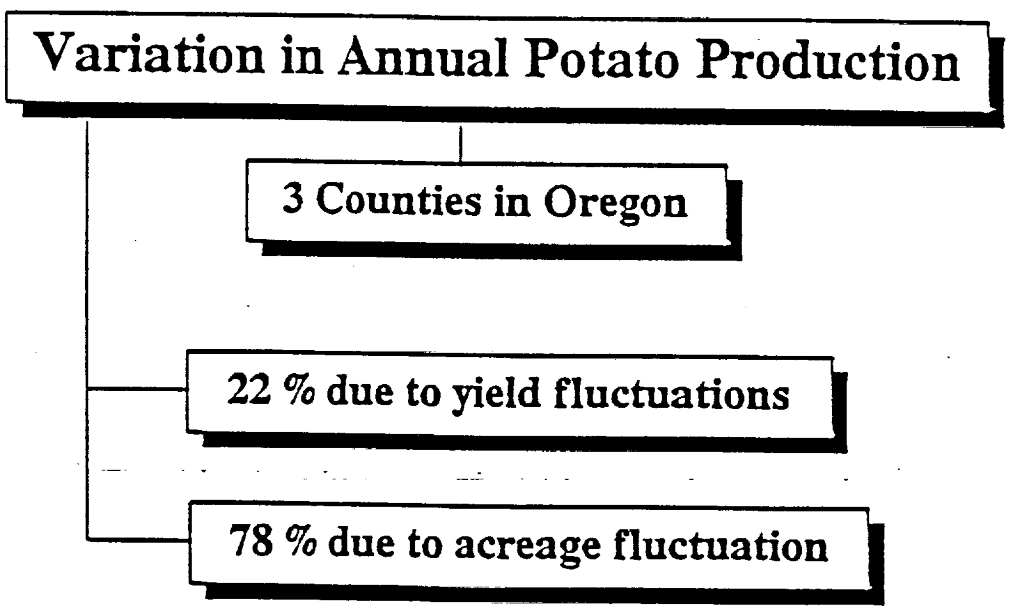

Variation in Annual Potato Production
3 Counties in Oregon
22 % due to yield fluctuations
78 % due to acreage fluctuation

FIGURE 1

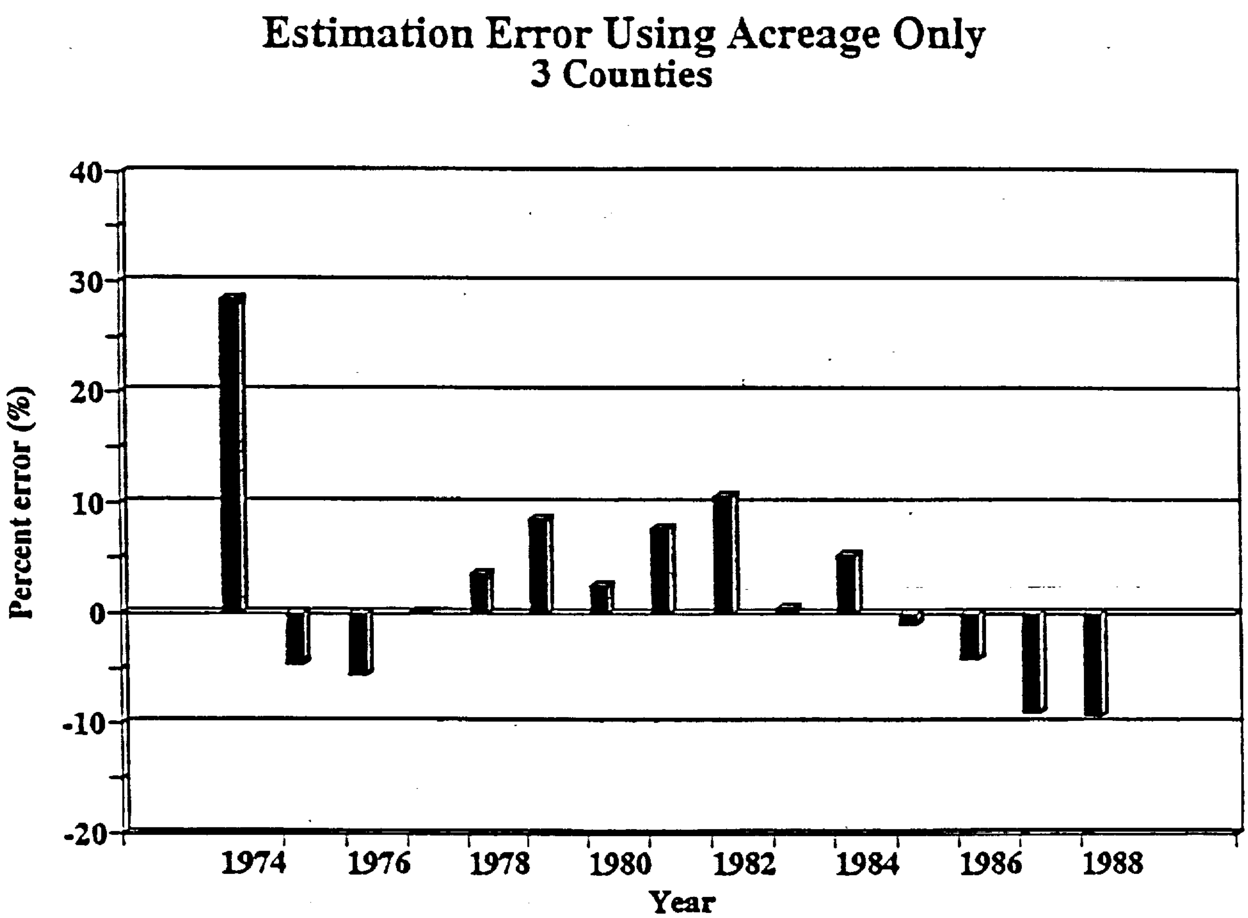

Estimation Error Using Acreage Only
3 Counties
40
30
20
10
0
-10
-20
Percent error (%)
1974
1976
1978
1980
1982
1984
1986
1988
Year

FIGURE 2

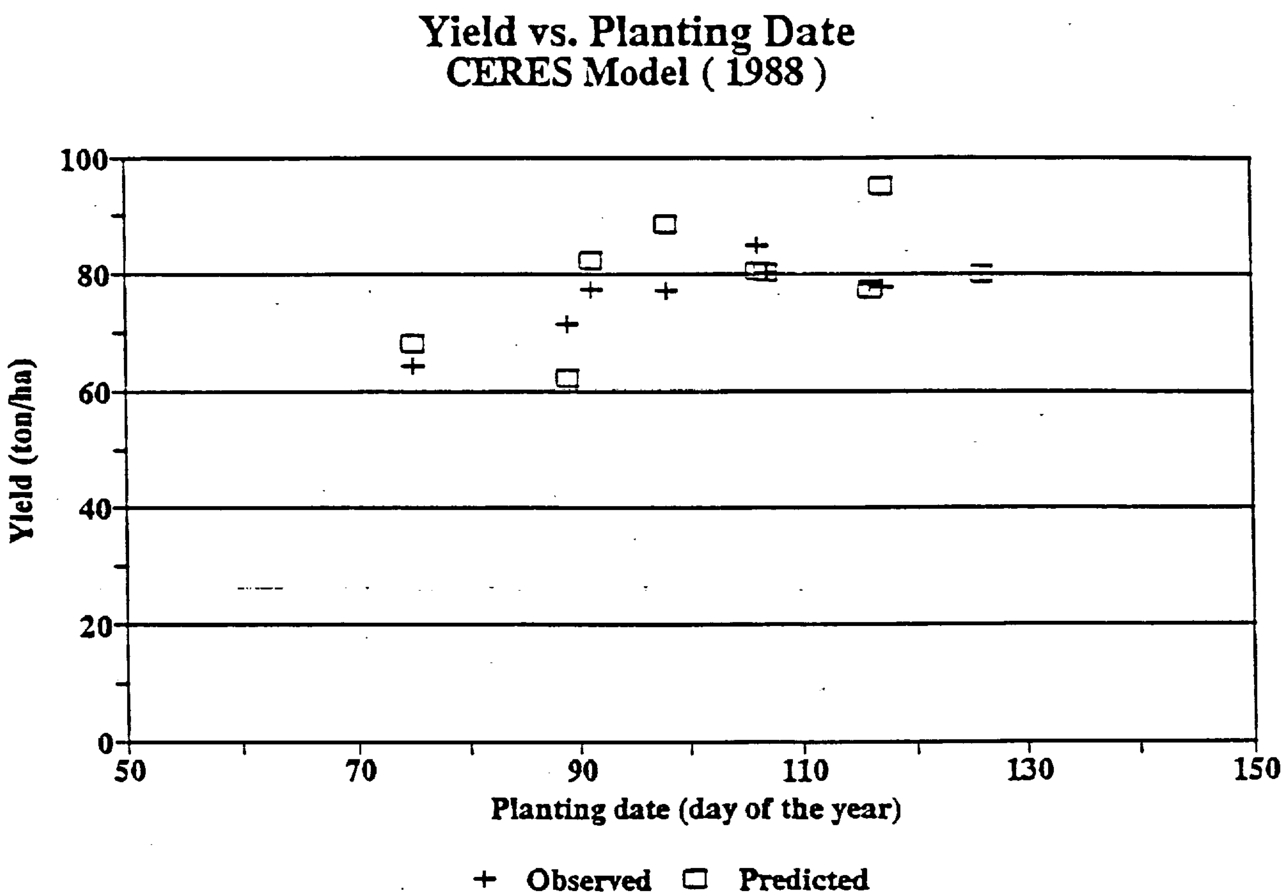

Yield vs. Planting Date
CERES Model (1988)
Yield (ton/ha)
100
80
60
40
20
0
50
70
90
110
130
150
Planting date (day of the year)
+ Observed
Predicted

FIGURE 3

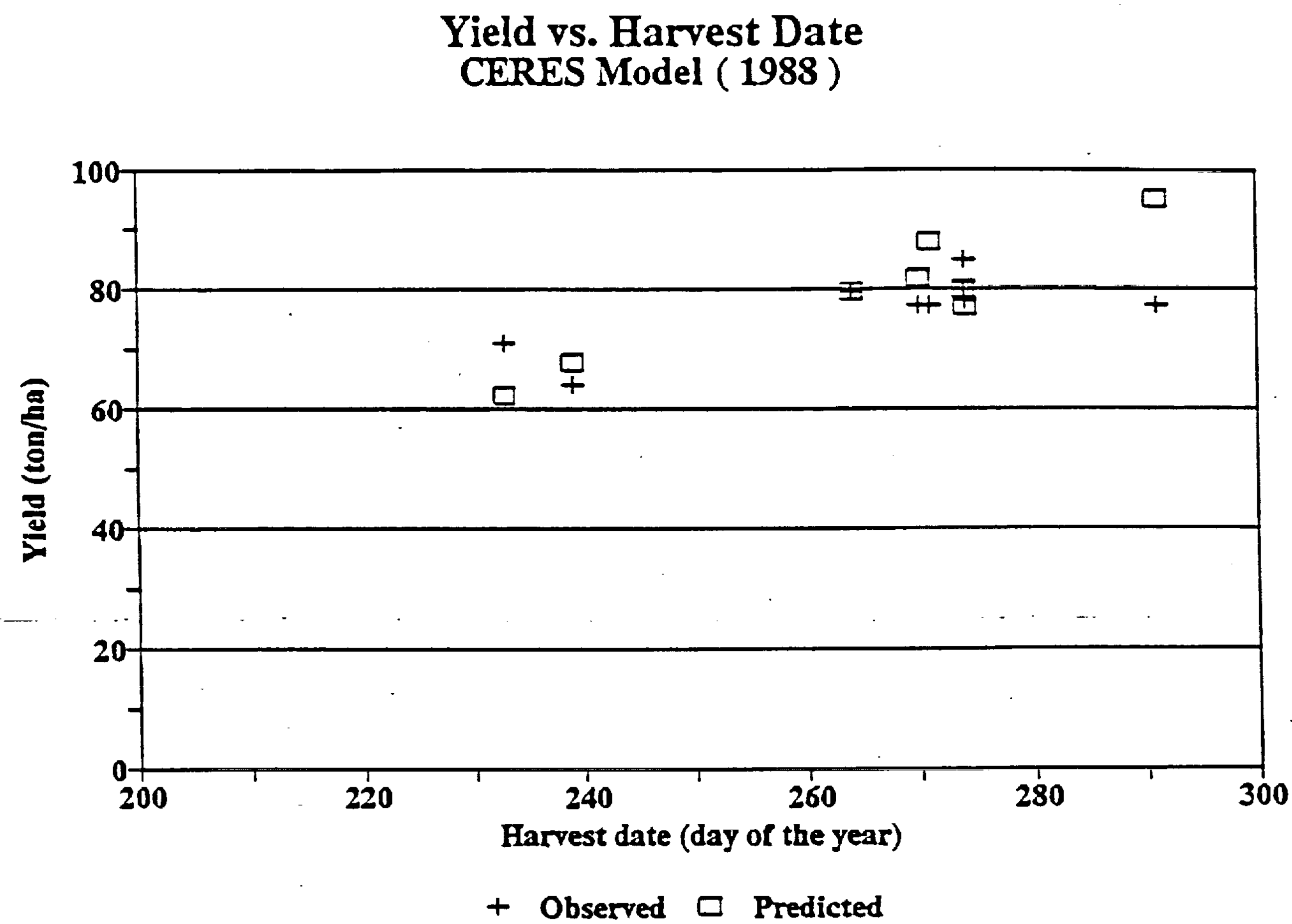

Yield vs. Harvest Date
CERES Model (1988)
100
80
60
40
20
0
Yield (ton/ha)
200
220
240
260
280
300
Harvest date (day of the year)
+ Observed
Predicted

FIGURE 4

Yield Surface from CERES Model (1989)

Model run with auto-irrigate, no auto-fertigate.
Fertilizer applied = 2kg N/ha*day
Weather= 1/01/89-8/15/89 +87-88 composite to 10/31

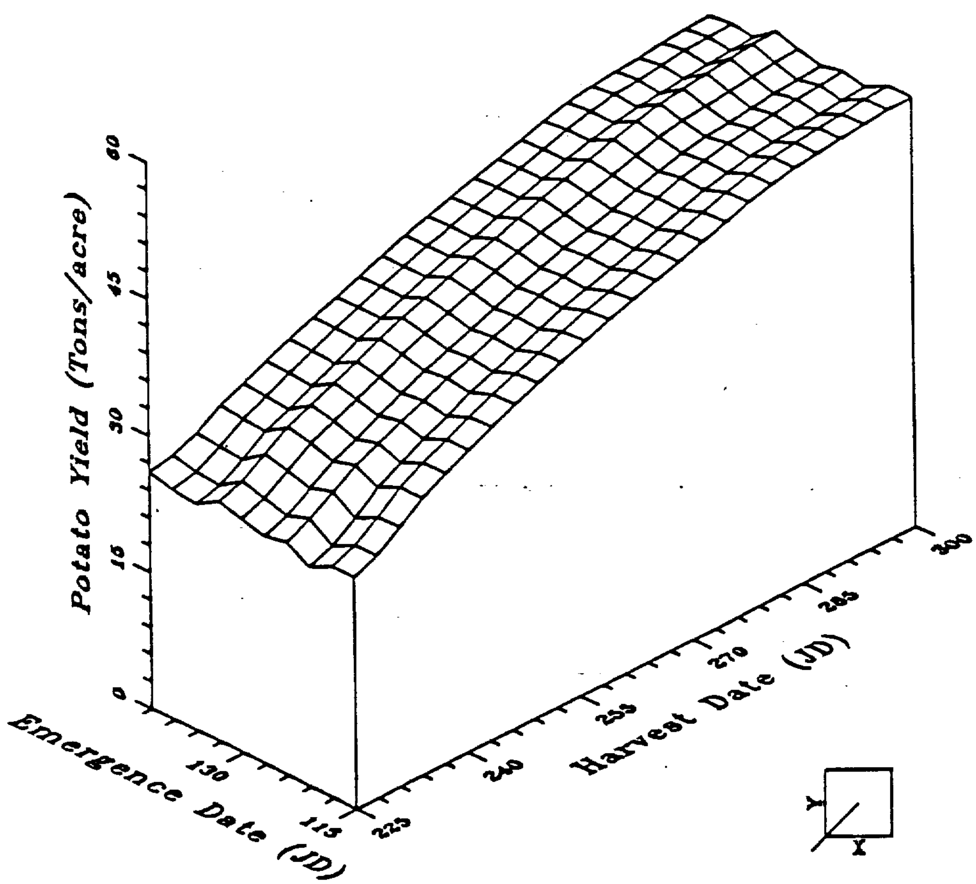


FIGURE 5

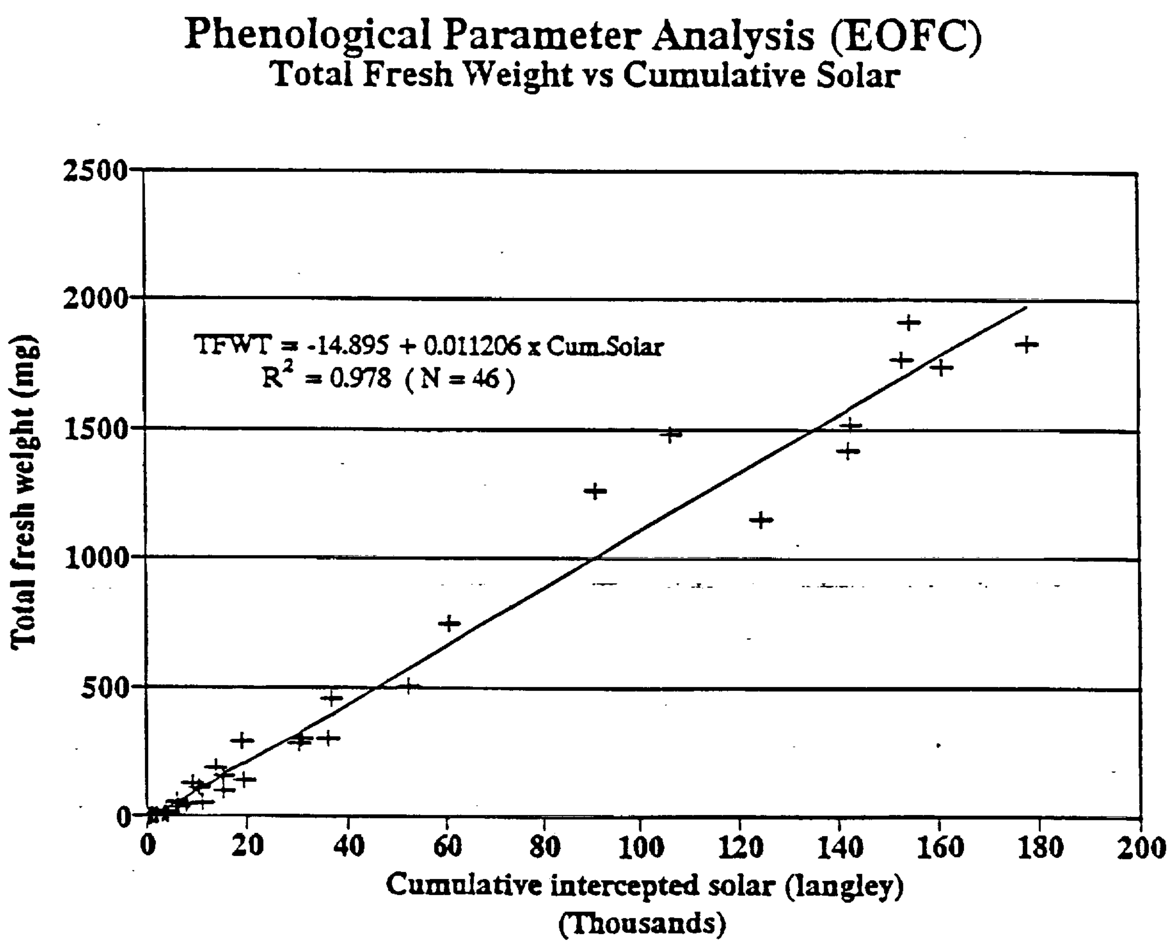

Phenological Parameter Analysis (EOFC)
Total Fresh Weight vs Cumulative Solar
TFWT = -14.895 + 0.011206 x Cum.Solar
R^2 = 0.978 (N = 46)
Total fresh weight (mg)
2500
2000
1500
1000
500
0
0
20
40
60
80
100
120
140
160
180
200
Cumulative intercepted solar (langley)
(Thousands)

FIGURE 6

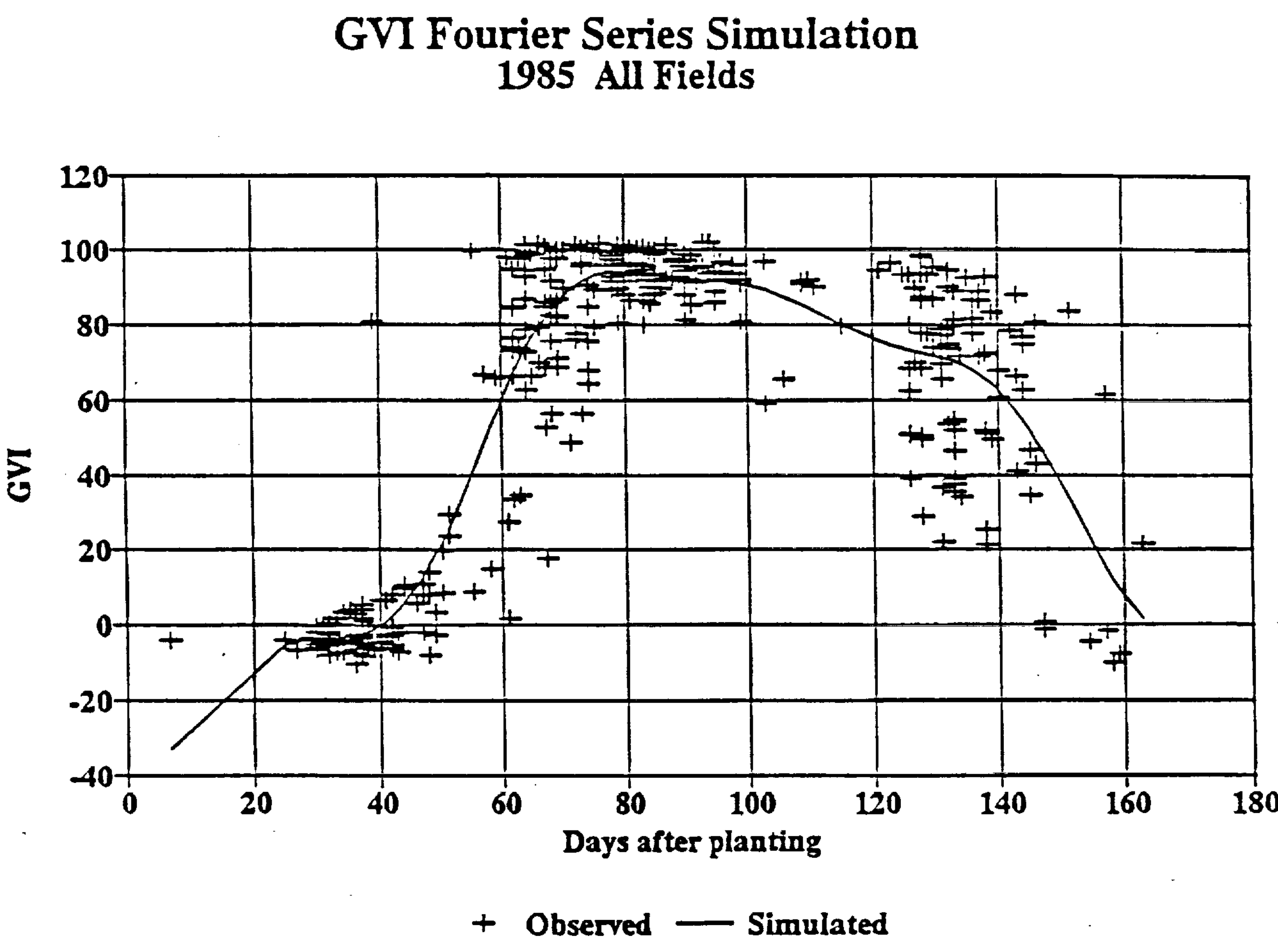

GVI Fourier Series Simulation
1985 All Fields
GVI
120
100
80
60
40
20
0
-20
-40
0
20
40
60
80
100
120
140
160
180
Days after planting
+ Observed
Simulated

FIGURE 7

APPROACH

- **Develop Algorithms to Relate Spectral Observations to Crop Development**
- **Augment Spectral Observations with Other information Such as :**
  - **Crop environment**
    (weather, soils, farming practices)
  - **Experimental knowledge**
    (embodied in simulation models)

FIGURE 8

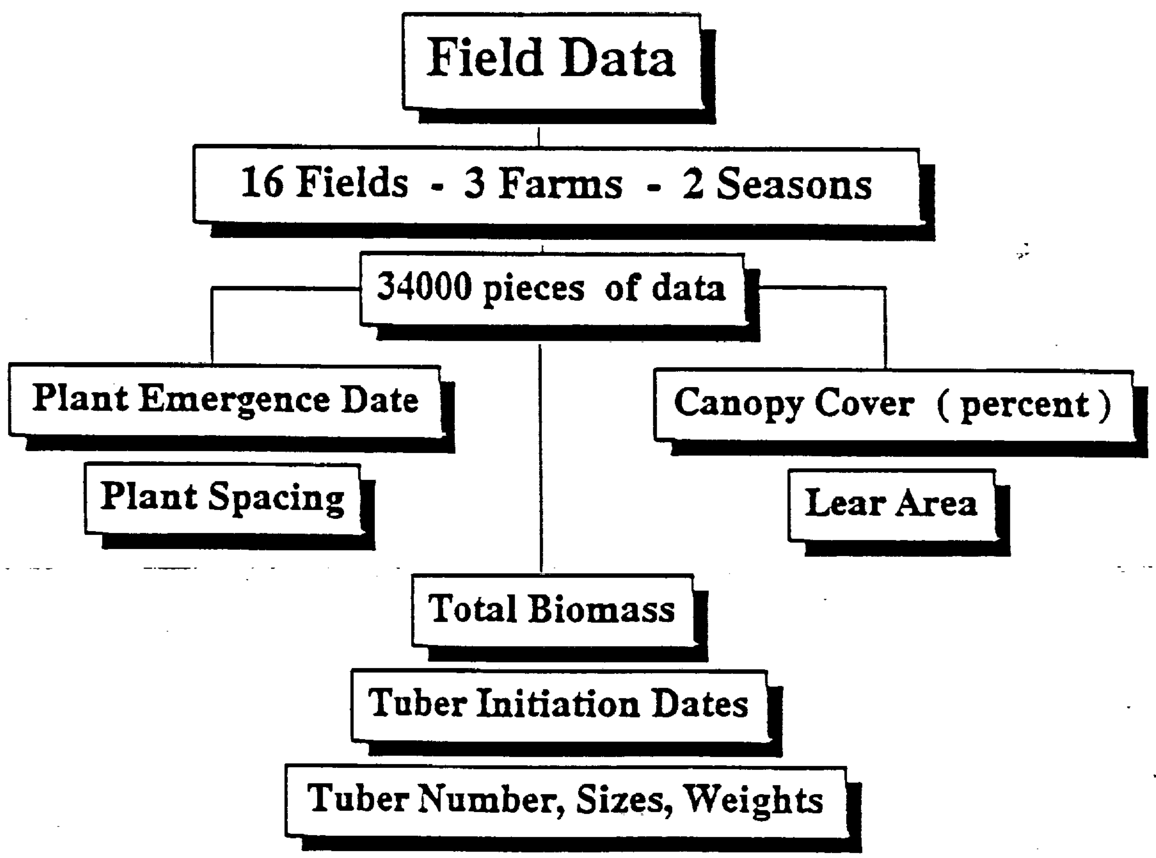

Field Data
16 Fields - 3 Farms - 2 Seasons
34000 pieces of data
Plant Emergence Date
Plant Spacing
Canopy Cover (percent)
Lear Area
Total Biomass
Tuber Initiation Dates
Tuber Number, Sizes, Weights

FIGURE 9

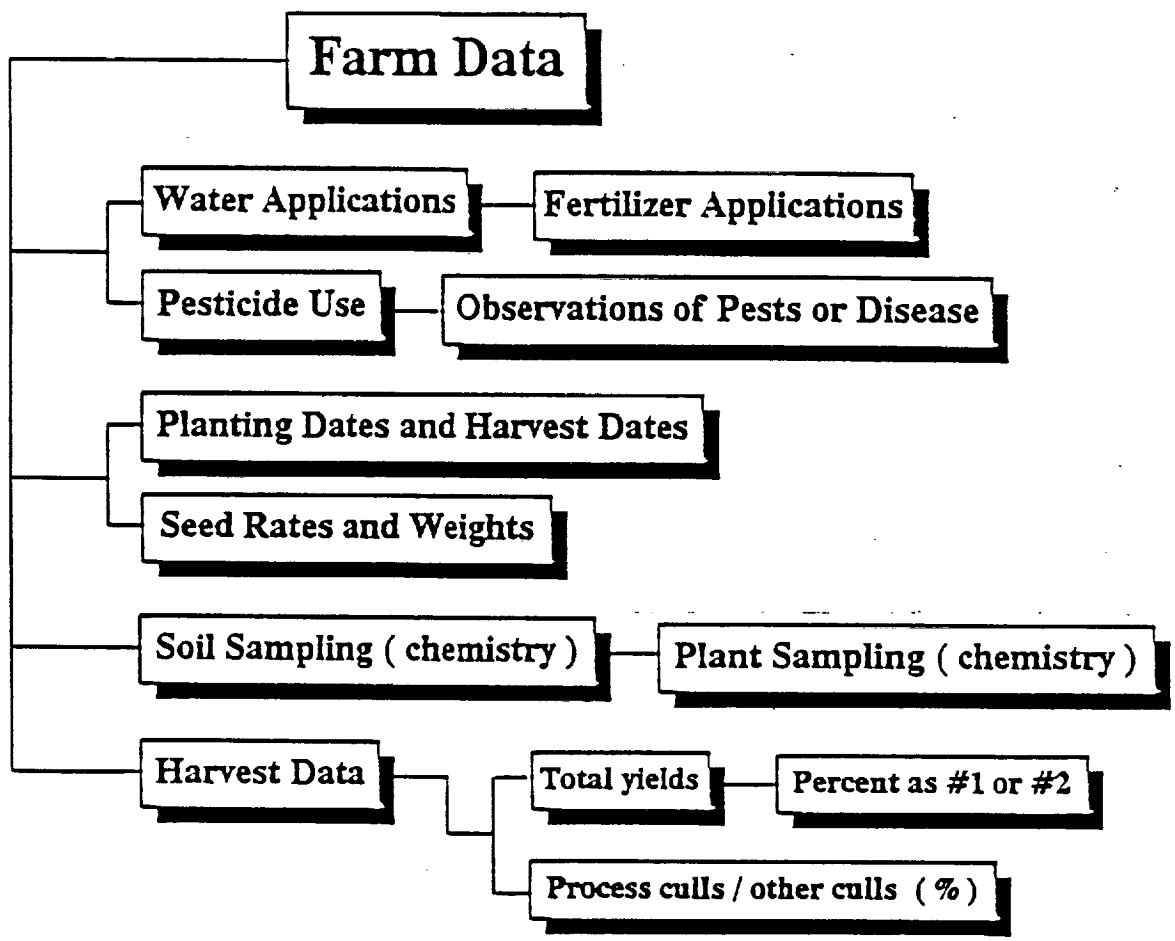

Farm Data
Water Applications
Fertilizer Applications
Pesticide Use
Observations of Pests or Disease
Planting Dates and Harvest Dates
Seed Rates and Weights
Soil Sampling (chemistry)
Plant Sampling (chemistry)
Harvest Data
Total yields
Percent as #1 or #2
Process culls / other culls (%)

FIGURE 10

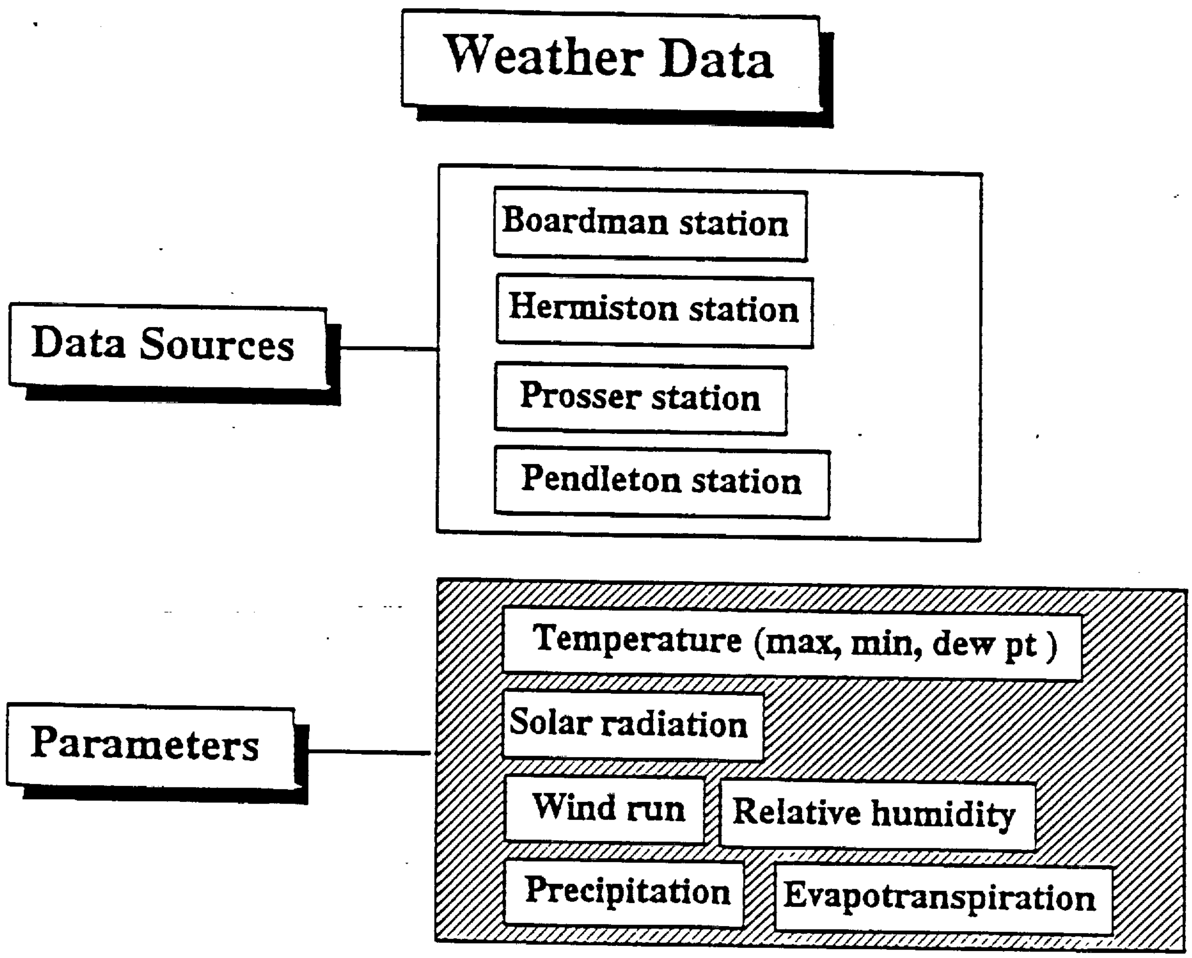

Weather Data
Data Sources
Boardman station
Hermiston station
Prosser station
Pendleton station
Parameters
Temperature (max, min, dew pt)
Solar radiation
Wind run
Relative humidity
Precipitation
Evapotranspiration

FIGURE 11

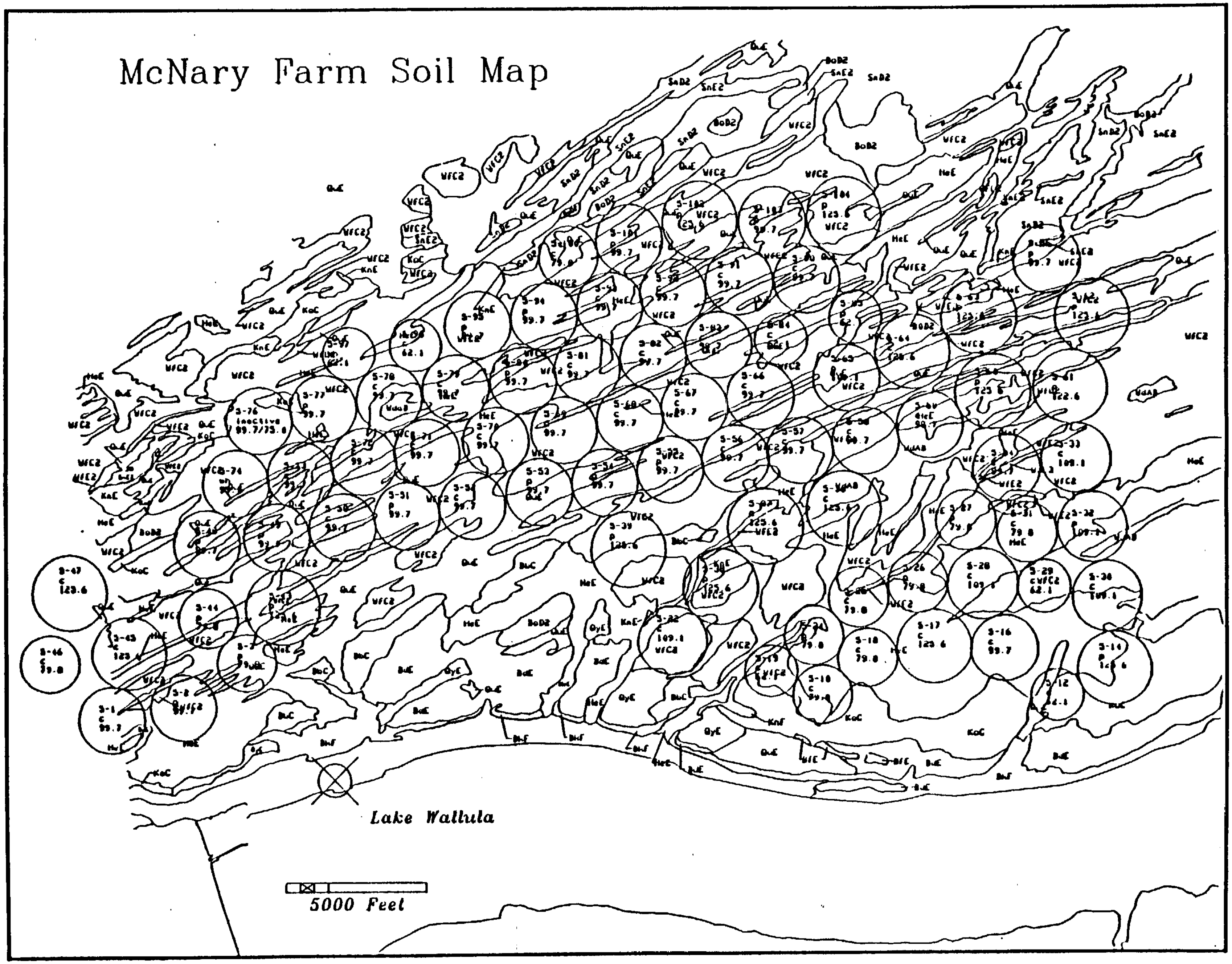


FIGURE 12

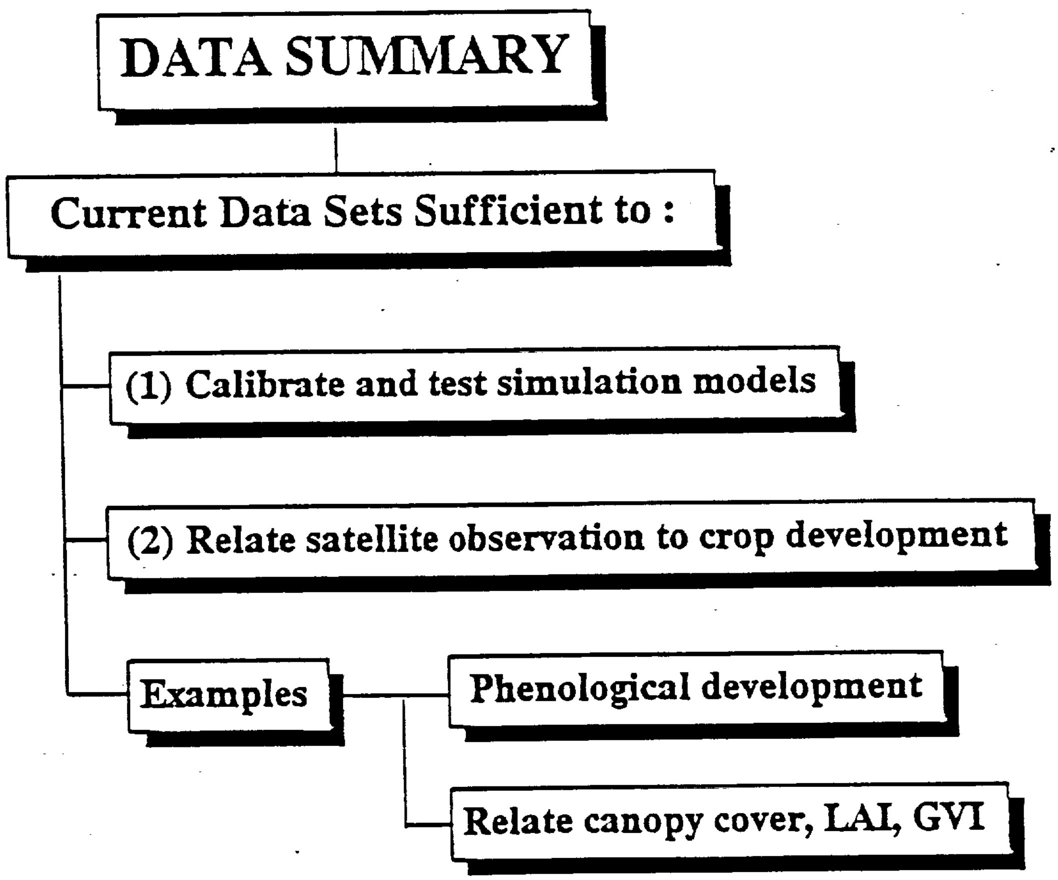

DATA SUMMARY
Current Data Sets Sufficient to :
(1) Calibrate and test simulation models
(2) Relate satellite observation to crop development
Examples
Phenological development
Relate canopy cover, LAI, GVI

FIGURE 13

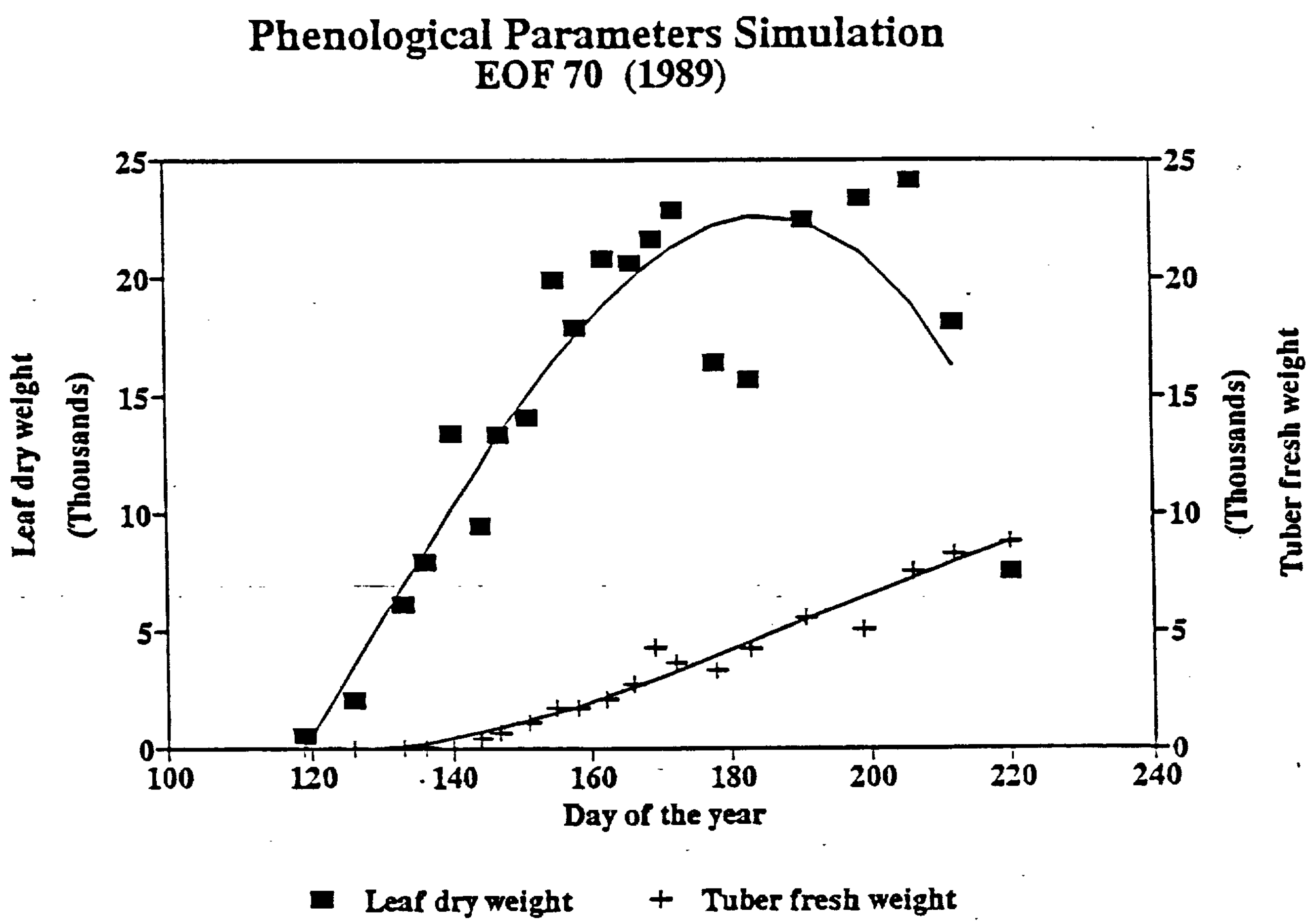

Phenological Parameters Simulation
EOF 70 (1989)
Leaf dry weight
(Thousands)
(Thousands)
Tuber fresh weight
25
20
15
10
5
0
100
120
140
160
180
200
220
240
Day of the year
Leaf dry weight
Tuber fresh weight

FIGURE 14

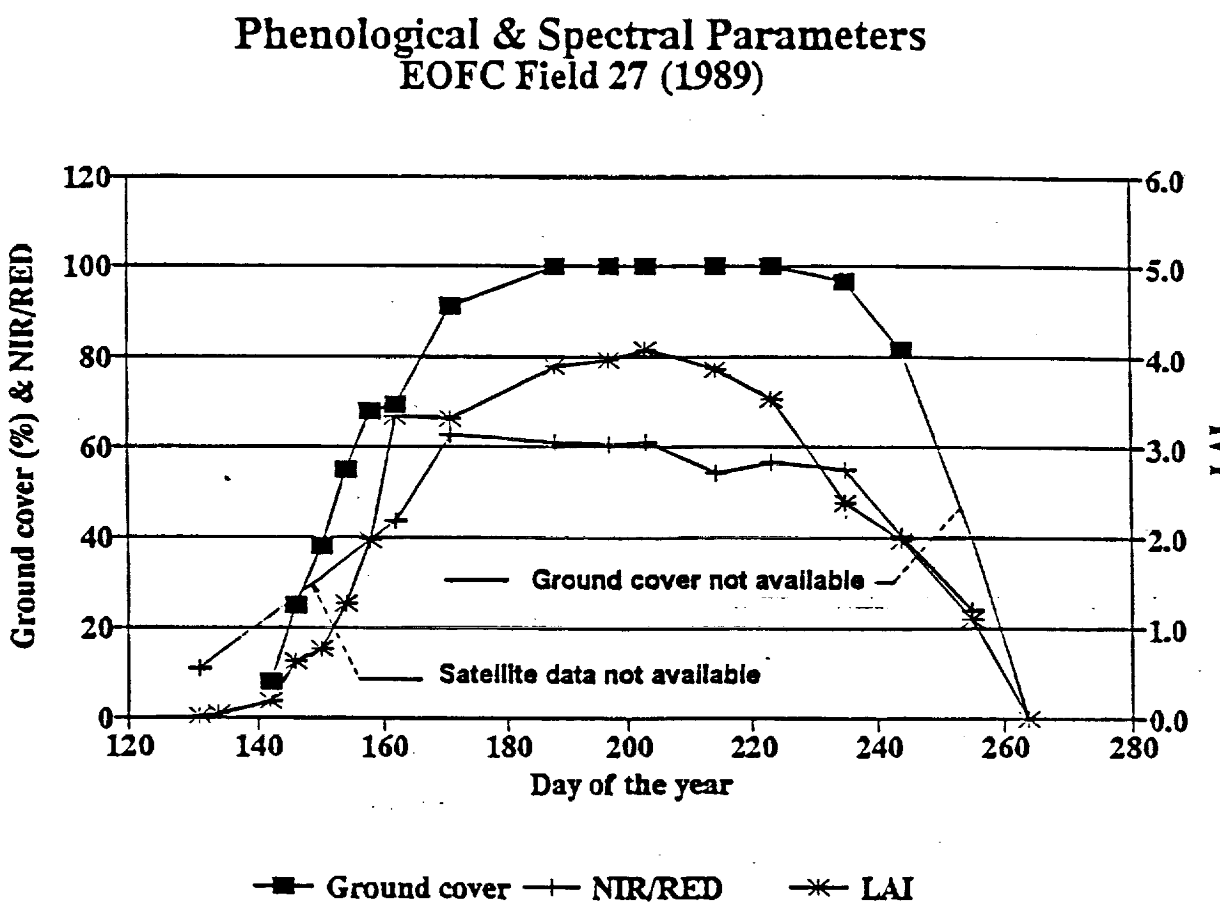

Phenological & Spectral Parameters
EOFC Field 27 (1989)
Ground cover (%) & NIR/RED
LAI
Day of the year
Ground cover not available
Satellite data not available
120
100
80
60
40
20
0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
120
140
160
180
200
220
240
260
280
Ground cover
NIR/RED
LAI

FIGURE 15

DATA SHARING

- Mary Powelson (Dept. of Botany/Plant Pathol. OSU)
- Gary Reid (Branch Experiment Station, OSU)
- Elmer Ewing (Cornell University) *
- Tom Hodges (Washington State University)
- Svetlana Fishman (Volcani Institute, Israel)
- IBSNAT Archives

* Potato modeling conference in Amsterdam (May 1990)

FIGURE 16

CERES Model vs. Observed Data
1988

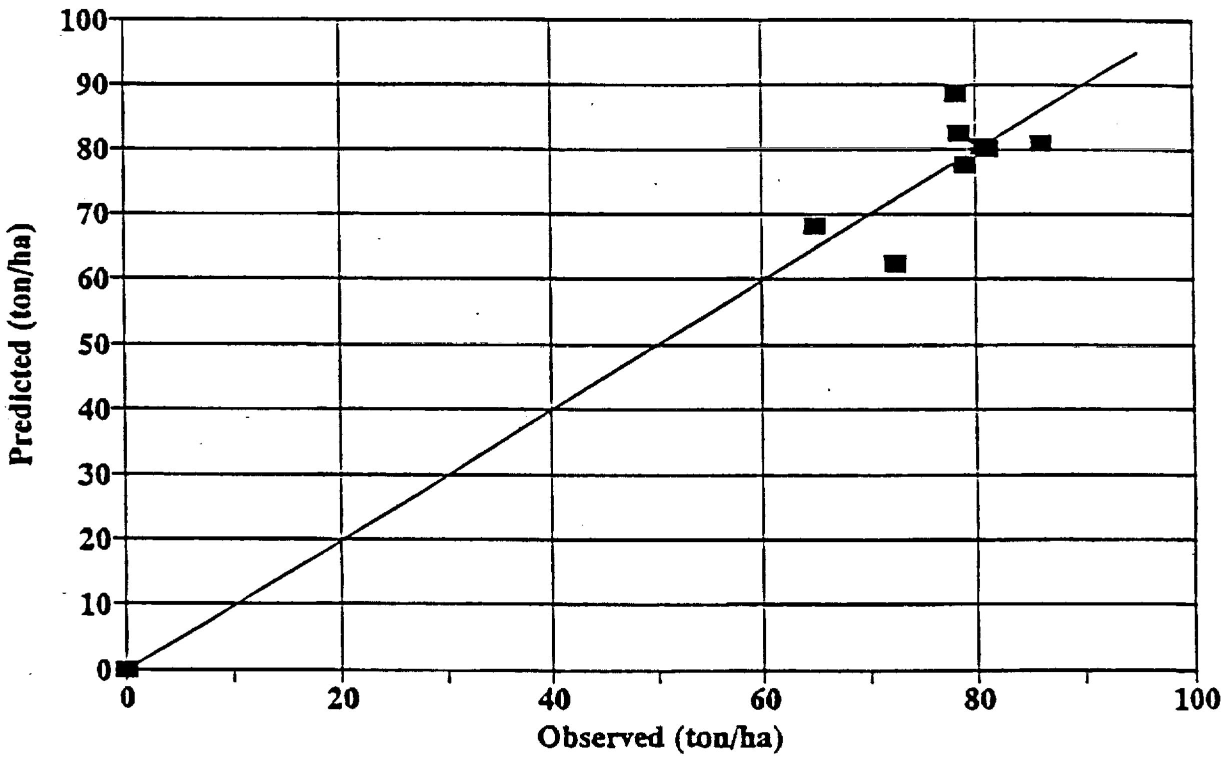


FIGURE 17

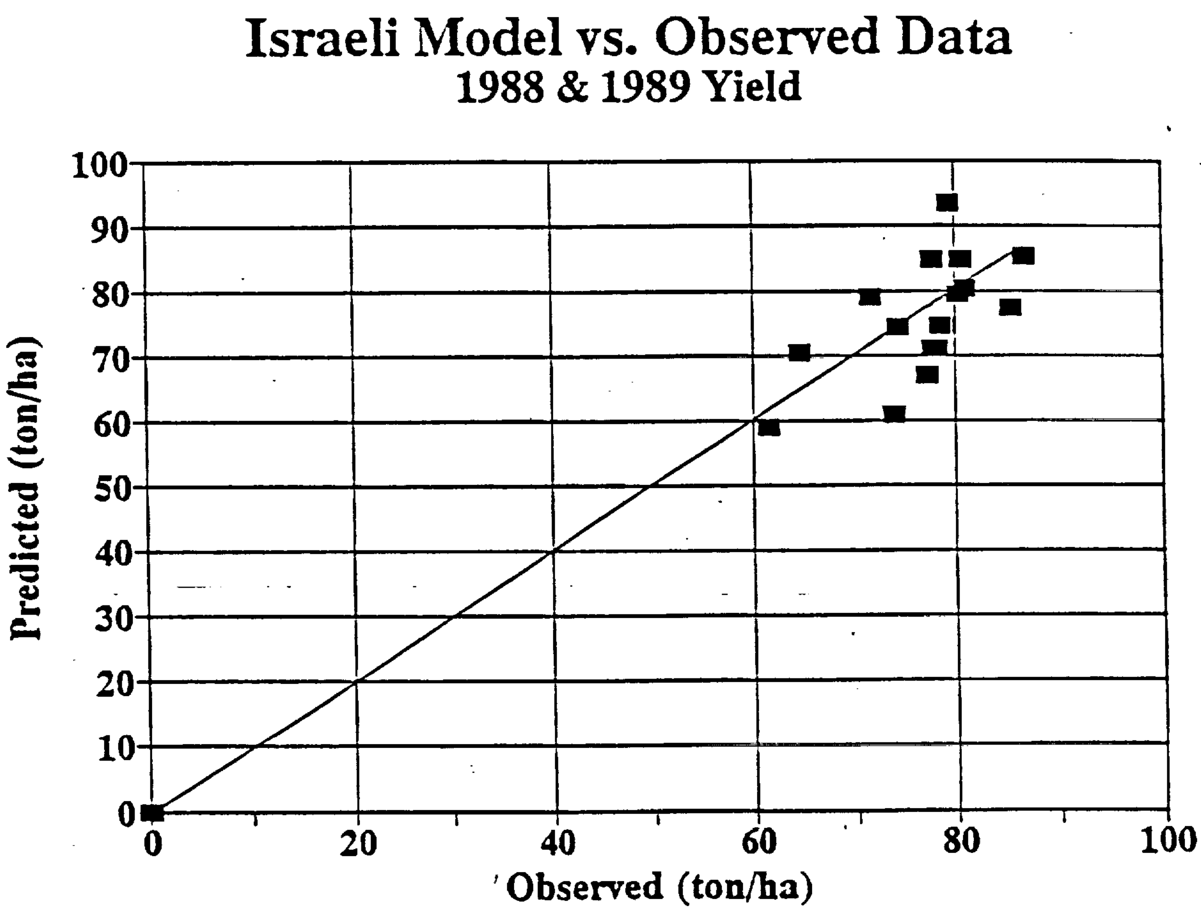
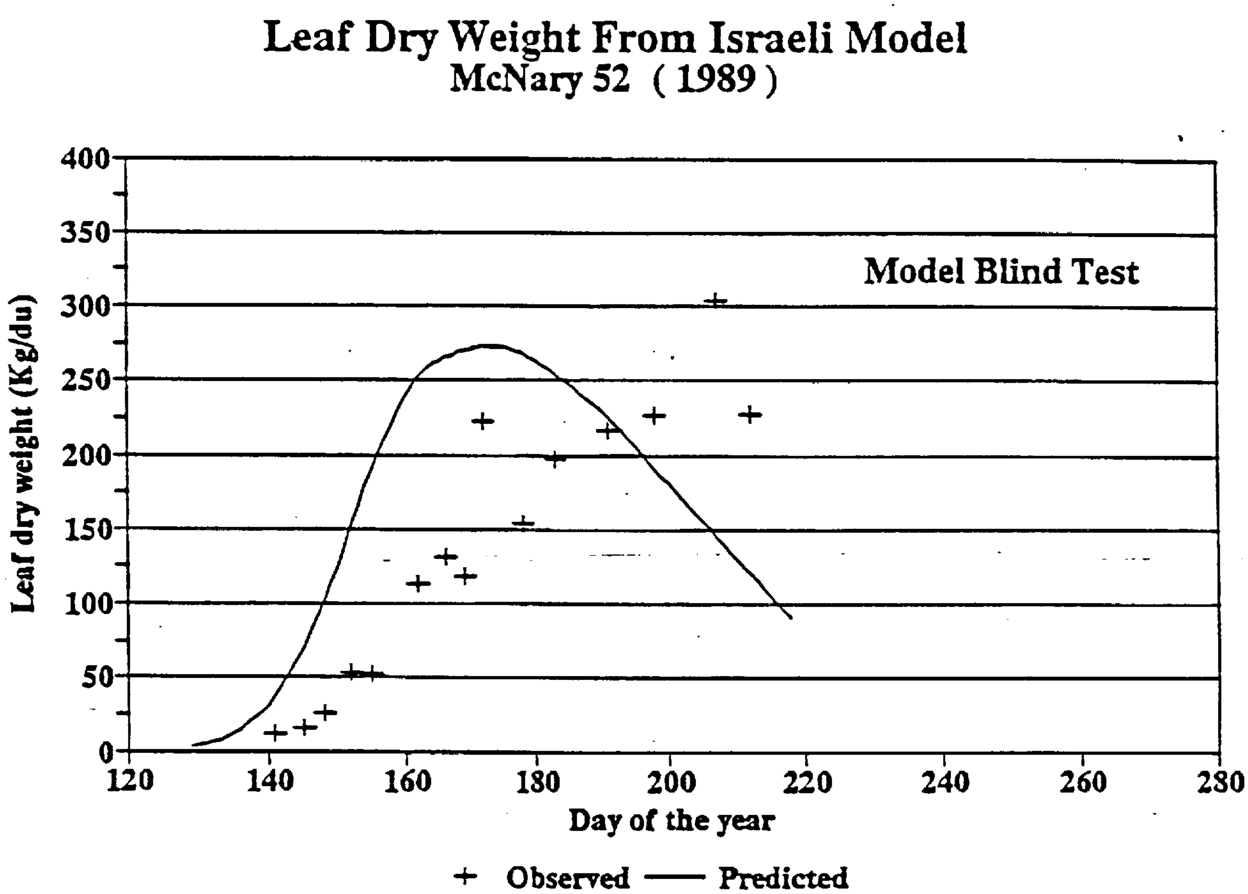

Israeli Model vs. Observed Data
1988 & 1989 Yield
Predicted (ton/ha)
Observed (ton/ha)
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100

FIGURE 18



Leaf Dry Weight From Israeli Model
McNary 52 (1989)
Model Blind Test
Leaf dry weight (Kg/du)
400
350
300
250
200
150
100
50
0
120
140
160
180
200
220
240
260
280
Day of the year
Observed
Predicted

FIGURE 19

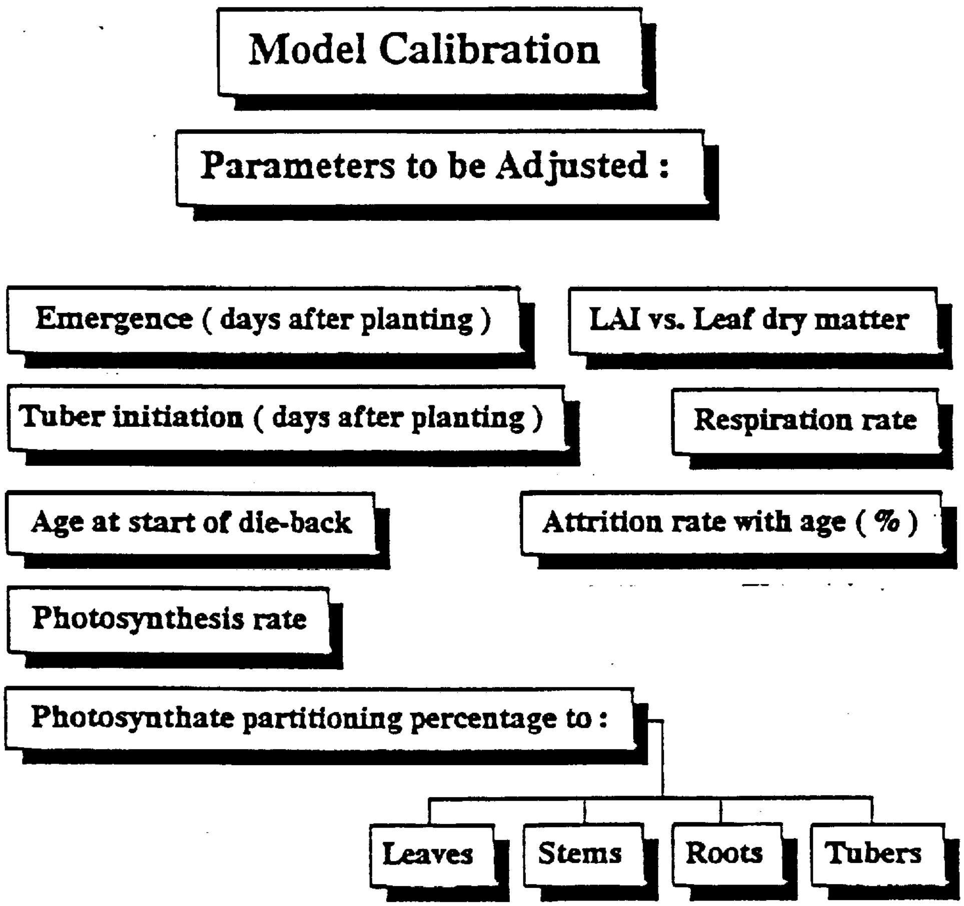

Model Calibration
Parameters to be Adjusted :
Emergence (days after planting)
LAI vs. Leaf dry matter
Tuber initiation (days after planting)
Respiration rate
Age at start of die-back
Attrition rate with age (%)
Photosynthesis rate
Photosynthate partitioning percentage to :
Leaves
Stems
Roots
Tubers

FIGURE 20

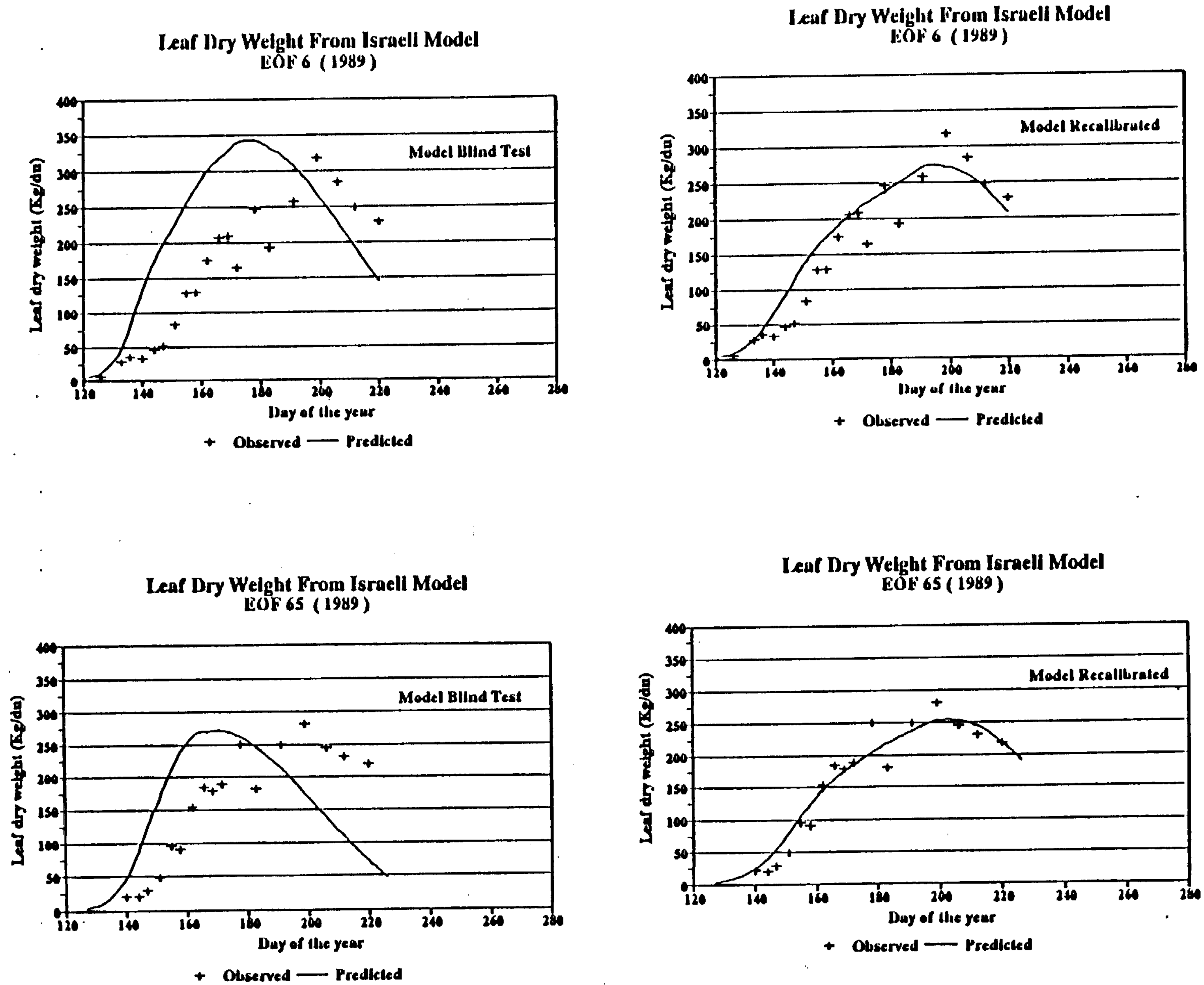

Leaf Dry Weight From Israeli Model
EOF 6 (1989)
Model Blind Test
Leaf dry weight (Kg/du)
Day of the year
+ Observed —— Predicted
Leaf Dry Weight From Israeli Model
EOF 6 (1989)
Model Recalibrated
Leaf dry weight (Kg/du)
Day of the year
+ Observed —— Predicted
Leaf Dry Weight From Israeli Model
EOF 65 (1989)
Model Blind Test
Leaf dry weight (Kg/du)
Day of the year
+ Observed —— Predicted
Leaf Dry Weight From Israeli Model
EOF 65 (1989)
Model Recalibrated
Leaf dry weight (Kg/du)
Day of the year
+ Observed —— Predicted

FIGURE 21

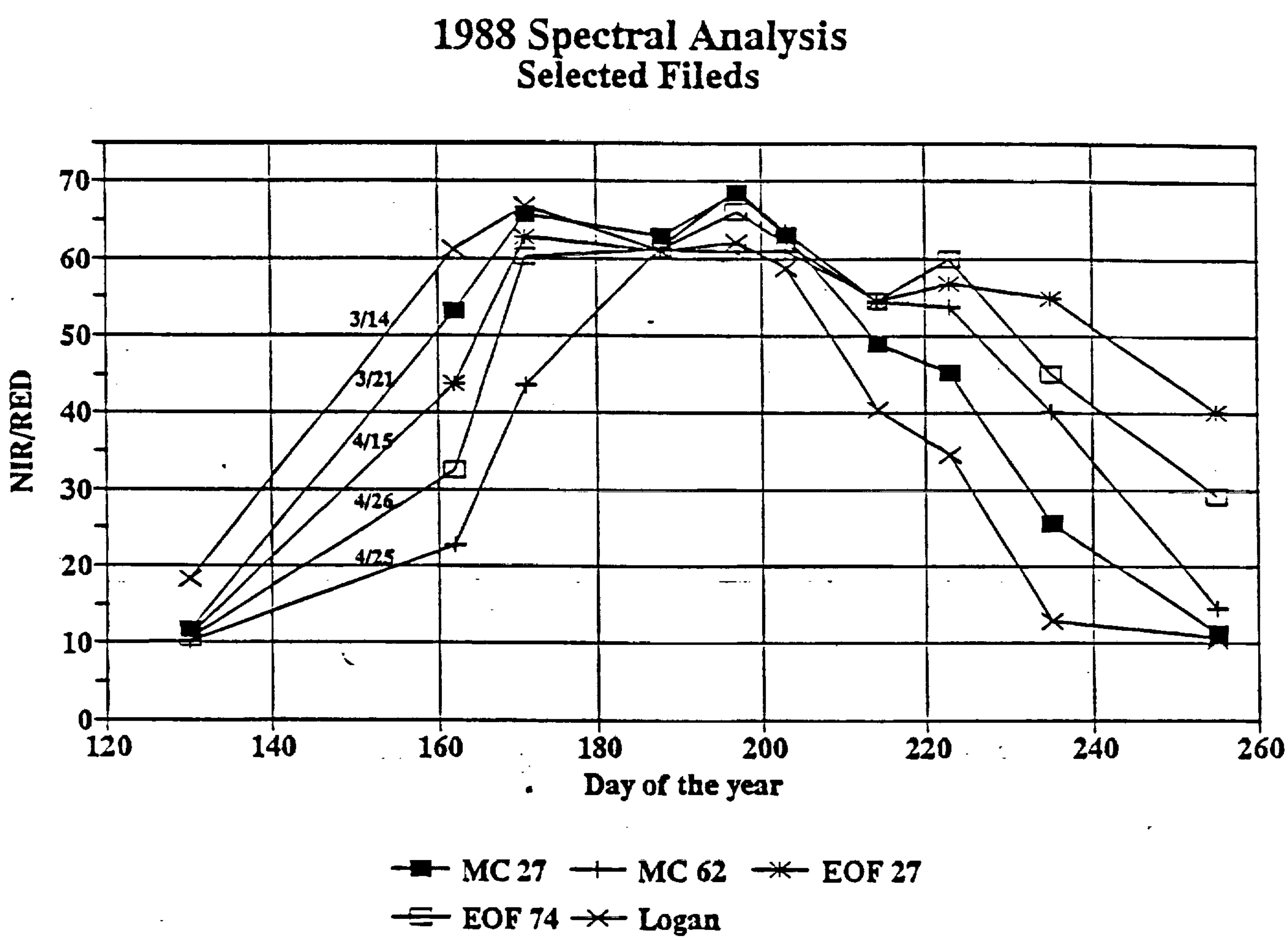

1988 Spectral Analysis
Selected Fileds
NIR/RED
Day of the year
3/14
3/21
4/15
4/26
4/25
MC 27
MC 62
EOF 27
EOF 74
Logan

FIGURE 22

1990 Field Data Collection

Spectrometer / Truck - mounted Boom

- **Boom on loan from Purdue / ERSAL**
- **Spectrometer provided by AMES**
- **Real time data display software (AMES)**

Modification by Ag Engineering, OSU

- **Increased elevation (30 ft)**
- **Universal connection to any angle**
- **Laser pointer**
- **Protective cage**

FIGURE 23

SUMMARY

Field data collection	Complete
Simulation model selection	Complete
Installation, calibration and testing of simulation models	70 % Complete
Development of empirical relationships	20 % Complete
Integration of model results into yield prediction algorithms	20 % Complete

FIGURE 24

Project Status; Third Year Plans

I. Calibration and Testing of the Israeli Model

This has been the area of greatest activity for the past two months, and will continue as a primary activity until the 1991 growing season is underway. Our activities in this area have included systematic efforts to understand the logic of the model, determining needed modifications, developing procedures for calibration and testing of the model and the process of actually calibrating and testing it.

Understanding the model is of central importance for two reasons. First because there is essentially no useable documentation on the computer code and such documentation will be needed to refine the model as users gain experience with it. Secondly, there are almost 100 parameters involved in the model. It would be possible to arbitrarily manipulate these parameter values to fit field data quite well but to do so would be pointless because the resulting model would be unreliable when used with new weather data or altered management practices. For that reason we are engaged in determining precisely how the model works; i.e. what assumptions are made, what parameters are involved and how they are used, how to relate the model code to the published papers that pertain to it, and so on. To do that we are working on duplicating the outputs of the model by hand calculations based on the publications of Fishman and others. This process has gone much more slowly than anticipated and is still only about 60% done. However we have reached a point where the basic structure of the model is clearer to us and we are progressing rapidly now. A few problems have surfaced in this exercise:

1. the algorithm for calculating the number of days from planting to emergence is not of practical value. A modified algorithm has been developed.
2. the influence of high temperature on respiration is not realistic when temperatures get above about 30 degrees C.
3. the model of the aging process seems to be unrealistic near the end of the season.
4. we are having difficulty understanding the procedures for calculating solar radiation interception and have asked Svetlana to help decipher the algorithms involved.

Preliminary calibration of the model has been carried out earlier, but is now being conducted more systematically. The data sources for calibration include the partitioning and growth data from the 16 fields monitored in 1988 and 1989, similar data along with the reflectance and solar radiation incterception data from field 44 in 1990, and reflectance data from five other fields in 1990. Because of the large number of parameters involved, the strategy is to determine values of as many as possible directly from field measurements. For example the relationship between leaf area index and leaf dry weight can be determined from data collected in the field during this project. Some parameters are, of necessity, being derived indirectly by adjusting them until model output conforms to field data. To utilize this process effectively with the great mass of field data involved, a procedure has been developed for rapid display of comparisons of model outputs with field data from the 16 fields. This allows the user to see quickly how a change in a parameter value will effect outputs and how those outputs compare with field data for any or all of the 16 fields.

Weather data files for the years 1984 to 1987 have been set up in the required format for input to the model. These are to be used for model testing once the calibration is complete. Management data from indivual fields will be required for these tests. Such data should include, at a minumum, planting and harvest dates and crop yield. Ideally the data should also include emergence dates and Landsat or SPOT observations of the fields.

Work to be done in third project year will include completion of the calibration and testing and development of procedures for integrating the model into Cropix operations.

II. Spectral Data Collection and Interpretation

Spectrometer data from 1990 have been assembled in a readily accessible data base. These data include the spectral data in each of 256 frequecies, the reflectance ratio after division by the appropriate calibration data, and canopy cover data as of the day of observation. The data have now been corrected for the frequency shift associated with the spectrometer.

Early in the analysis of these data some of the ground cover data were thought to be in error. All canopy cover readings were therefore reviewed and approximately 5% of the readings were found to be in error by up to 10%

At this stage the data are ready for use in analysis of the spectral characteristics of potato canopies. Preliminary results indicate that red-ratio and NDVI-7 may be suitable for estimation of ground cover after approximately 40% cover has been achieved. At lower levels of these indices the uncertainty of estimates will be substantial. NDVI-8 seems to be less sensitive to ground cover. GVI has not yet been evaluated as an index of ground cover because the necessary readings of soil reflectance have not yet been obtained. Soil samples to be used in detgermining reflectance characteristics have been collected and brought back to Corvallis. Data will be taken as soon as a spectrometer becomes available.

Peripheral studies based on the reflectance data collected in the field have been carried out to gain additional understanding of the potential uses of spectral data for monitoring crop growth. These include:

1. determination of the first derivative of the [redacted] spectral curve. [redacted]. This index is not available from current satellite platforms, but could be determined using aircraft-based data. Preliminary results suggest this index may be a useful indicator of ground cover.
2. determinations of red ratio at various sun angles. Data taken throughout the day indicate that sun angle has little effect on red ratio.
3. sensor viewing angles of + and - 15 degrees off-nadir.

Anticipated work this spring will include completion of the studies of characteristic GVI for potatoes, selection of the most effective indicator of canopy vigor and ground cover, and a final determination of the ability to estimate ground cover from reflectance charateristics.

Comparison of the various indices with LAI,

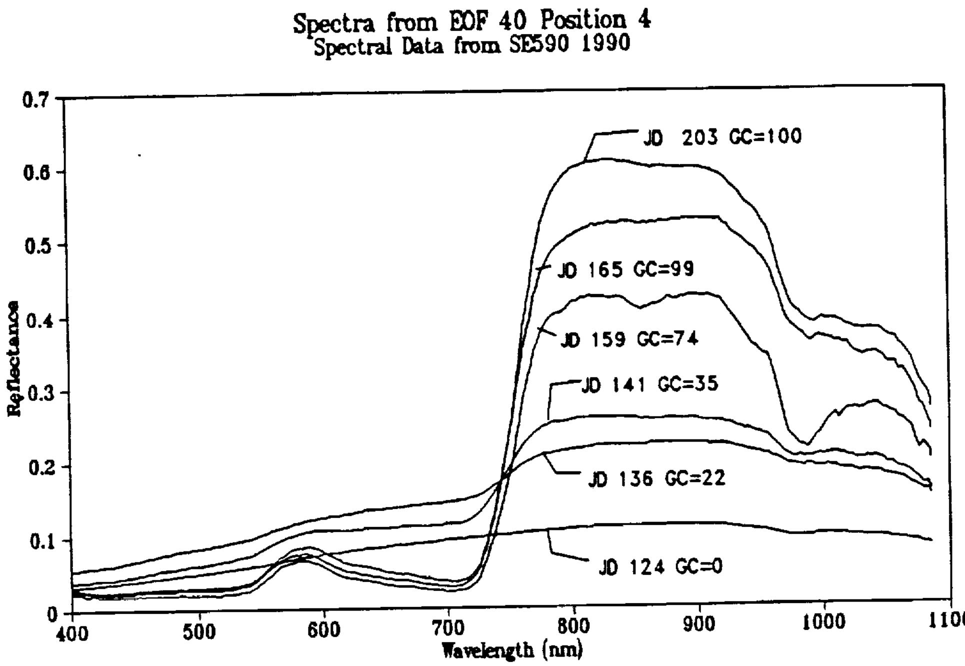

Spectra from EOF 40 Position 4
Spectral Data from SE590 1990
JD 203 GC=100
JD 165 GC=99
JD 159 GC=74
JD 141 GC=35
JD 136 GC=22
JD 124 GC=0
Reflectance
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
400
500
600
700
800
900
1000
1100
Wavelength (nm)

FIGURE 26

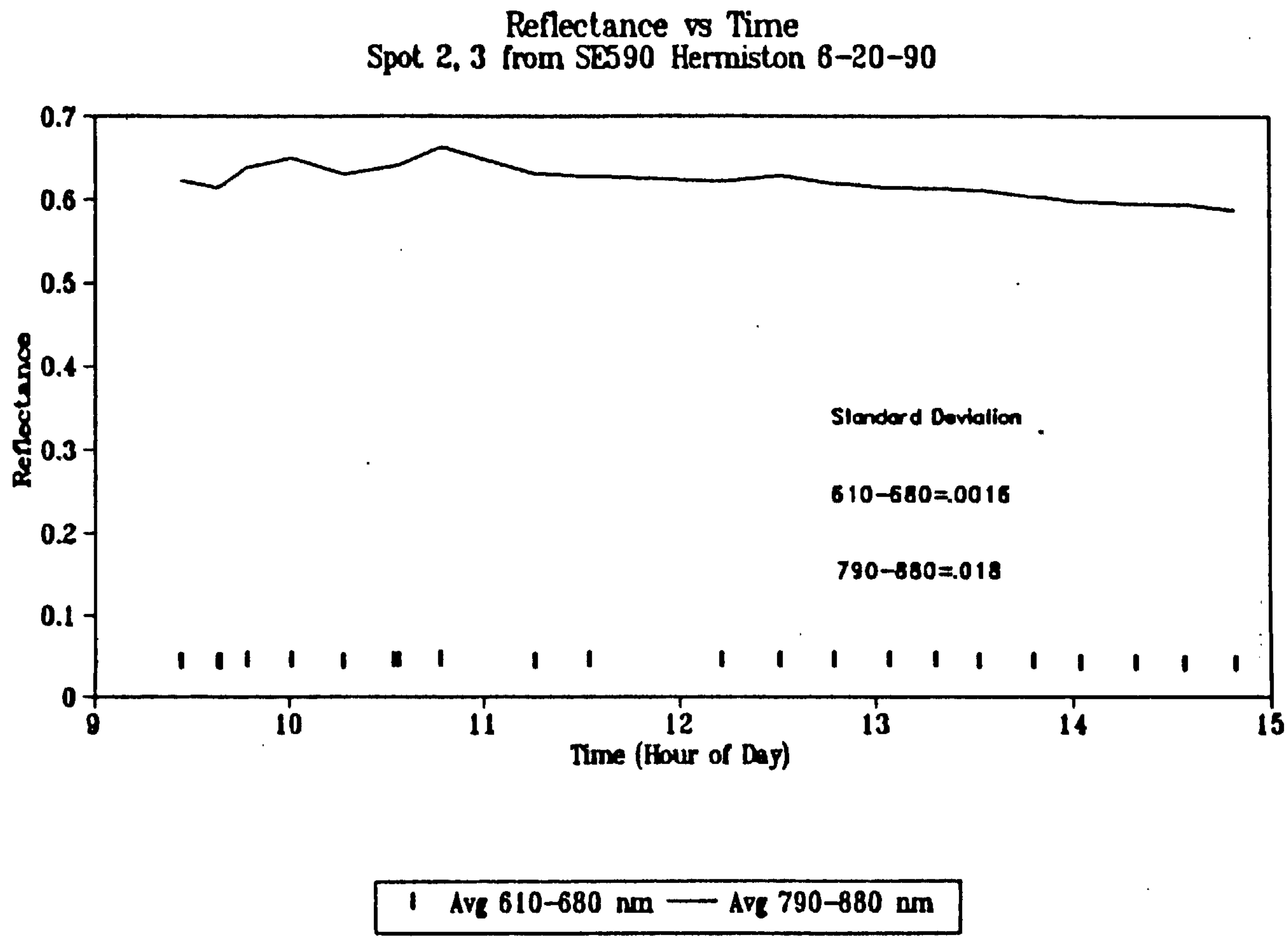

Reflectance vs Time
Spot 2, 3 from SE590 Hermiston 6-20-90
Reflectance
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
9
10
11
12
13
14
15
Time (Hour of Day)
Standard Deviation
610-680=.0016
790-880=.018
Avg 610-680 nm
Avg 790-880 nm

Figure 25

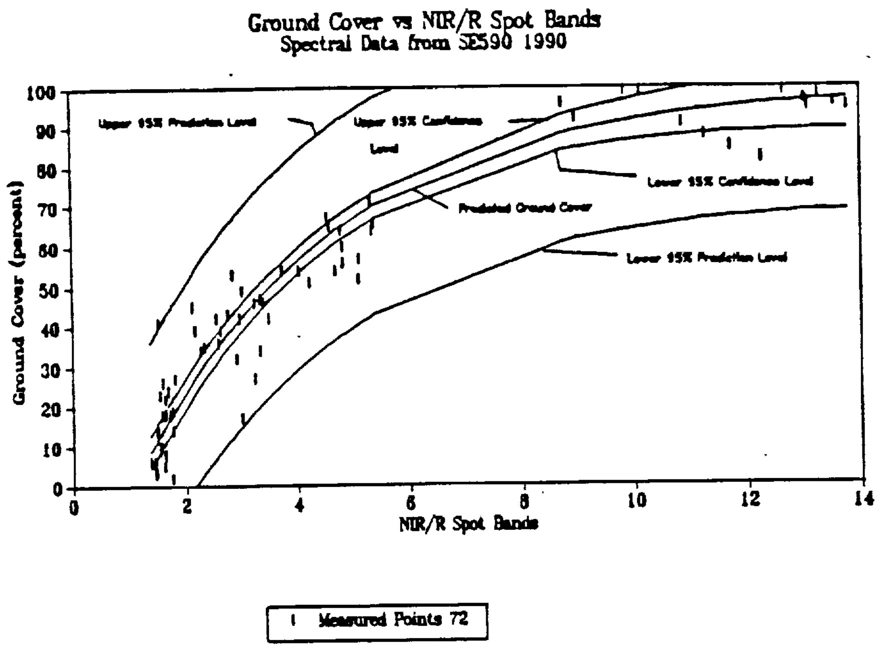


Figure 27

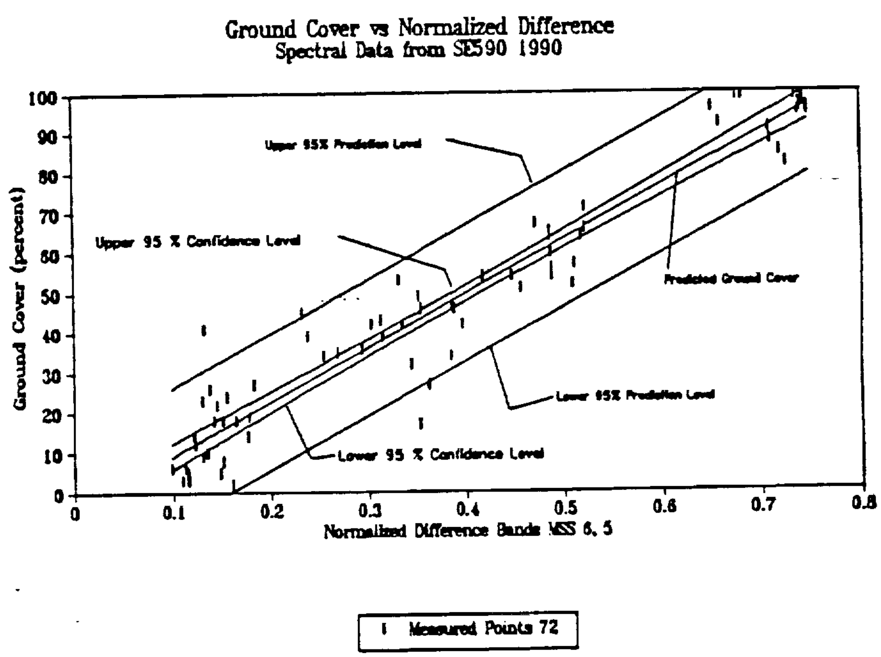


Figure 28

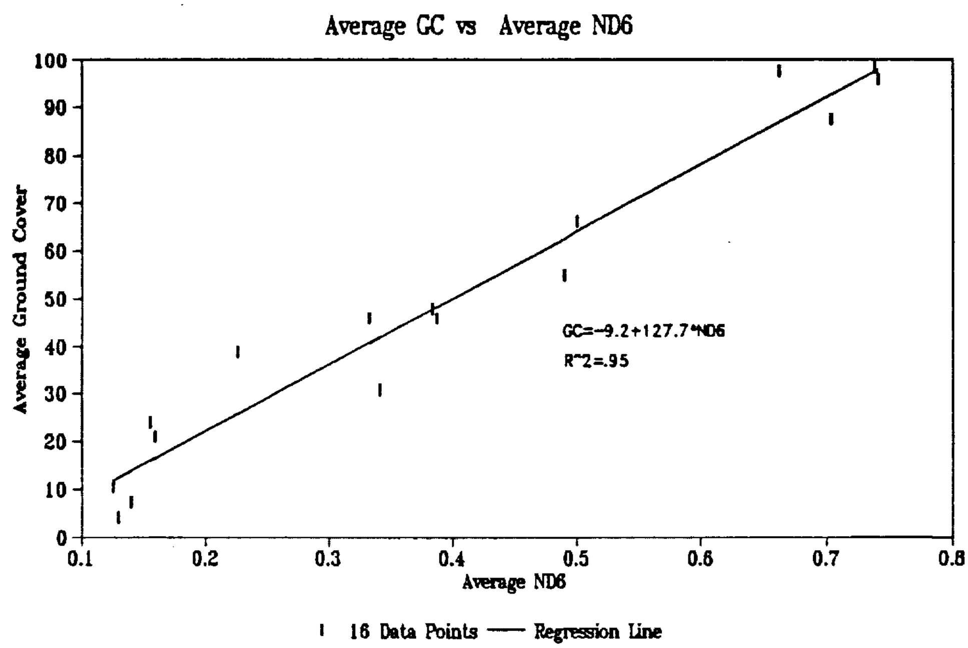
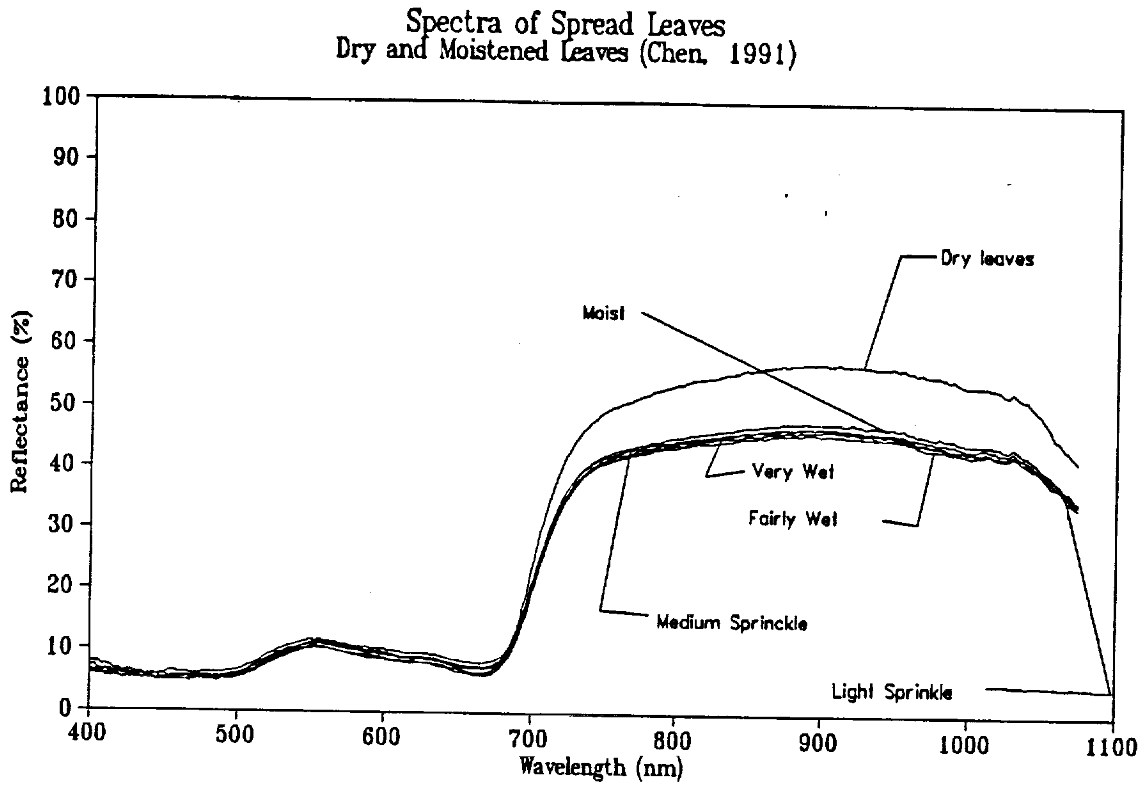

Average GC vs Average ND6
Average Ground Cover
Average ND6
100
90
80
70
60
50
40
30
20
10
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
GC=-9.2+127.7*ND6
R^2=.95
16 Data Points
Regression Line

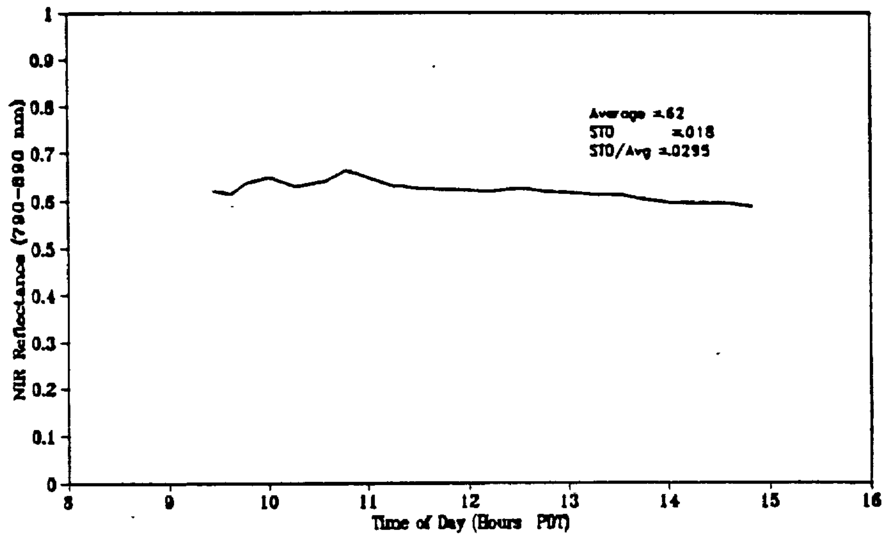
Figure 29



Spectra of Spread Leaves
Dry and Moistened Leaves (Chen, 1991)
Reflectance (%)
Wavelength (nm)
Dry leaves
Moist
Very Wet
Fairly Wet
Medium Sprinckle
Light Sprinkle
0
10
20
30
40
50
60
70
80
90
100
400
500
600
700
800
900
1000
1100

Figure 30

NIR Reflectance vs Time of Day
EOF 40, 6-20-90



Red Reflectance vs Time of Day
EOF 40, 6-20-90

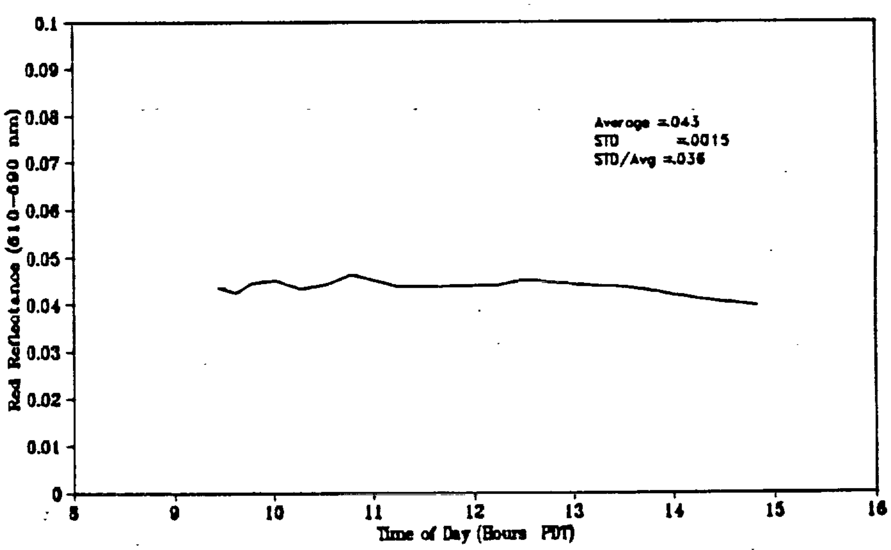


Figure 31

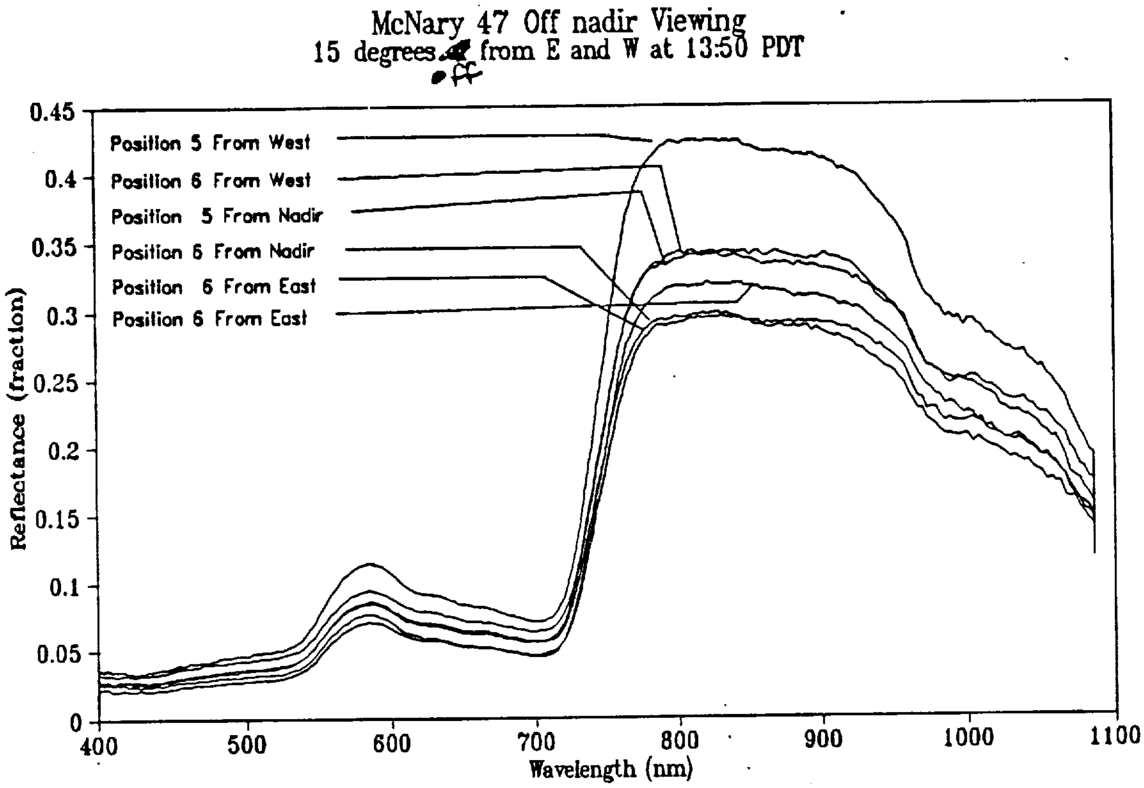

McNary 47 Off nadir Viewing
15 degrees off from E and W at 13:50 PDT
Position 5 From West
Position 6 From West
Position 5 From Nadir
Position 6 From Nadir
Position 6 From East
Position 6 From East
Reflectance (fraction)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
400
500
600
700
800
900
1000
1100
Wavelength (nm)

Figure 32