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Plant-process model corn yield forecasts for Iowa

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Plant-process model corn yield forecasts for Iowa

by

David Russell Krog

A Dissertation Submitted to the
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I. INTRODUCTION

During the growing season, many market participants in agricultural and related sectors once a month focus on the well-known USDA crop reports. These crop reports provide forecasts of the current year's crop acreage, yields, and production. Crop reports are released by the Agricultural Statistics Board (prior to 1986 known as the Crop Reporting Board) of the National Agricultural Statistics Service (prior to 1986 known as the Statistical Reporting Service).

Participants in agricultural markets rely heavily on these forecasts during the growing season in forming their supply and price expectations. Inventory holders make inventory decisions based upon the future prices they expect to receive. Suppliers of storage make storage decisions based upon expected crop size and the resulting demand for storage services. Grain carryiers and shippers are also influenced by expected levels of supply and the resulting demand for transporation services. The information content of yield and production forecasts reduces uncertainty associated with future national, regional, and local supply conditions. The effect of reducing uncertainty is to improve efficiency in the market and reduce losses associated with suboptimal decision-making. In forming expectations, therefore, market participants seek the best source of yield and production forecasts available.

Crop yield and production forecasts provided each month by the NASS are the most widely used crop forecasts available. NASS has an extensive network of personnel using systematic methods of collecting acreage and yield information and in processing these data to develop yield and production forecasts. Years of providing forecasts has also allowed NASS to maintain a "track record" from which forecast reliability can be obtained.

The yield information provided by NASS, however, is less than ideal. Like most public service organizations, NASS must operate within budget constraints that limit the quantity and quality of services that it provides. Forecasts are made only once a month during the growing season. Collection of yield data using current survey methods is costly, and increasing the frequency of forecasts is outside the budget of NASS. Also, early-season (August) yield forecasts are sometimes plagued with significant amounts of forecast error (Warren and Cook, 1988). Objective yield surveyors are faced with measurement problems associated with undeveloped plant parts. Further, recent budget cuts have forced elimination in some states of certain NASS services, including the reporting of crop reporting district crop yield and production forecasts made during the growing season (Iowa Agricultural

Statistics, 1987). NASS is eager, therefore, to investigate the use of alternative, more cost-effective yield and production measurement techniques and in replacing lost services.

One potential source of additional yield information is plant-process models. Plant growth and development processes have been modeled for several years, but only relatively recently have plant and soil scientists come together to develop comprehensive models referred to as plant-process models that account for most of the factors determining final crop yield (Jones and Kiniry, 1986). These models typically require detailed plant, soil, weather, management, and other information. However, in large part due to improving computer technology and increasing availability of needed data systems, operation of the plant process models under a wide variety of conditions is possible. In particular, use of plant process models (PPM) for large-area crop yield and production estimation is now feasible (Botner et al., 1986). PPM corn yield forecasts could potentially supplement existing NASS yield forecasts. It is because of this opportunity for adding to the existing information system and reducing its cost that the NASS and others are particularly interested in developing and evaluating plant process model-based crop yield forecasts. Yield information obtained from plant process models is a potentially valuable supplement to existing yield information obtained and reported by the NASS.

PPM forecasts and NASS forecasts could be combined into a composite forecasts that would be superior to either of the individual forecasts by themselves. Contributions to the literature on composite forecasting include Bates and Granger (1969), Reid (1969), Nelson (1972), and Granger and Newbold (1974). Two applications of the composite forecasting approach were conducted by Bessler and Brandt (1979) and Falconer and Sivesino (1977). The later was one of the first applications of composite forecasting. The former used composite forecasting for short-term livestock market prices. Both applications showed that the composite forecasting method is a potentially valuable method of combining independent forecasts.

The value of combining PPM forecasts with NASS forecasts is associated with the reduction in forecast error of the composite compared to the forecast error of NASS forecast alone. Methods for assessing the value of improved forecast information have been demonstrated by Hayami and Peterson (1972) and Bradford and Kelejian (1977). The former work uses concepts of social welfare to measure the social returns of reducing sampling error of crop and livestock statistics reported by the NASS. The later work extended Hayami and Peterson's framework to include two different types of forecasters - naive and sofisticated. Both works show the usefulness of using the social welfare concepts in assessing the value of improved forecasts. The same social welfare concepts can be used to value the improvement of composites NASS and PPM forecasts.

Objectives

The general objective of this study is to investigate the use of an alternative source of information from which corn yield forecasts can be derived. With the latest budget cuts and the elimination of corn yield forecasts for crop reporting districts (CRDs) in Iowa, valuable information is no longer available to market participants. Loss of information results in increased uncertainty, more market inefficiencies, and a general reduction in welfare among market participants in total (Hayami and Peterson, 1972; Bradford and Kelejian, 1977). Other sources of yield information, however, exist which may partially or fully replace lost forecasting services and, in general, improve crop yield forecasts made by the NASS. This study examines the use of the rich weather, soil, and related information and recently developed plant-process models for contributing to improved corn yield forecasts.

The specific objectives of the study are:

- Develop a plant-process, corn yield forecasting model for Iowa that is capable of providing crop reporting district and state corn yield forecasts during the growing season.

- Combine the plant-process model forecasts with NASS yield forecasts to obtain composite forecasts at the district and state levels.
- Test the reliability of the plant-process model and composite yield forecasts.
- Evaluate the economic value of using plant-process model forecasts in terms of improved corn yield forecasts.

Organization of the Paper

This paper is divided into seven chapters. The introduction in Chapter I provides background information and lists the objectives of the study. Chapter II reviews existing methods of forecasting crop yields. In Chapter III, the CERES-Maize plant-process model and its data requirements are described. Chapter IV describes the framework for making and using plant-process model corn yield forecasts. Chapter V reports results of using the plant-process model for forecasting corn yields in Iowa. Chapter VI contains an economic evaluation of using plant-process model yield forecasts. In Chapter VII, a summary of the study is provided and real-time implementation considerations are discussed.

CHAPTER II. FORECASTING CROP YIELDS AND PRODUCTION

The purpose of this chapter is to review some of the methods used for forecasting crop yields and production. The focus is on the types of data collected and the tools and procedures used for processing data and deriving forecasts. This review is not comprehensive, and the work of many forecasters is not included here. The primary aim is to review the history of the National Agricultural Statistics Service (NASS) and how they forecast crop yields and to contrast this approach with alternative approaches that draw upon different, yet useful, sources of information and models.

NASS Yield and Production Forecasting Methods

The most visible crop yield and production forecasts are those released by NASS. NASS derives its forecast data from its several surveys conducted over the year. Data obtained from these surveys is processed using simple models developed by NASS. Data collection and processing procedures used by NASS have evolved out of its long history of reporting agricultural statistics in the United States.

Over its more than 100-year history, NASS has evolved in name and method, but its purpose has remained the same - providing farmers, grain merchandisers, policy-makers, and others in agriculture with reliable and up-to-date statistics on the nation's agriculture. Currently, NASS reports supply, demand, price, and other statistics for about 120 crops and 45 livestock commodities. In addition, it provides statistics on financial conditions, labor supply, farm size and numbers, and other aspects of agriculture. To ensure accurate and timely estimates, NASS relies on a combination of long experience in conducting surveys and constant improvements in techniques (USDA, 1983). Some of the major developments in agricultural statistics reporting are summarized in Table 1.

NASS can be traced back to 1839 when Congress appropriated $1,000 to the Patent Office for "collection of agricultural statistics and distribution of seeds" (USDA, 1983). Establishment of the Division of Statistics within the U.S. Department of Agriculture (USDA) in 1863, however, signalled a serious commitment to the collection and reporting of agricultural statistics. In that same year the first monthly crop report was issued by the USDA. It reported on the May-June crop conditions.

Methods of collecting and interpreting agricultural data in the early years was unsophisticated. The first report was based upon the subjective assessment of 2,000 farmer-correspondents. As time passed, however, more and more farmer-reporters were providing information. By 1892, 15,000

Table 1. Major historical developments in the collecting and reporting of agricultural statistics (USDA, 1983)

Year	Development
1839	Congress appropriates $1000 to Patent Office for "collection of agricultural statistics."
1841	Using the 1840 Agricultural Census as a benchmark, the Patent Office issues first crop report. The annual release was discontinued in 1848.
1863	Division of Statistics formed in the USDA.
	First monthly crop report issued by the USDA showing May-June crop conditions reported by 2,000 farmer-correspondents.
1905	The Crop Reporting Board is established for reviewing information and setting national and state estimates.
1910	A shift is made from reporting monthly crop conditions to forecasting crop production.
1917	Wisconsin signs the first formal agreement establishing cooperative Federal-State crop reporting program.
1928	Objective measurements for forecasting crop yields are started but are discontinued at the start of World War II.
1954	The June enumerative survey of crop acreages is begun on a research basis.
1961	Objective yield survey for corn becomes operational.
1965	June enumerative survey becomes operational.
1977	Crop reports begin reporting root mean square errors of forecasts in order to assist users in evaluating the reliability of crop forecasts.
1979	The list frame becomes operational.
1982	Budget constraints force free statistical publications to become available only by subscription.

Table 1. (continued)

Year	Development
1986	Further budget cuts force elimination of some crop yield forecasts including corn yield forecasts for Crop Reporting Districts.

farmers provided data for monthly surveys and 125,000 furnished data for the annual estimates. In addition, several thousand ginners, millers, elevator operators, and agents of the railroads reported on agricultural conditions. A significant step in improving the interpretation of incoming data was made in 1905 with the creation of the Crop Reporting Board (CRB). The aim of the CRB was to review information and set national as well as State estimates. Further improvements in the coordination of collection, compilation, and interpretation of agricultural data were made in 1917 when Wisconsin signed the first formal agreement establishing a cooperative Federal-State crop-estimating program. Today all 50 states have similar cooperative agreements.

During the first several decades of agricultural statistics reporting, crop condition and yield and acreage estimates were based on subjective assessments. Mailed surveys were completed by farmers and subjective evaluations were made by other agents in the countryside. In 1919, however, steps were taken to incorporate objective measurements into the data collection process. In that year, fieldwork began on objective measurements of crop acreage. By 1928, objective yield measurements had been extended to forecasting yields. Objective yield measurements were discontinued at the start of World War II but were again implemented in 1961 for corn and cotton.

The June enumerative survey of crop acreage was another significant addition to the information system in 1965. The enumerative survey is a means of collecting data through an intensive interview between a qualified USDA interviewer and a farmer. Personal as well as telephone interviews are conducted.

During the decades of the 1960s and 1970s, objective yield surveys were implemented for corn, soybeans, wheat, and cotton. These surveys supplemented the mail surveys for making crop yield forecsts. With information from these two sources, corn yield forecasts were reported at both the state and district levels.

Budget cuts have been a significant factor within NASS in the 1980s. In 1982, statistical publication, once free of charge, became available only by subscription. In 1987, further cuts forced elimination of several surveys and reports. Included among the discontinued surveys were the mailed crop yield surveys conducted during the growing season. Without these surveys, yield forecasts in Iowa are now based solely on objective survey information. As a result, crop reporting district yield forecasts in Iowa have been eliminated. The objective yield survey, given the current number of field samples, cannot provide district forecasts with an acceptable level of sampling error.

Increasing the objective survey sample size to accommodate district forecsts is beyond the budget of NASS.

With that abbreviated history, it is apparent that surveys have been and still are the standard information-gathering approach used by NASS. For crops, a sample of all farmers and/or fields are surveyed to obtain current data on yields, acreage, and production for a particular area - county, district, state, or for the entire country. The size of the sample is determined by the accuracy that is desired for the area in question. The type of survey used depends upon the desired accuracy of the estimates, the nature of the population to be sampled, and the resources available.

Over the years, the NASS has used a number of different surveys to collect agricultural data. Currently, four types of surveys are being used: mailed surveys, enumerative surveys, objective measurement surveys, and multi-frame surveys. The type of information obtained, the levels of aggregation of the data, and the period of the year for each type of survey made is shown in Table 2.

Mailed Surveys

Two general types of mail surveys are now in use - nonprobability sample surveys and probability sample surveys. Prior to 1961, the NASS used mail surveys as the primary means of collecting acreage, yield, and production data.

Table 2. Summary of NASS survey types

Survey Type	Information Collected	Aggregation Level	Time of Year
Mailed Survey	• Crop planting intensions	National, State	First week in March
	• Crop conditions and yield (until 1987)	National, State, CRD	
Enumerative Survey	• Planted acreage	National, State, CRD, County	June
	• Harvested acres, yield	National, State, CRD, County	December
Objective Measurement Survey	• Crop yields	National, state	Last week of July Last week of Aug. Last week of Sept. Last week of Oct.
Multi-frame Survey	• Crop yields (until 1987)	National, state, CRD	Last week of July Last week of Aug. Last week of Sept. Last week of Oct.

Mail surveys asked farmers to provide crop data for their own farms as well as to report their subjective assessments on the status of the crop in neighboring farms. During that period, the names and addresses of farmers were maintained on a mailing list. Farmers responding to the surveys sent their responses to their respective State Statistical Office (SSO), where results were compiled and reviewed and then sent (in "Special A" envelopes) on to the Washington office for final processing.

In general, these early mailing lists had a respondent selection bias. Prior to 1960, surveys were typically sent to persons who produced the commodities being surveyed, who were believed to be well informed, and who would report regularly (USDA, 1983). These types of surveys are referred to as nonprobability surveys, and data collected in this manner are generally biased. Linear regression models are typically used to correct for this sample bias.

In the late 1960s and early 1970s, mailing lists were made more complete so that they could be used to conduct probability surveys. A problem still exits with these types of surveys in that nonresponse of farmers causes bias in the sample data. Resurveying nonrespondents and/or using regression models is a means of correcting for the bias.

Beginning in 1987, the use of mail surveys to collect crop condition and yield information was discontinued in

Iowa. This action was a result of budget cuts within the Iowa Agricultural Statistics Service. Yield forecasts are currently based only on objective yield surveys. Mailed surveys are still, however, an important part of the enumerative surveys.

Enumerative Surveys

As the name suggests, enumerative surveys involve a detailed accounting of agricultural statistics. These surveys are conducted by mail, telephone interview, or personal interview. A predetermined number of selected producers are associated with each sampling unit. These producers are randomly selected within specified sampling frames. Two types of sampling frames are used by the NASS, area frames and list frames. Enumerative surveys for crops typically rely on area frames. Two of the more important enumerative surveys are the June enumerative survey and the December enumerative survey. For crops, planted acreage information is derived from the June survey while harvested acreage and final, detailed estimates of crop yields are obtained from the December survey.

Objective Measurement Surveys

Beginning in 1961, NASS personal began collecting actual yield measurements in fields. Today, objective yield measurements are used as the primary means of deriving crop yield forecasts for corn, soybeans, wheat and cotton. In addition, pilot objective surveys are underway for rice, sorghum, and sunflowers (USDA, 1983). Objective yield surveys for corn are currently conducted in ten states - Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Nebraska, Ohio, South Dakota, and Wisconsin.

In 1986, a total of 1920 samples were used for estimating corn yields in this ten-state, Corn Belt area. In Iowa, 240 samples were used in 1986. Samples are selected with probabilities proportional to the number of planted acres of corn. The corn acreage is based on the June enumerative survey. Typical sample locations for Iowa are shown in Figure 1 (these are hypothetical locations based on 1984 acreage data). Each sample consists of two randomly selected plots within the selected field, and each plot contains two rows fifteen feet long. Within each sample section, field measurements are obtained that are used to estimate or forecast two components of yield - number of ears and ear weight. Combined, these two components provide a corn yield forecast or estimate for each sample.

Objective yield measurements for corn are made four times a year based on conditions on August 1, September 1, October 1, and November 1. Measurements made in August, September, and usually October go into making a yield

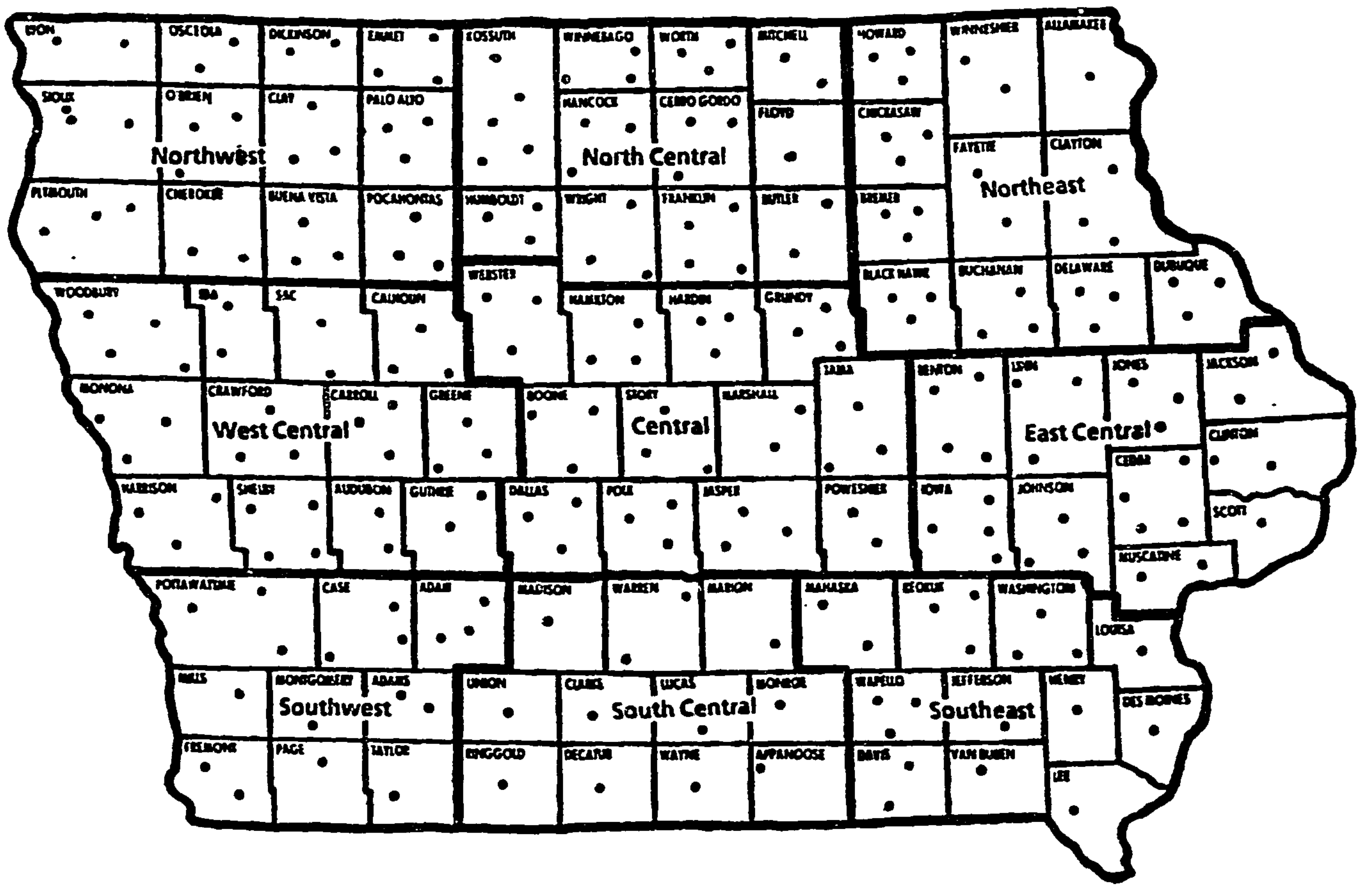


Figure 1. Example locations of NASS objective survey samples

forecast since the growing season has not been completed in those months. By November, most corn fields have matured and actual yield measurements can be made. Harvest losses must, however, be forecast for the November yield forecast.

Objective yield forecasts are derived from collected field data and regression models estimated on a state-by-state basis. Early (August) forecasts are typically susceptible to large errors since corn plants may still be in early stages of development. Because of this, two sets of regression models are used to forecast yields. These are referred to by the NASS as Models I and Model II. Both Model I and Model II are sets of equations that forecast ear number and ear weight. The equations used depend upon the stage of development of the corn and are estimated using the previous five years of survey data. Six stages of development are identified: pre-blister, blister, milk, dough, dent, and mature. The general specification for both Model I and Model II equations is:

$$Y = a + b \cdot X$$

where Y is the number of ears or weight per ear, a and b are parameters to be estimated, and X is a set of independent variables from current field counts. The models are estimated using data from the previous five years.

The independent variables, X, are different for Model I and Model II and also vary depending upon the stage of corn development. Tables 3 and 4 lists independent variables used for each model, respectively. For Model I, when the corn is in the pre-blister, blister, and milk stages, stalk counts are used for estimating ear numbers. Actual ear counts are used in the dough, dent, and mature stages. For ear weights in Model I, a 3-year average weight is used during the pre-blister stage and before ears are formed. During the blister through dent stages, the average, 5-year kernel row length is used as the independent variable in the ear weight equation. At maturity, ears from the sampling unit are picked and weighed. For Model II, equations for ear weight and number are identical to those in Model I when corn is in the dough, dent, and mature stages. However, in the pre-blister, blister, and milk stages, the independent variable for ear number is the ratio of stalks with ears or ear shoots to total stalks. In the same three stages, average length of the ear over the husk is used for estimating ear weight with Model II.

The Model I and Model II estimates of ear number and ear weight are combined to form a composite forecast for each sample. Weights used in combining the predictions are determined by the correlation of the two model predictions with final data (USDA, 1983).

Table 3. Explanatory variables used by NASS to predict ear number and weight using Model I

Maturity Stage	Model I	
	Number of Ears	Ear Weight
Pre-blister	Stalk count	Three-year average
Blister	Stalk count	Average kernel row length
Milk	Stalk count	Average kernel row length
Dough	Ear count	Average kernel row length
Dent	Ear count	Average kernel row length
Mature	Ear county	Actual weight

Table 4. Explanatory variables used by NASS to predict ear number and weight using Model II

Maturity Stage	Model II	
	Number of Ears	Ear Weight
Pre-blister	Stalks with ears/ total stalks	Average length of ear
Blister	Stalks with ears/ total stalks	Average length of ear
Milk	Stalks with ears/ total stalks	Average length of ear
Dough	Ear count	Average length of ear
Dent	Ear count	Average length of ear
Mature	Ear county	Actual weight

Once the regression models have provided a forecast of ear number and weight, the two forecasts are combined to give a gross yield forecast for each of the samples. Estimated average harvest losses are subtracted giving net yield forecasts. These yields are expanded to an acre basis.

Since samples are proportional to acreage, simple averages of sample yields are used to derive the state and national yield forecasts.

Multi-frame Surveys

The newest approach used by the NASS to make forecasts and estimates is the multi-frame surveys approach. In this approach, both area and list frames are used. The idea behind this approach is that sampling reliability can be improved by using data from two separate sampling frames. The multi-frame approach is used extensively for collecting livestock data but is no longer used for making crop yield forecasts since the mail surveys for crop conditions and yield have been discontinued.

Other Yield Forecasting Methods

Yield forecasting methods used by the NASS rely primarily on sample data collected using various surveys. Other forecasting methods have been developed and have evolved over the years which transform routinely collected observations on weather, soils, fertilization, technology, and other data into crop yield predictions and forecasts. Many of these methods initially relied on statistical correlations between data, particularly weather data, and reported yields in order to predict yields. Over time, more and more of the methods have incorporated prior knowledge of relationships between observable variables and factors that directly influence yield. Plant-process models are an example of those models that incorporate a great deal of prior information.

Correlation models and weather data were used by many of the first to develop methods of predicting and forecasting crop yields in the United States. A pioneer in the field, J. Warren Smith, used correlation analysis in order to predict Ohio corn yields from temperature and rainfall data (Smith, 1914). Another of the first to recognize the usefulness of correlation analysis was Henry L. Moore. Using correlation models and monthly weather variables, Moore was able to make cotton yield forecasts that were "more accurate than the official reports..." (Moore, 1917).

From the correlation models evolved a number of models based on regression analysis. Ezekiel (1941) and Houseman (1942) were two pioneers in applying multiple regression techniques to predicting corn yields. Their non-linear regression models shed light on critical time periods during the growing season when temperature and rainfall were significanlty important in determining corn yields in the Midwest.

Some of the best known statistical models used for estimating crop yields were those developed by Thompson (1969 and 1970). Thompson used monthly precipitation and temperature departures from normal to explain average state yields of corn and wheat. He used these models for explaining the impact of weather on crop yields and also for short-term yield forecasting.

Models were later developed that instead of using weather variables, used variables that were more closely linked to crop yields. Oury (1965) developed a daily soil moisture budget that reflected the amount of water in the soil. With this budget, the water-holding capacity of the soil was predetermined and water loss due to evaporation and transpiration was subtracted while water gain from rainfall was added to the budget (Benson, 1972). The moisture budget was used to identify "drought days" that may adversely affect crop yields. Gilmore and Rogers (1958) went beyond using simple temperature variables and incorporated degree days into their model.

Variables that reflected the influence of technology were also introduced into some models. Doll (1967) used weather variables as well as time trend variables in his regression models. The trend variables indirectly reflected the influence of improving technology on corn yields. Changnon and Neill (1968) attempted to represent technology more directly. In addition to weather variables, their models incorporated nitrogen applications, a soil productivity index, plant populations, and planting dates. Colyer and Knoth (1968) also incorporated nitrogen and plant population variables into their corn yield prediction models. Zuber (1966) used different types of hybrids in his work.

By the mid-1970s, models began to be developed that incorporated large amounts of prior knowledge related to soil properties and plant growth and development processes. These models were referred to as plant-process models and were developed out of the many years of work of agronomists, plant physiologists, engineers, and others from various disciplines. These comprehensive models were designed to simulate soil, water, air, and plant processes in order to predict plant growth, development, and yield. According to Baier (1977), these models are simplified representations of physical, chemical, and physiological mechanisms underlying plant and crop growth processes. The basic processes that are simulated include production and distribution of dry matter and water and nutrient relations. With these and other processes properly modeled, the entire response of the plant to its environmental conditions can be simulated (Baier, 1977).

A number of plant-process models have been developed in the last several years. Most of these models are for corn, soybeans, and wheat. Table 5 briefly summarizes the best known of these models.

The plant-process model CERES-Maize is used to simulate corn yields in this study. CERES is an acronym for Crop Estimation through Resource and Environment Synthesis. This model is chosen because it is the most comprehensive and the most widely tested (Jones and Kiniry, 1986; Duchon, 1984; and Cooter, 1986) of the plant process models for corn.

Development of CERES-Maize (along with CERES-Wheat) was begun in the late 1970s under the direction of J. T. Ritchie at the Grassland, Soil and Water Research Laboratory in Temple, Texas. The objective was to develop a comprehensive, daily-incrementing model capable of accurately simulating corn growth, development, and yield. The current version of the model incorporates the contributions of many; Kiniry, et al. (1983a and 1983b), Kiniry and Ritchie (1985), Ritchie (1972), Tollenaar, et al. (1979), Warrington and Kanemasu (1983), Hanway and Russell (1969), Jones (1983), and others. Extensive model evaluations are reported in Jones and Kiniry (1986) although testing and evaluation is continuing.

Table 5. Summary of selected plant-process models

Reference	Model Name	Crop
Hanks (1974)	N.G.	Corn
Hill, Asce, and Hanks (1978)	N.G.	Corn
Strapper and Arkin (1980)	CORNF	Corn
Jones and Kiniry (1986)	CERES-Maize	Corn
Meyer et al. (1979)	SOYMOD	Soybeans
Hill, Johnson, and Ryan (1979)	N.G.	Soybeans
Wilkerson et al. (1985)	SOYGRO	Soybeans
Maas and Arkin (1980)	N.G.	Wheat
Hanks and Puckridge (1980)	N.G.	Wheat
Goodwin et al. (1984)	CERES-Wheat	Wheat

N.G. = None Given

Use of the CERES-Maize for large-area corn yield prediction is one of the long-run goals of its developers. Application of the model for this purpose has been conducted in three separate studies. Duchon (1984) demonstrated the feasibility of making intra-year yield forecasts by generating yield distributions using historical weather information. This work, however, is limited to evaluating only a single location, Peoria, Illinois.

Cooter (1985) extended Duchon's work by generating intra-season, location-specific yield forecasts for 42 locations. She also examined more closely the statistical properties of the predictions. Data were limiting, however, and she had to make simplifying assumptions concerning soil characteristics and plant maturity. Further, no attempt was made to derive aggregated, large-area yield estimates from the location-specific yield predictions.

The first attempt at using the CERES-Maize model to generate intra-year, corn yield forecasts for aggregated regions was made in 1985 by Botner et al. (1986). They generated yield predictions for 51 locations in the Cornbelt and used a set of weights based on harvested acres to aggregate location-specific yields into State and National yield index forecasts. However, input data were limiting and simplifying assumptions similar to Cooter's were required. Further, subjective weather forecasts were incorporated into the model and no statistical analysis of the outcomes were attempted. Their work, however, demonstrated the feasibility of using a plant-process model to make large-area yield forecasts.

Summary

Over the past century, NASS has developed and refined reliable techniques for collecting and processing sample data used to make crop yield and production forecasts. Currently, NASS uses four types of surveys - mailed, enumerative, objective measurement, and multi-frame. In Iowa, yield forecasts now rely only on the objective measurement survey data. Mail surveys that were once used to supplement objective surveys were eliminated in 1987. As a result, yield forecasts reported during the growing season are for state average yields -- crop reporting district forecasts are no longer reported. Desired levels of forecast reliability cannot be achieved at the district level using the roughly 250 objective yield samples in the state, and increasing sample size of the survey is beyond the NASS budget.

Other approaches to forecasting corn yields have been developed and used in the past. Most of these approaches rely on statistical models using primarily weather data. Recently, plant-process models have been developed. These models contain deterministic equations that simulate various plant and soil processes. These models typically contain a great deal of *a priori* information on the influence of weather, soil, plant genetics, management practices, and other factors on plant growth, development, and yield. Due in large part to immense data requirements, plant-process models have limited use for making large-area yield forecasts.

All approaches used for making yield forecasts are potentially valuable. Supplementing existing NASS sample survey-based forecasts with information from alternative forecasting approaches may lead to forecasts that are more reliable and more useful than NASS forecasts alone. This study investigated the use of a plant-process model to improve NASS corn yield forecasts in Iowa. The next chapter describes the plant-process model and data that was used in this study.

CHAPTER III. PLANT-PROCESS MODEL AND DATA DESCRIPTION

The first objective of this study is to develop a framework from which corn yield forecasts can be made using a plant-process model (PPM). The primary components of this framework are shown in Figure 2. The function of this framework is to (1) derive point yield forecasts from the PPM using weather, soils, plant variety, and management data that are representative of specific locations in Iowa and (2) aggregate and calibrate the point yield forecasts into county, crop reporting district, and state yield forecasts. The purpose of this chapter is to describe the PPM and its data requirements. The next chapter will focus on the aggregation and calibration of the forecasts.

The CERES-Maize Plant Process Model

The CERES-Maize plant process model was used in this study to capture the influence of weather, soils, and other factors on the growth and development of the corn crop. A brief history of the model was given in Chapter II. Here a general overview of the model's functions and data requirements is provided. A complete description and documentation of the model is found in Jones and Kiniry (1986).

CERES-Maize is a comprehensive, daily-incrementing simulation model of corn growth, development, and yield. Two

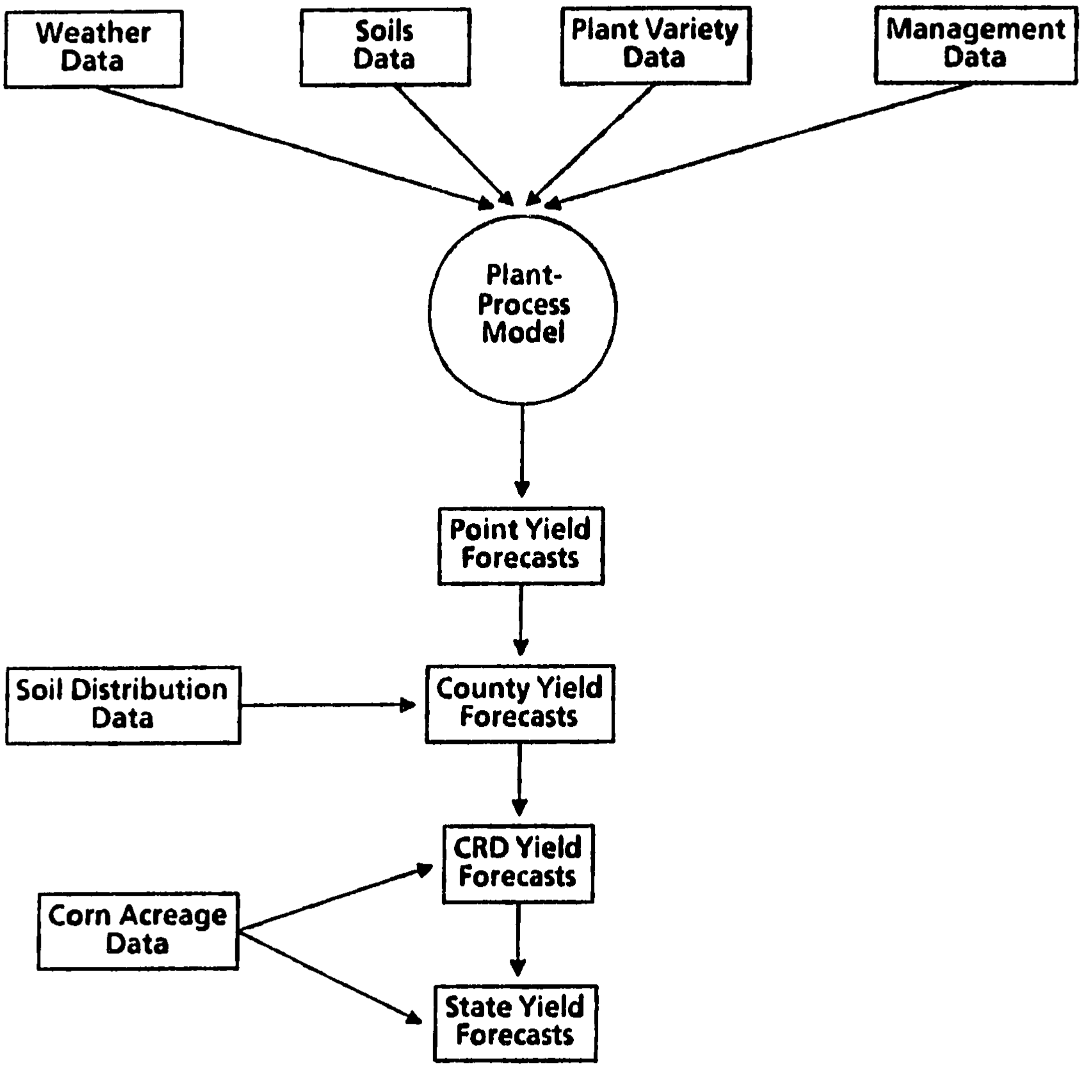


Figure 2. Basic framework used for forecasting Iowa corn yields using a plant-process model

versions of CERES-Maize are available. The "standard" version considers the influence of genotype, weather, soils, and hydrology. In addition, the modifying influence of management and other factors are taken into account. The "nitrogen" version considers these factors as well as soil and plant nitrogen dynamics (Jones and Kiniry, 1986). This study uses the nitrogen version of CERES-Maize adapted to meet the particular needs of this study. Adaptions to the model relate to the batch processing of data.

CERES-Maize simulates many soil and plant processes. Some of the more important of the processes include (Jones and Kiniry, 1986):

- phenological development, especially as it is affected by genetics and weather;
- extension growth of leaves, stems, and roots;
- biomas accumulation and partitioning, especially as phenological developments affect the development and growth of reproductive organs;
- soil water balance and water use by the crop;
- soil nitrogen transformations, uptake by the crop, and partitioning among plant parts.

The source code for simulating these processes is written in FORTRAN. The model is compiled and executed on Iowa State University's mainframe computer.

The version of CERES-Maize adapted for this study uses a main program and twenty-six subroutines. Figure 3 lists the subroutines in order of execution and gives a brief description of the function of each. Figure 4 is a flow chart of the model. Two subroutines, WDUMP and RDUMP, are not shown in Figures 3 and 4. These two subroutines allow the model simulation to be stopped at any given day, variables saved, and the model restarted at a later time. This feature allows the model to be run in a real-time mode.

Adaptations are made to the model allowing batch processing of data. The model is able to process data for multiple locations, soils, and years. In addition, the real-time mode allows the model to generate several yield estimates at a specified "forecast date" using historical weather information. Once an annual simulation is complete, the model can return to a specified forecast date and complete another simulation with a different set of historical weather. As discussed in Chapter IV, this feature is used to generate yield distributions at several forecast dates. Figure 5 is a schematic of the batch-processing decisions made by the CERES-Maize model.

Weather Data

Weather information is an important input into the CERES-Maize model. Required by the model are daily

```
Subroutines            Function
---------------------------------------------------------------
    MAIN
         PROGRI - program initialization
              FIXED - fixed parameters initialized
              OUTNU - soil nitrogen output
              OUTMN - uptake and plant N output
         SOILRI - read and initialize soil information
              SOILIN - read soil properties information
         SOLSIM - calculate solar radiation
         SOILNI - soil nitrogen initialization
              SOLT - soil temperature
         CALDAT - Julian to calendar date
         SOWDAT - planting date
         MINIMO - mineralization and mobilization
              SOLT - soil temperature
              NITRIF - nitrification
         WATBAL - water balance
              DNIT - denitrofication
              NFLUX - drainage and leaching
                   CADAT - Julian to calendar date
         PHENOL - determine phenological stage
              CALDAT - Julian to calendar date
              PHASEI - phase initialization
         GROSUB - plant growth
              NFATO - nitrogen deficiency factor
              NUPTAK - nitrogen uptake
         NWRITE - nitrogen output control
              NBAL - detailed nitrogen balance output
              OUTMN - soil nitrogen output
              OUTNU - uptake and plant N output
         WRITE - write output
              OUTWA - water balance output
                   CALDAT - Julian to calendar date
              OUTGR - growth output
   daily loop      CALDAT - Julian to calendar date
     soils loop
       location loop
```

Figure 3. Subroutines included in the CERES-Maize plant-process model

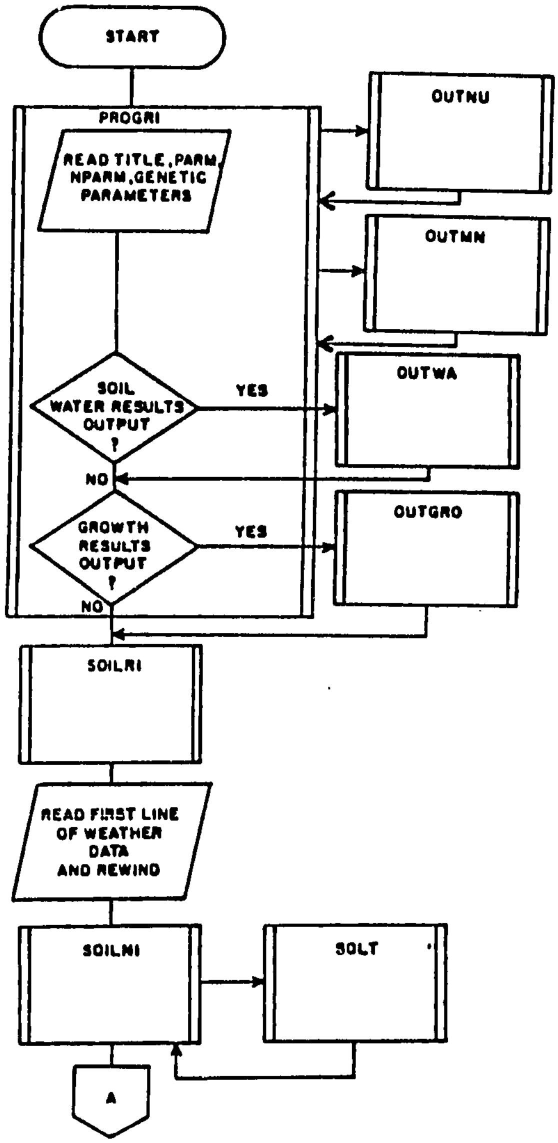


Figure 4. Flow diagram of the CERES-Maize plant-process model

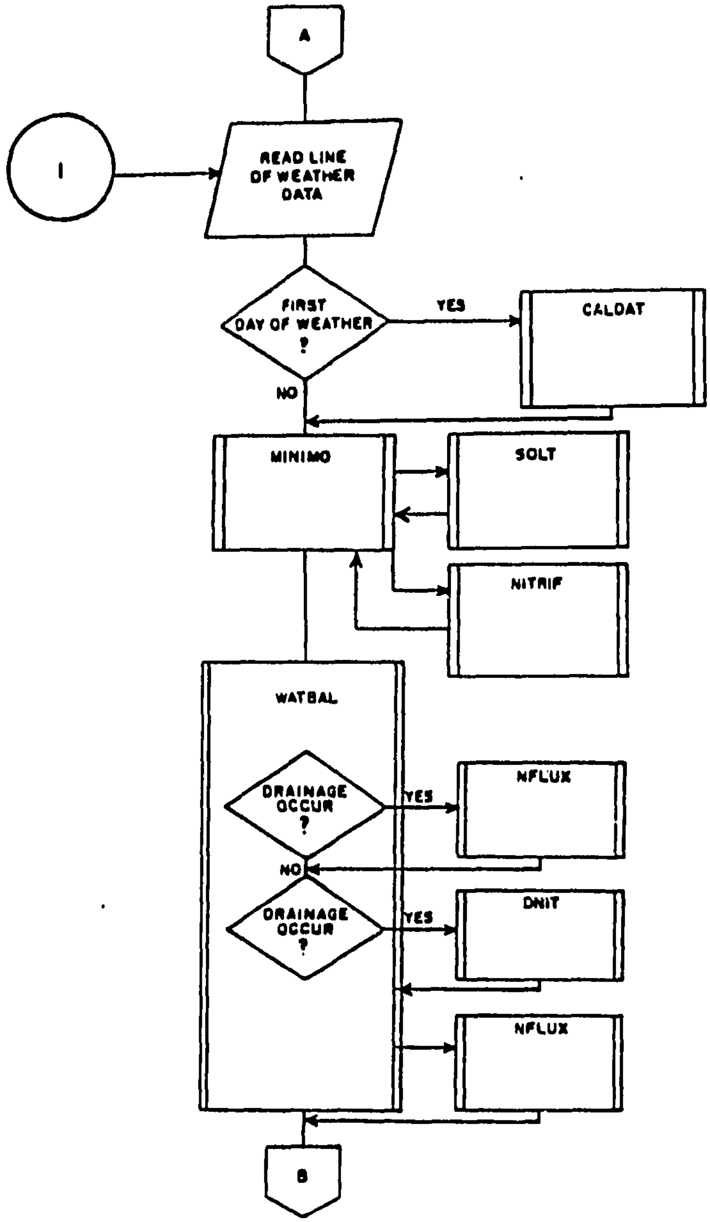


Figure 4. (continued)

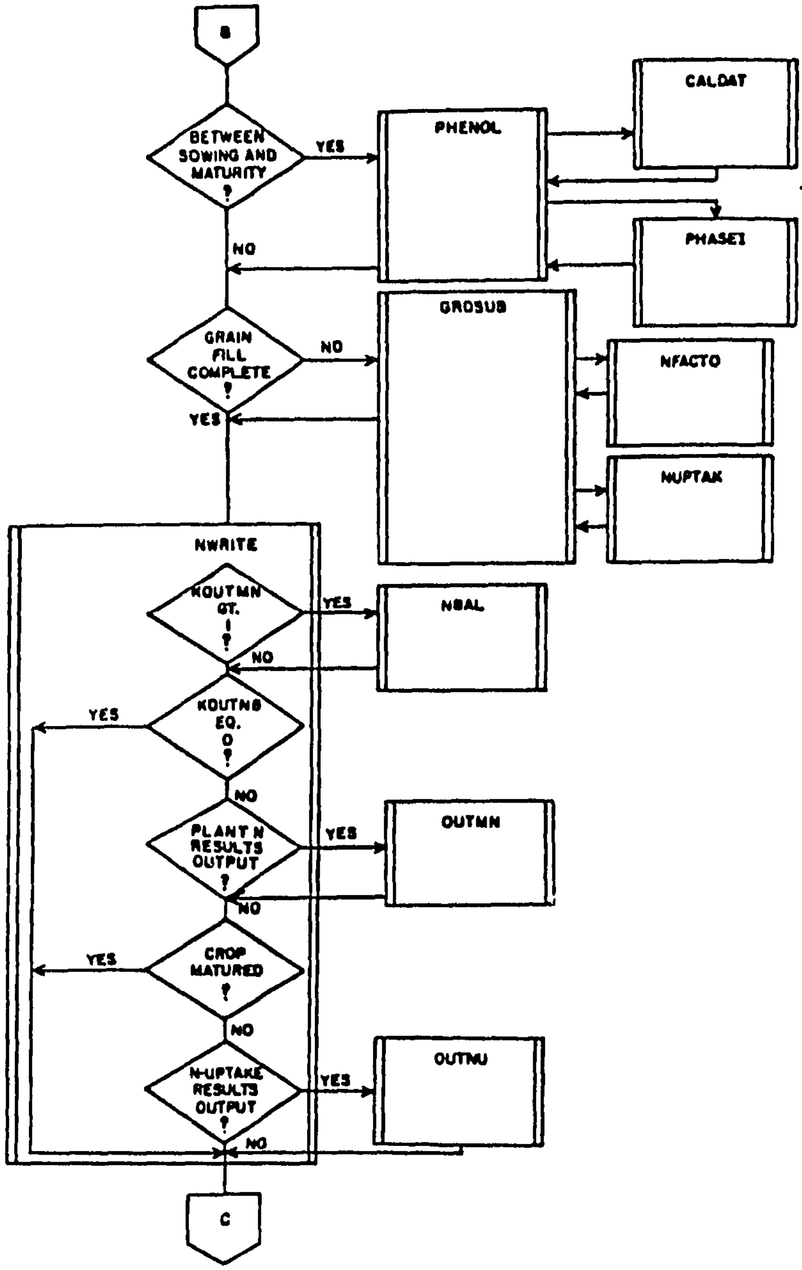


Figure 4. (continued)

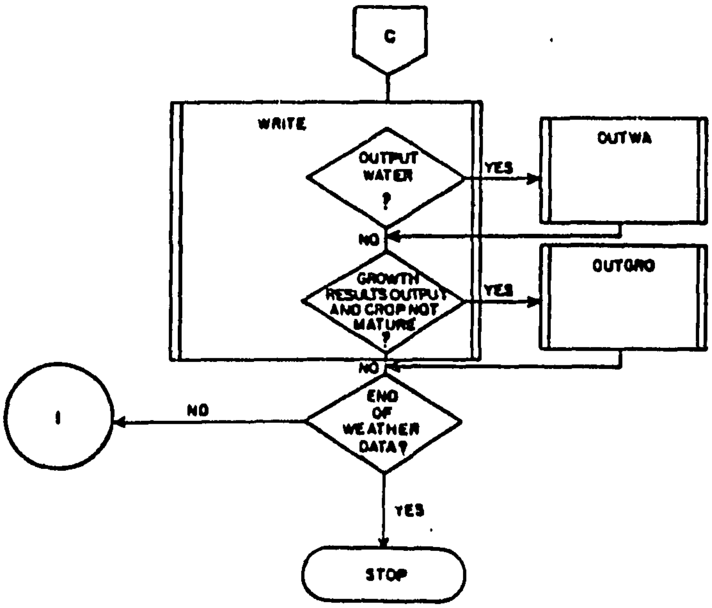


Figure 4. (continued)

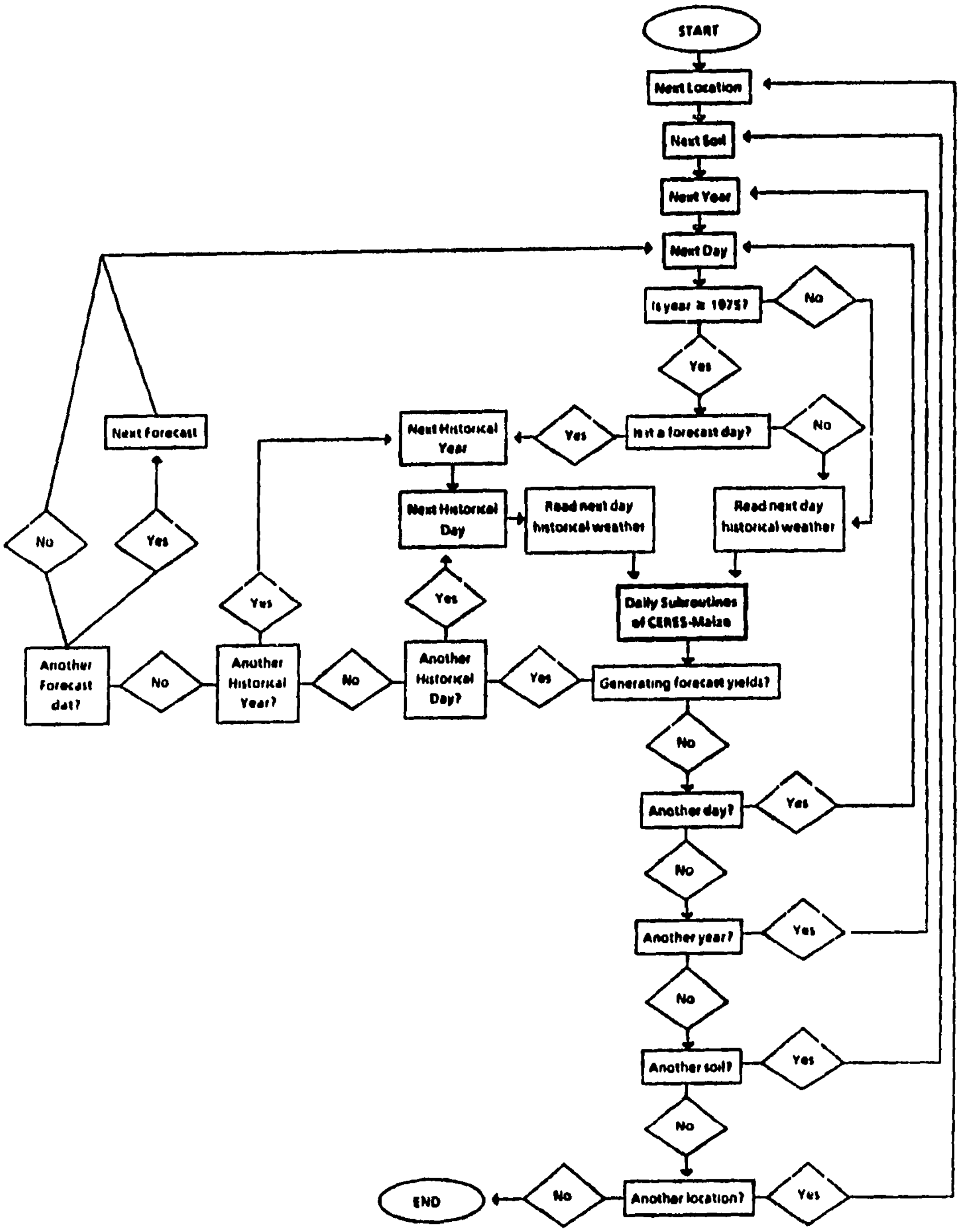


Figure 5. Decision diagram for batch operation of the CERES-Maize model

information on precipitation, minimum and maximum air temperature, and solar radiation. Precipitation and temperature data are collected at many weather reporting stations around Iowa. Solar radiation observations are generally not available for all reporting locations but are estimated using correlation techniques and information on precipitation and temperature.

Daily weather information is available from two general sources. Daily weather data are collected and reported by a network of first-order weather stations and also by a network of cooperative weather stations. There are about 400 first-order weather stations in the United States. There are four first-order stations in Iowa. First-order station weather data are used primarily by radio and television weather departments for reporting current weather information to the general public. These data are available on a real-time basis through the National Weather Service. There are currently about 5,000 cooperative weather stations throughout the United States. About 125 of these are located in the state of Iowa. Cooperative weather data are, therefore, spatially more dense than first-order data. Cooperative data are, however, not available as quickly as first-order data. Cooperative data for Iowa is currently available through the National Oceanic and Atmospheric Administration (NOAA) with not less than a week lag. Cooperators send their data to NOAA by mail once per week.

The weather data used in this study consists entirely of cooperative station weather data. In order to cut down on computation time, not all cooperative weather stations are used to supply weather information to the model. Several stations in close proximity to another station were not used. A total of 99 weather stations are selected. All but nine counties are represented by a weather station. Some counties have multiple cooperative weather stations. Table 6 provides descriptions and Figure 6 shows the locations of the selected weather stations. Weather station numbers indicated in Table 6 correspond to the numbers shown in Figure 6. Twenty-five years of daily weather data are obtained for each of these locations.

All weather information used here is obtained from the Oklahoma Climatological Survey (OCS) in Norman, Oklahoma. The OCS gets the "raw" cooperative data from NOAA and subsequently "cleans" the data. That is, interpolation routines are run on all data in order to filter any data outliers and to fill missing observations which are quite common in the raw data. At this time, there is a time lag of about one and one-half year between a year's worth of cooperative weather data and availability from OCS. As a result, weather data was obtained only through the year 1984.

Table 6. Selected Iowa cooperative weather station locations by crop reporting district

County Name	City	Weather Station No.	Weather Station Code
Northwest District			
Buena Vista	Storm Lake	105	1307979
Buena Vista	Sioux Rapids	103	1307726
Cherokee	Cherokee	23	1301442
Clay	Spencer	104	1307844
Dickinson	Lake Park	62	1304561
Dickinson	Milford	74	1305493
Emmet	Estherville	40	1302724
Lyon	Rock Rapids	92	1307147
Osceola	Sibley	98	1307664
O'Brien	Primghar	90	1306800
O'Brien	Sheldon	96	1307594
O'Brien	Sanborn	95	1307386
Palo Alto	Emmetsburg	39	1302689
Plymouth	Le Mars	66	1304735
Plymouth	Sioux City	102	1307713
Plymouth	Akron	1	1300088
Pocahontas	Pocahontas	89	1306719
Sioux	Hawarden	53	1303718
Sioux	Sioux Center	100	1307700
North Central District			
Butler	Allison	4	1300157
Butler	Dumont	37	1302388
Cerro Gordo	Mason City	73	1305235
Cerro Gordo	Mason City	72	1305230
Floyd	Charles City	22	1301402
Franklin	Hampton	51	1303584
Hancock	Britt	15	1300923
Kossuth	Algona	3	1300133
Mitchell	Osage	84	1306305
Winnebago	Forest City	43	1302977
Worth	Northwood	80	1306103
Wright	Clarion	25	1301541

Table 6. (continued)

County Name	City	Weather Station No.	Weather Station Code
Northeast District			
Allamakee	Corchester	35	1302311
Allamakee	Lansing	64	1304620
Allamakee	Waukon	112	1308755
Bremer	Tripoli	108	1308339
Chickasaw	New Hampton	78	1305952
Clayton	Elkader	38	1302603
Clayton	Guttenberg	50	1303517
Dubuque	Cascade	17	1301257
Dubuque	Dubuque	36	1302364
Fayette	Oelwein	82	1306200
Fayette	Fayette	42	1302846
Howard	Cresco	30	1301954
Sioux	Alton	5	1300181
Winneshiek	Decorah	32	1302110
West Central District			
Audubon	Audubon	8	1300385
Calhoun	Rockwell City	93	1307161
Carroll	Carroll	16	1301233
Crawford	Denison	33	1302171
Greene	Jefferson	58	1304228
Guthrie	Guthrie Center	49	1303509
Harrison	Logan	67	1304894
Ida	Ida Grove	54	1304038
Monona	Onawa	83	1306243
Monona	Monona	69	1305127
Monona	Castana	18	1301277
Sac	Sac City	94	1307312
Shelby	Harlan	52	1303632
Woodbury	Sioux City	101	1307708
Woodbury	Mapleton	68	1305123

Table 6. (continued)

County Name	City	Weather Station No.	Weather Station Code
Central District			
Dallas	Perry	88	1306566
Grundy	Grundy Center	48	1303487
Hamilton	Webster City	113	1308806
Hardin	Iowa Falls	57	1304142
Jasper	Newton	79	1305992
Marshall	Marshalltown	71	1305198
Polk	Des Moines	34	1302203
Poweshiek	Grinnell	47	1303473
Tama	Toledo	107	1308296
Webster	Fort Dodge	44	1302999
East Central District			
Benton	Belle Plaine	10	1300600
Benton	Vinton	109	1308568
Cedar	Tipton	106	1308266
Clinton	Clinton	27	1301640
Clinton	Clinton	26	1301635
Iowa	Williamsburg	114	1309067
Jackson	Bellevue	11	1300608
Jackson	Maquoketa	70	1305131
Johnson	Iowa City	56	1304101
Jones	Anamosa	6	1300213
Linn	Cedar Rapids	19	1301319
Muscatine	Muscatine	77	1305837
Scott	Le Claire	65	1304705
Southwest District			
Adair	Greenfield	46	1303438
Adams	Corning	29	1301833
Cass	Atlantic	7	1300364
Mills	Glenwood	45	1303290
Montgomery	Red Oak	91	1306940
Page	Shenandoah	97	1307613
Page	Clarinda	24	1301533
Pottawattamie	Oakland	81	1306151
Taylor	Bedford	9	1300576
Taylor	Blockton	12	1300745

Table 6. (continued)

County Name	City	Weather Station No.	Weather Station Code
South Central District			
Appanoose	Centerville	20	1301354
Clarke	Osceola	85	1306316
Decatur	Lamoni	63	1304585
Lucas	Chariton	21	1301394
Madison	Winterset	115	1309132
Marion	Knoxville	61	1304502
Monroe	Albia	2	1300112
Ringgold	Mount Ayr	75	1305749
Union	Creston	31	1301962
Warren	Indianola	55	1304063
Southeast District			
Davis	Bloomfield	13	1300753
Henry	Mt. Pleasant	76	1305796
Jefferson	Fairfield	41	1302789
Keokuk	Sigourney	99	1307678
Lee	Keokuk	59	1304381
Louisa	Wapello	110	1308668
Louisa	Columbus Jcn	28	1301731
Mahaska	Oskaloosa	86	1306327
Van Buren	Keosauqua	60	1304389
Wapello	Ottumwa	87	1306389
Washington	Washington	111	1308688

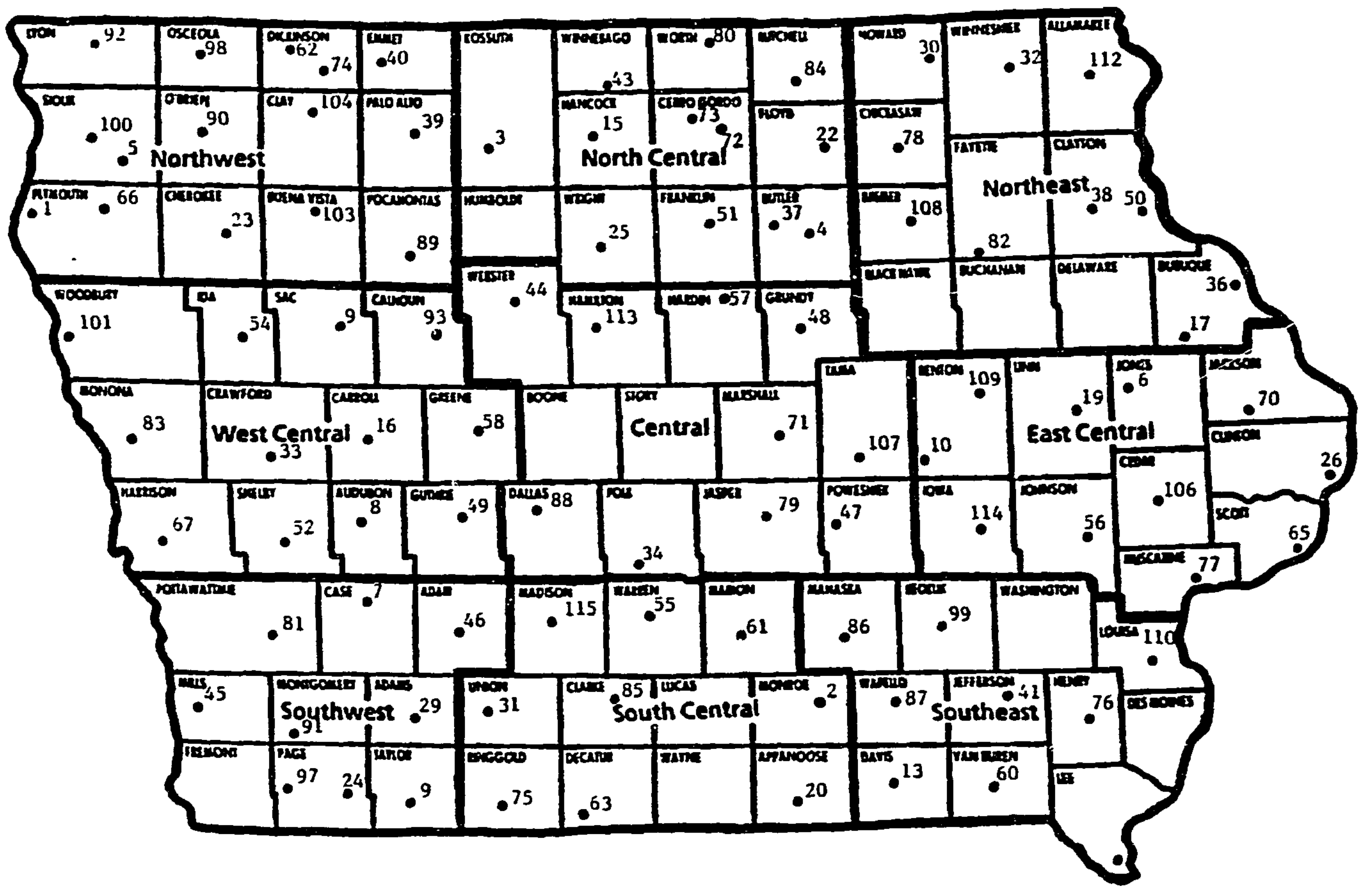


Figure 6. Locations of selected cooperative weather stations in Iowa

Real-time operation of the plant-process model will require that data be obtained directly from NOAA.

Latitude and longitude information accompanies the weather data. These variables are used for generating solar radiation estimates for respective weather station locations. Also, latitude is needed for calculating day length which is crucial for estimating the rate of corn development.

Corn Acreage Data

Harvested corn acreage is used to derive weights used for aggregating the individual location yield forecasts into CRD and state yield forecasts. Harvested corn acreage information for Iowa is obtained for the period 1975 through 1984. Harvested corn acreage by county for Iowa are shown in Tables A.1 and A.2 of the Appendix. Harvested corn acrage by CRD is shown in Table 7.

Acreage information is obtained from the National Agricultural Statistics Service (NASS) data tapes. Each year NASS conducts a June enumerative survey of farmers that is used to estimate the number of planted acres that have been planted to various crops in the United States. These estimates are made at the state and national level. In December, another enumerative survey is conducted from which more precise acreage estimates are made. From this survey, national, state, and county planted and harvested estimates

Table 7. Harvested corn acreage in Iowa by crop reporting district, 1975-1984

Crop Reporting District	Year									
	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
	thousand acres									
Northwest	1757	1779	1784	1860	1900	1891	1968	1890	1195	1816
North Central	1617	1729	1648	1682	1700	1742	1804	1745	1096	1701
Northeast	1304	1373	1386	1426	1460	1517	1612	1538	1037	1568
West Central	1768	1901	1841	1877	1950	1960	2007	1918	1222	1826
Central	1800	1949	1901	1862	1870	1916	1946	1856	1191	1771
East Central	1325	1439	1438	1468	1475	1496	1590	1563	1057	1553
Southwest	970	1017	1029	1025	1065	1070	1092	994	664	994
South Central	576	653	610	632	650	653	716	610	395	651
Southeast	1013	1060	1063	1018	1030	1055	1118	1036	693	1021
Iowa (million)	12.13	12.90	12.70	12.85	13.10	13.30	13.85	13.15	8.55	12.90

are finalized. Since this study is focusing on historical period, only the finalized harvested acreage estimates are used. Real-time operation of the model would require that the June planted acreage estimates be used to make harvested acreage forecasts.

Soils Data

Soils information is also an important input into the CERES-Maize model. Precipitation (and/or irrigation) is the source of moisture to any given field, but the soil type influences the availability of the moisture to the plants. Soil characteristics such as texture, reflectability, water holding capacity, and other factors are all important in influencing plant water availability. Soil types vary considerably across the state of Iowa. It is important, therefore, to know how the different soils are distributed throughout the corn growing regions and to know the detailed characteristics of each the soils.

Two types of soils data were, therefore, gathered for the study. The first type consisted of data with information on how the different soil types are distributed across the state. Acres of each soil type by county were available from National Resource Inventory (NRI) data sets. From this information, the most prominent soils in each county were determined. Table 8 shows the three most prominent soils in

Table 8. The three most prominent soil types in each of Iowa's ninty-nine counties

County Name	County No.	Soil Types		
Northwest District				
Buena Vista	21	Clarion	Canisteo	Nicollett
Cherokee	35	Galva	Primghar	Colo
Clay	41	Primghar	Clarion	Nicollet
Dickinson	59	Clarion	Nicollet	Webster
Emmet	63	Clarion	Nicollet	Canisteo
Lyon	119	Moody	Galva	Primghar
O'Brien	141	Galva	Primghar	Marcus
Osceola	143	Clarion	Sac	Primghar
Palo Alto	147	Clarion	Nicollet	Canisteo
Plymouth	149	Galva	Ida	Radford
Pocahontas	151	Webster	Canisteo	Clarion
Sioux	167	Galva	Primghar	Ida
North Central District				
Butler	23	Clyde	Kenyon	Floyd
Cerro Gordo	33	Clarion	Clyde	Kenyon
Floyd	67	Clyde	Kenyon	Readlyn
Franklin	69	Clarion	Dinsdale	Webster
Hancock	81	Canisteo	Nicollet	Clarion
Humboldt	91	Nicollet	Clarion	Webster
Kossuth	109	Clarion	Nicollet	Canisteo
Mitchell	131	Dinsdale	Clyde	Klinger
Winnebago	189	Clarion	Canisteo	Webster
Worth	195	Webster	Clarion	Maxfield
Wright	197	Webster	Canisteo	Nicollet
Northeast District				
Allamakee	5	Fayette	Downs	Dubuque
Black Hawk	13	Kenyon	Clyde	Dinsdale
Bremer	17	Readlyn	Clyde	Tripoli
Buchanan	19	Kenyon	Clyde	Floyd
Chickasaw	37	Clyde	Floyd	Bassett
Clayton	43	Fayette	Downs	Exette
Delaware	55	Kenyon	Floyd	Clyde
Dubuque	61	Fayette	Downs	Eleroy
Fayette	65	Kenyon	Clyde	Downs
Howard	89	Clyde	Floyd	Ostrander
Winneshiek	191	Downs	Fayette	Winneshiek

Table 8. (continued)

County Name	County No.	Soil Types		
West Central District				
Audubon	9	Marshall	Judson	Shelby
Calhoun	25	Webster	Clarion	Nicollet
Carroll	27	Marshall	Clarion	Judson
Crawford	47	Monona	Marshall	Napier
Greene	73	Clarion	Nicollet	Canisteo
Guthrie	77	Clarion	Sharpsburg	Nicollet
Harrison	85	Monona	Napier	Ida
Ida	93	Galva	Monona	Ida
Monona	133	Luton	Monona	Ida
Sac	161	Galva	Primghar	Clarion
Shelby	165	Marshall	Monona	Judson
Woodbury	193	Ida	Monona	McPaul
Central District				
Boone	15	Canisteo	Clarion	Nicollet
Dallas	49	Clarion	Canisteo	Nicollet
Grundy	75	Tama	Muscatine	Dinsdale
Hamilton	79	Clarion	Canisteo	Webster
Hardin	83	Clarion	Webster	Harps
Jasper	99	Tama	Downs	Ackmore
Marshall	127	Tama	Kilduff	Colo
Polk	153	Clarion	Nicollet	Webster
Poweshiek	157	Tama	Otley	Colo
Story	169	Clarion	Webster	Nicollet
Tama	171	Tama	Colo	Judson
Webster	187	Webster	Nicollet	Clarion
East Central District				
Benton	11	Dinsdale	Tama	Ely
Cedar	31	Tama	Downs	Fayette
Clinton	45	Fayette	Colo	Tama
Iowa	95	Otley	Ladoga	Clinton
Jackson	97	Fayette	Downs	Nodaway
Johnson	103	Tama	Ladoga	Clinton
Jones	105	Fayette	Dinsdale	Tama
Linn	113	Kenyon	Dinsdale	Clyde
Muscatine	139	Downs	Fayette	Tama
Scott	163	Tama	Downs	Colo

Table 8. (continued)

County Name	County No.	Soil Types		
Southwest District				
Adair	1	Sharpsburg	Shelby	Nira
Adams	3	Sharpsburg	Shelby	Colo
Cass	29	Marshall	Judson	Sharpsburg
Fremont	71	Marshall	Monona	Nodaway
Mills	129	Exira	Marshall	Monona
Montgomery	137	Marshall	Colo	Exira
Page	145	Sharpsburg	Colo	Exira
Pottawattamie	155	Monona	Marshall	Judson
Taylor	173	Shelby	Sharpsburg	Nodaway
South Central District				
Appanoose	7	Clarinda	Seymour	Edina
Clarke	39	Grundy	Shelby	Adair
Decatur	53	Grundy	Shelby	Adair
Lucas	117	Shelby	Grundy	Haig
Madison	121	Sharpsburg	Ladoga	Macksburg
Marion	125	Ladoga	Sharpsburg	Clinton
Monroe	135	Pershing	Gosport	Gara
Ringgold	159	Adair	Colo	Grundy
Union	175	Sharpsburg	Macksburg	Shelby
Warren	181	Sharpsburg	Zook	Macksburg
Wayne	185	Seymour	Clarinda	Shelby
Southeast District				
Davis	51	Armstrong	Kniffin	Edina
Des Moines	57	Mahaska	Clinton	Taintor
Henry	87	Otley	Pershing	Mahaska
Jefferson	101	Weller	Grundy	Haig
Keokuk	107	Clinton	Ladoga	Taintor
Lee	111	Weller	Pershing	Grundy
Louisa	115	Mahaska	Fayette	Taintor
Mahaska	123	Ladoga	Otley	Clinton
Van Buren	177	Adair	Weller	Edina
Wapello	179	Weller	Otley	Pershing
Washington	183	Otley	Mahaska	Clinton

each county. The soil names typed in bold-face were the soils selected for the model simulations.

The second type of soils data consisted of the detailed soil characteristics. Data sets were maintained for each of the prominent soils mentioned above. Soil characteristics included soil albedo, soil evaporation coefficient, soil water conductivity coefficient, and runoff curve number. In addition, soil characteristics were identified for up to ten soil layers including for each layer soil thickness, lower and drained upper limits of plant extractable water, saturated water content, root distribution weighting factor, organic carbon content, bulk density, soil pH, and others. Soil characteristic data were obtained from the Grassland, Soil and Water Laboratory in Temple, Texas. This detailed soils information was required by the CERES-Maize model.

Plant Variety Data

Plant genetic factors influence the rate of corn growth and development in the CERES-Maize model. Genetic inputs into the CERES-Maize model include growing degree days from seedling emergence to the end of the juvenile phase, photoperiod sensitivity, growing degree days from silking to physiological maturity, potential kernel number, and potential kernel growth rate. These genetic factors have been estimated for several common varieties and were obtained from Jones and Kiniry (1986). A 110-day maturity (Pioneer 3780) was selected since it was determined to be a maturity that could be grown in all areas of Iowa.

Management Data

Management of a crop has several facets. Those considered to be of the most importance and included in the CERES-Maize model include planting date, planting depth, planting density, nitrogen fertilizer application rate and date, and the amount and time of irrigation. Information on these management inputs are obtained from various sources.

The State Statistical Offices (SSO) of the NASS are very active in collecting planting date information each year for corn. Each week during planting season, the SSOs conduct informal, nonprobability telephone surveys to assess the progress made in corn plantings. Estimates are in the form of percent of the corn crop planted in each of the crop reporting districts (CRDs) for the respective week. From this information, average planting dates for each CRD are derived for the period 1975 through 1984. The average planting date is determined to be the midpoint of the week when 50 percent or more of the CRDs' corn crop had been planted. Average planting dates by CRD and year are shown in Table 9.

Table 9. Average planting dates by Iowa crop reporting district, 1975-1984

Year	NW	NC	NE	WC	C	EC	SW	SC	SE
	Crop Reporting District								
					Julian Day[a]				
1975[b]	135	135	135	135	135	135	135	135	135
1976[b]	130	130	130	130	130	130	130	130	130
1977[b]	125	125	125	125	125	125	125	125	125
1978	130	130	135	135	135	135	140	145	145
1979	135	135	135	135	135	135	135	135	135
1980	125	125	125	125	125	125	125	125	125
1981	130	130	135	130	130	130	110	130	135
1982	130	130	135	135	130	130	160	160	130
1983[b]	130	130	130	130	130	130	130	130	130
1984	135	135	135	135	135	135	135	135	135

[a]Julian date 120 is May 1 (April 30 on leap year)
[b]only state figures are available

Planting depth and planting density are kept constant in all model simulations. A planting depth of two inches and a planting density of about 26,000 seeds per acre were selected.

For simplicity, it was assumed that nitrogen application rates were invariate over the state and over the 1975 through 1984 period. Also, it was assumed that nitrogen is applied in the Spring at the time of planting.

No irrigation was assumed to be used in Iowa. This assumption may have lead to slightly lower model yield forecasts in the Northwest district.

CHAPTER IV. FRAMEWORK FOR MAKING AND USING PLANT-PROCESS MODEL CORN YIELD FORECASTS

This chapter describes the framework from which plant-process model (PPM) yield forecasts for Iowa were generated, aggregated, calibrated, and tested. The study was conducted *ex post* over the ten-year period 1975 through 1984. Sufficient data were not available for years prior to 1975 and after 1984. The PPM was used to generate corn yield forecasts at the county, crop reporting district (CRD), and state level for Iowa. The CERES-Maize model is a daily-incrementing model and, therefore, forecasts could conceivably have been made at any or all days during the growing season. Yield forecasts were generated, however, only for the days July 1, August 1, September 1, and October 1 for each of the years 1975 through 1984. With the exception of July 1, these days correspond to NASS forecast days. Once PPM forecasts were obtained, they were combined with NASS forecasts to form composite corn yield forecasts at the state and district level. Table 10 summarizes the descriptive characteristics of the yield forecasts of interest in the study.

The next three sections explain in more detail how corn yield forecasts were derived from the PPM, how PPM corn yield

Table 10 . Descriptive characteristics of corn yield forecasts for Iowa

Type of Forecast	Levels of Aggregation	Dates of Forecasts
NASS	Field/Farm	July 1
PPM	County	August 1
Composite	CRD	September 1
	State	October 1
		November 1

forecasts were aggregated and calibrated, and how performance tests were made.

Plant-Process Model Corn Yield Forecasts

The CERES-Maize plant process model was not developed as a large-area, forecasting model. The plant-process model generates growth and development information for a single plant for a specific location given current and past conditions at that location. A yield estimate is generated only after the simulated plant reaches maturity. One problem to overcome, therefore, is how to account for future conditions (especially weather conditions) beyond the day of the forecast. A second problem relates to aggregating location or point forecasts into large-area forecasts. This section focuses on the problem of forecasting future conditions. The following section deals with the aggregation problem.

Plant-process models are designed to generate yield estimates. These estimates are generated only after the model has been supplied with a set of conditions for the entire growing season. The problem in generating yield forecasts with the PPM was one of providing the model with weather data for days past the forecast date. The approach taken in this study was to simulate the corn plant using actual, known weather up to the forecast date and use historical weather information for days beyond the forecast date when weather was uncertain. In other words, the PPM generated for each forecast date a discrete distribution of yield estimates using a discrete distribution of weather data. Twenty-five years of historical weather were used in this study. The forecast was assumed in this study to be equal to the mean of the yield distribution.

Hypothetical examples are shown in Figure 7 to illustrate the forecasting procedure. In panel (a), a yield forecast was generated for forecast date 1. The PPM simulated the corn plant using known pre-season and known growing season weather up to forecast date 1. Beyond the forecast date weather information from one of the historical years was used. Once the corn plant reached maturity and the PPM generated a yield estimate, another historical year of weather was used by the PPM to generate another yield estimate. This process was repeated until all historical weather was put through the PPM, and twenty-five yield estimates were generated. The same procedure was repeated for the other forecast dates.

For the later season forecast dates (panels a and b in Figure 7), yield estimates depend more upon known weather and less upon possible weather as reflected by historical data. Yield distributions are, therefore, expected to be "tighter" for later forecast dates compared to earlier forecast dates.

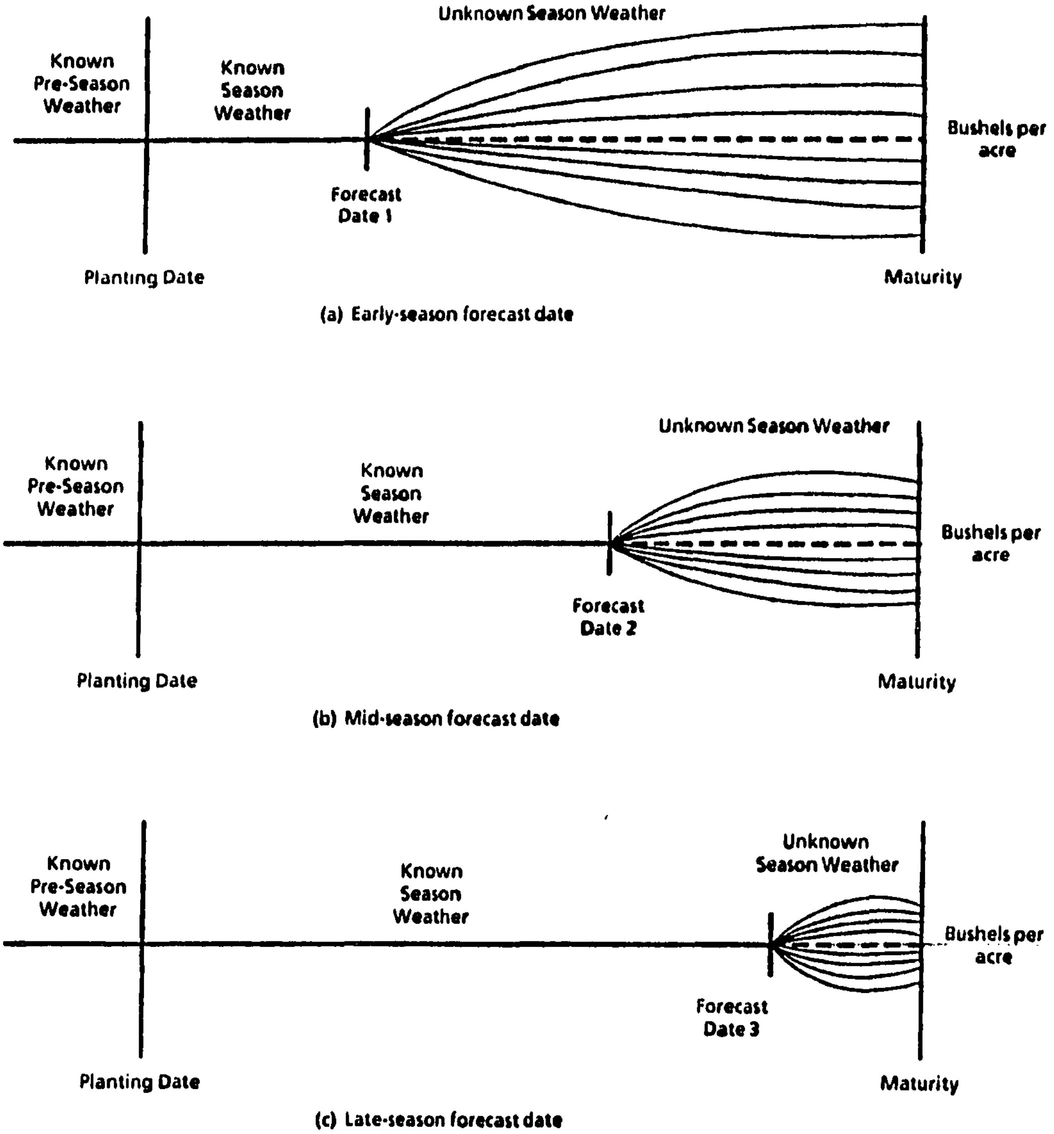


Figure 7. Plant-process model yield forecast distributions for three hypothetical forecast dates

This is to say the forecast variance is expected to fall as the growing season progresses. If, for example, a forecast date was beyond the date of maturity (not shown in Figure 7), all twenty-five yield estimates for that date would be equal, and the forecast variance would equal zero. This procedure was used to generate "point" corn yield forecasts.

Point Corn Yield Forecasts

A "point" corn yield forecast was defined as a forecast for a specific weather station location, soil, corn variety, and planting date. Several point forecasts were generated by the PPM for each of five forecast dates for the years 1975 through 1984. As indicated, a point yield forecast was derived from several point yield estimates. A point yield estimate was represented as:

$$\hat{Y}_{wsvpjklt} = f(W_{wjt} \Big|_{K} w_{wjl}, S_s, V_v, M_{jt}, O_{jt}, \theta) \qquad (4.1)$$

where

$\hat{Y}_{wsvpjklt}$ = the corn yield estimate for county j at forecast date k in year t using historical year l for weather location w, soil s, variety v, and planting date p;

$W_{wjt} \Big|_{K} w_{wjl}$ = set of actual weather up to and set of historical weather from year l after forecast day k for weather location w in county j;

S_s = set of soil data for soil s;

V_v = set of genetic data for variety v;

M_{jt} = set of planting date data for county j in year t;

O_{jt} = set of other data for county j in year t; and

θ = set of plant-process model parameters.

The corn yield forecasts were calculated as:

$$\hat{Y}_{wsvpkjt} = (\sum_{l=1}^{L} \hat{Y}_{wsvpkjlt})/L \tag{4.2}$$

where

$\hat{Y}_{wsvpkjt}$ = the corn yield forecast for county j in year t for weather location w, soil s, variety v, and planting date p; and

L = the number of years of historical weather.

The above expression indicates that the corn yield forecast was a simple average of the L yield estimates. In this study, L was equal to twenty-five years.

Once point forecasts are obtained, these forecasts are aggregated into county, CRD, and state yield estimates. Procedures for the aggregations are discussed in the following sections.

County Yield Forecasts

The first aggregation step involved aggregating all of the point forecasts for a given county into one county forecast. Potentially yield forecasts could be generated for multiple weather station locations, soils, corn varieties, and planting dates for a given county. A county forecast was derived from a weighted average of all these individual point forecasts. Weights were determined a priori from information sources discussed in Chapter III. The expression representing this first aggregation step is:

$$\hat{Y}_{jkt} = \sum_{w=1}^{W} \sum_{s=1}^{S} \sum_{v=1}^{V} \sum_{p=1}^{P} \alpha_{wt} \cdot \alpha_{st} \cdot \alpha_{vt} \cdot \alpha_{pt} \cdot \hat{Y}_{wsvpkjt} \qquad (4.3)$$

where

$\hat{Y}_{jkt}$ = the corn yield forecast for county j at forecast day k in year t;

α_{wt} = the weight on weather station w in year t;

α_{st} = the weight on soil s in year t;

α_{vt} = the weight on variety v in year t; and

α_{pt} = the weight on planting date p in year t.

This aggregation procedure generated a corn yield forecast for all Iowa counties with one or more weather stations. No yield forecasts were made for counties without a weather station.

Crop Reporting District Yield Forecasts

County yield forecasts were next aggregated into nine crop reporting district (CRD) yield forecasts. CRD forecasts were obtained using weighted averages of the county yield forecasts. Initially, two different weighting approaches were tried. The first approach assumed uniform weights on each county within respective districts. That is, the CRD forecast was calculated as a simple average of the county forecasts. This weighting approach was:

$$\hat{Y}_{dkt} = \sum_{j=1}^{N_d} \alpha_{dj} \cdot \hat{Y}_{jkt} \tag{4.4}$$

where

$\hat{Y}_{dkt}$ = the PPM corn yield forecast for CRD d at forecast day k in year t;

α_{dj} = the simple average weight (1/Nd) on the PPM yield forecast for county j in CRD d; and

N_d = the number of counties in CRD d.

The second weighting approach used weights that reflected the harvested acres of corn in each county. Since harvested corn acres varied from year to year, the weights also varied. The aggregation was:

$$\hat{Y}_{dkt} = \sum_{j=1}^{N} \alpha_{djt} \cdot \hat{Y}_{jkt} \tag{4.5}$$

where

α_{djt} = the harvested acres weight on the PPM corn yield forecast for county j in CRD d for year t.

Review of the CRD yield forecasts showed only a small difference between forecasts derived from the two weighting approaches. It was decided, therefore, to not consider forecasts generated from the simple average approach and use only those forecasts generated using the acreage weights. Yield forecast obtained from this aggregation were referred to as "uncalibrated" CRD yield forecasts.

Recall that the county yield forecasts were likely to be biased. As a result, the CRD yields were also likely to be biased. That is,

$$E(\hat{Y}_{dkt} - Y_{dt}) \neq 0 \qquad (4.6)$$

where

Y_{dt} = the actual average yield for CRD d in year t.

This means that the expected value of any CRD's corn yield forecast was not equal to the actual average yield for the respective CRD. Using simple regression techniques, this bias was eliminated. Actual yields were regressed on PPM yields. This was a way of calibrating the PPM forecasts. A regression or calibration model was specified as:

$$Y_{dt} = \beta_{0dk} + \beta_{djk} \cdot (\Sigma\, \alpha_{djt} \cdot \hat{Y}_{jkt}) + e_{dt} \qquad (4.7)$$

where β_{0d} and β_{1d} were the parameters of the calibration model, and e_{dt} is the model error. When estimating equation (4.7), the weights, α_{djt}, were restricted to be proportional to historical, harvested corn acreages in respective counties. These weights are, of course, invariant over the different forecast days.

The calibration regression equation was estimated for each of the nine Iowa CRDs for each of the five forecast days. Results of the calibration estimations are reported in Chapter V. Calibrated CRD forecasts using Model I are obtained from:

$$\hat{Y}_{dkt} = \hat{\beta}_{0dk} + \hat{\beta}_{djk}\, (\Sigma\, \alpha_{djt} \cdot \hat{Y}_{jkt}) \qquad (4.8)$$

State Average Corn Yield Forecasts

The final aggregation step gave average corn yield forecasts for the state. The state average corn yield forecasts were obtained by aggregating the CRD forecasts. The aggregation was:

$$\hat{Y}_{kt} = \sum_{d=1}^{9} \alpha_{dt} \cdot \hat{Y}_{dkt} \qquad (4.9)$$

where

$\hat{Y}_{kt}$ = the state corn yield forecast and

α_{dt} = the weight on the forecast for CRD d in year t

The weight on the forecast for CRD d was proportional to the number of harvested corn acres in CRD d in year t relative to acres in the other CRDs. The weights were expressed as:

$$\alpha_{dt} = \frac{HA_{dt}}{TA_t} \tag{4.10}$$

where

HA_{dt} = harvested corn acres in CRD d in year t and

TA_t = total harvested corn acres in the state in year t

Of course, the sum of the nine weights was equal to one. Results of the state yield forecasts are reported in Chapter V.

Composite Forecasts

The discussion in the sections above focused on deriving the PPM yield forecasts - point, county, CRD, and state. This section describes the next step of combining PPM forecasts with NASS forecasts. PPM and NASS forecasts were derived from two different sets of data and models. The NASS forecasts were derived from survey data and linear regression models. The PPM forecasts were derived from weather, soil, and other data; a comprehensive plant-process model; and a set of aggregation regression models. Individually, the NASS and PPM forecasts contained information from data and prior knowledge not contained in the other forecast. Composite or combination forecasting provides a means of combining individual forecasts into single composite forecasts that are superior to the individual forecasts.

Composite forecasts were derived at both the state and the district level. Two different approaches were taken. The first was termed the "bottom-up" approach, and the second was termed the "top-down" approach. The basic difference between the two was the level at which the composite forecasts were initially derived. Figures 8 and 9 illustrate the difference between the bottom-up and top-down approaches, repsectively.

The bottom-up approach initially combined PPM and NASS forecasts at the district level. The resulting CRD composite forecasts were aggregated to obtain a composite state forecast. This approach was done in this ex post study since NASS district forecasts were available for the 1975 to 1984 period. Real-time implementation of this approach can not be done, however, since CRD forecasts were discontinued in 1987. The justification for using the bottom-up approach in this study is that in an ex post sense, the predictive ability of

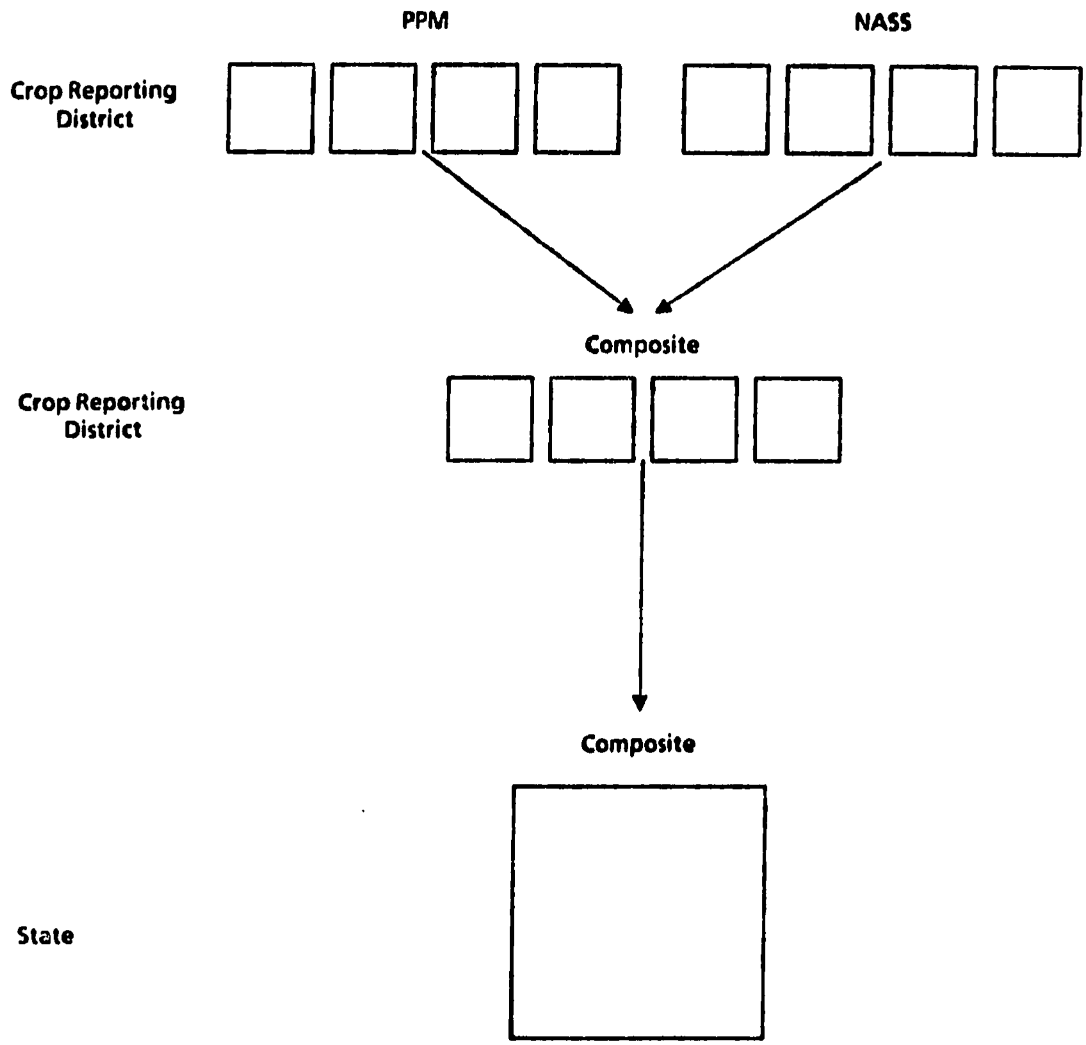


Figure 8. Schematic representation of the bottom-up approach to deriving the composite yield forecasts

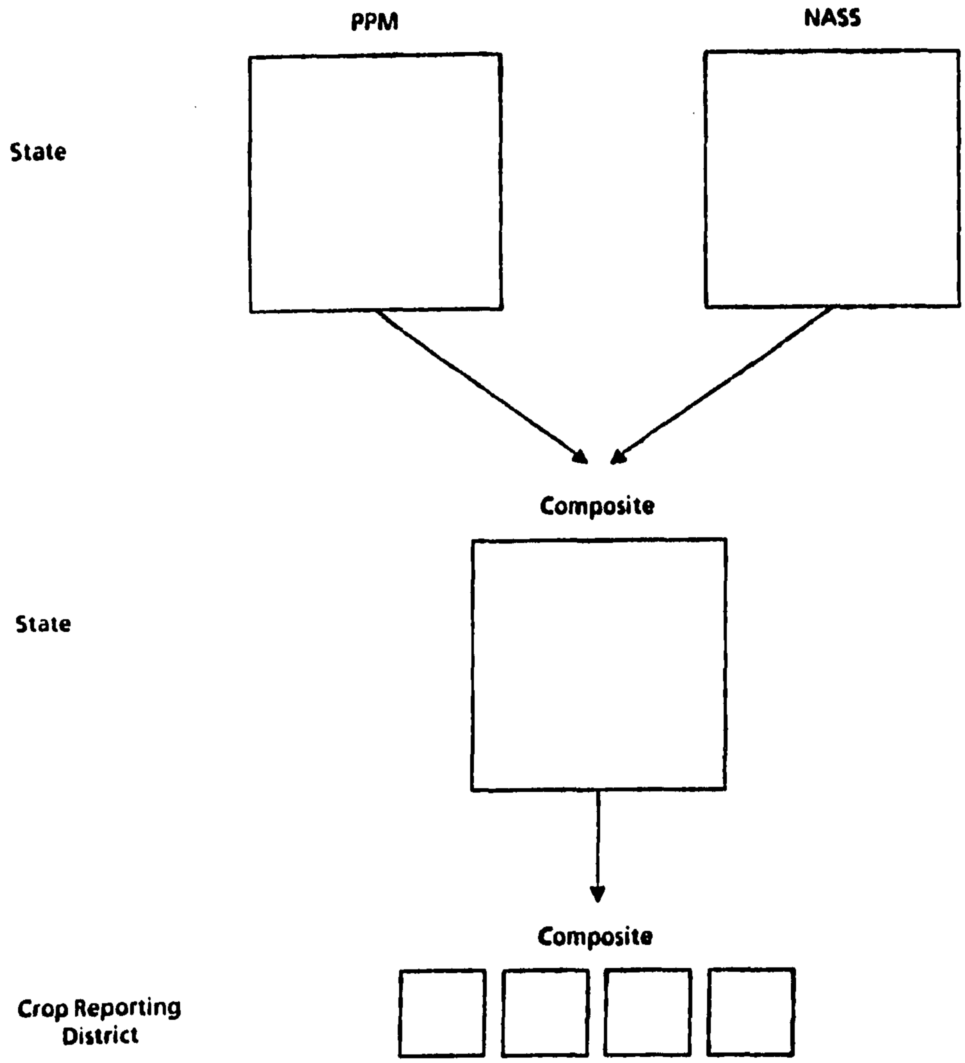


Figure 9. Schematic representation of the top-down approach to deriving the composite yield forecasts

the PPM district forecasts can be compared relative to that of the NASS district forecasts. Comparison of weights gives insight into the performance of PPM compared to NASS forecasts.

The top-down approach initially combined PPM and NASS forecasts at the state level. Using the relative yield relationships derived from the PPM district forecasts, district-level composite forecasts were derived from the state composite forecast. That is, if in a given year the yield forecast in the Central district is 10 percent higher than in the Northwest district, the same relative differential would exist in the composite. The top-down approach would be required for real-time implementation of the composite forecasting method.

The following develops the theoretical framework for constructing composite forecasts. The assumption underlying the framework is that the individual forecasts are unbiased. That is, in time t, the expected value of the errors of the individual forecasts was assumed to equal zero. Using notation,

$$E(Y_t - \hat{Y}_t^f) = 0 \quad \text{for all } f = 1\ldots, F \text{ and all } t \qquad (4.11)$$

where

Y_t = the value in time t of the variable to be forecast, and

$\hat{Y}_t^f$ = the forecast of Y_t using forecast method f.

Representing the forecast errors as e_t, the additional assumptions are:

$$E(e_t^f) = \sigma_f^2 \quad \text{for all } f = 1, \ldots, F \text{ and all } t \tag{4.12}$$

$$E(e_t^f \, e_t^g) = \sigma_{fg} \quad \text{for all } f \neq g \text{ and all } t \tag{4.13}$$

and

$$E(e_t \, e_s) = 0 \quad \text{for all } f,\ g \text{ and } t = s \tag{4.14}$$

Along with unbiasness, equations (4.11) through (4.14) establish the assumptions of a constant variance-covariance structure and uncorrelated forecasts. Following Fomby and Samanta (1988), the assumptions can be summarized in matrix notation as:

$$\underline{e}_t \sim \text{i.i.d. } (\underline{0}, \Sigma) \tag{4.15}$$

where i.i.d. stands for independent and identically distributed and Σ is an F x F variance-covariance matrix with elements σ_{fg}.

A composite forecast of two or more forecasts can be expressed as:

$$Y_t^c = \sum_{i=1} \alpha_i \cdot Y_{it} \qquad \Sigma\, \alpha_i = 1;\ \alpha_i < 0 \qquad (4.16)$$

where the composite forecast, Y^C, is a weighted average of the N individual forecasts, Y_i, and the composite weights, α_i, are each less than zero and sum to one.

Assuming that the individual forecasts are mutivariate normal, the variance of the composite forecast can be expressed as:

$$\delta_C^2 = \sum_{i=1}^{N} \alpha_i^2 \cdot \delta^2 + \sum_{i \neq j}^{N} \Sigma\, \alpha_i \cdot \alpha_j \cdot \rho_{ij} \cdot \delta_i \delta_j \qquad (4.17)$$

where

δ_C^2 = the error variance of the composite forecast;

δ_i^2 = the error variance of the forecast i;

ρ_{ij} = the correlation coefficient between the errors of the forecasts i and j; and

δ_i and δ_j = the standard deviation of the forecasts i and j, respectively.

The composite forecast is derived by assigning weights to each of the individual forecasts. If the forecasts are unbiased, the optimal weights will be such that the variance of the composite forecast is minimized. Following Johnson and Rausser (1972), the minimum composite variance can be determined from the Lagrangian expression:

$$L = \sum_{i=1}^{N} \alpha_i \cdot \delta^2 + \sum_{i \neq j}^{N} \sum \alpha_i \cdot \alpha_j \cdot \ _{ij} \cdot \delta_{i\delta j} + \lambda[1 - \Sigma \alpha_i] \quad (4.18)$$

where is the Lagrangian multiplier and all other variables are as defined previously. The variance minimizing weights are determined from the n+1 equations:

$$\frac{\delta L}{\delta \alpha_i} = 2 \cdot \alpha_i \cdot \delta^2 + 2 \cdot \Sigma \ \alpha_j \cdot \rho_{ij} \cdot \alpha_i \cdot \alpha_j - \lambda = 0 \qquad i = 1, \ldots, n \quad (4.19)$$

$$\frac{\delta L}{\delta \lambda} = 1 - \Sigma \ \alpha_i = 0 \quad (4.20)$$

Using the theoretical framework described above, composite forecasts using NASS and PPM forecasts are developed for both the bottom-up and top-down approaches.

Bottom-up Approach Using the bottom-up approach, PPM and NASS forecasts were combined at the district level. The composite CRD forecasts were obtained as:

$$\hat{Y}^C_{dkt} = \pi^P_{dk} \cdot \hat{Y}^P_{dkt} + \pi^N_{dk} \cdot \hat{Y}^N_{dkt}; \ \pi^P_{dk} + \pi^N_{dk} = 1; \ \pi_{dk}, \ \pi_{dk} < 0$$

$$= \pi^P_{dk} \cdot \hat{Y}^P_{dkt} + (1 - \pi^P_{dk}) \cdot \hat{Y}^N_{dkt} \quad (4.21)$$

where

$\hat{Y}^C_{dkt}$ = the composite corn yield forecast for CRD d at forecast day k in year t;

$\hat{Y}^{P}_{dkt}$ = the PPM corn yield forecast for CRD d at forecast day k in year t;

$\hat{Y}^{N}_{dkt}$ = the NASS corn yield forecast for CRD d at forecast day k in year t;

π^{P}_{dk} = the weight assigned to the PPM forecast in CRD d at forecast day k; and

π^{N}_{dk} = the weight assigned to the NASS forecast in CRD d at forecast day k.

In the case of only two forecasts, PPM and NASS, only one weight needed to be determined. The other weight was simply one minus the first weight. From equations (4.19) and (4.20), the analytical solution for the weights on the PPM forecasts was:

$$\pi^{P}_{dk} = \frac{\delta^{2N}_{dk} - \rho_{NP} \cdot \delta_{dk} \cdot \delta_{dk}}{\delta^{2P}_{dk} + \delta^{2N}_{dk} - 2 \cdot \rho_{NP} \cdot \delta^{P}_{dk} \cdot \delta^{N}_{dk}} \tag{4.22}$$

where

δ^{2P}_{dk} = the error variance of the PPM corn yield forecasts for CRD d at forecast day k;

δ^{2N}_{dk} = the error variance of the NASS corn yield forecasts for CRD d at forecast day k;

δ^{P}_{dk} = the standard deviation of the PPM corn yield forecasts for CRD d at forecast day k;

δ^N_{dk} = the standard deviation of the NASS corn yield forecasts for CRD d at forecast day k; and

ρ_{NP} = the correlation coefficient between the PPM and NASS forecasts for CRD d at forecast day k (note that district and forecast day subscripts are omitted).

Using the result from equation (4.22) and substituting into equation (4.17), the variance of the variance-minimizing composite forecast was:

$$\delta^2{}^{C*}_{dk} = \frac{\delta^2{}^P_{dk} \cdot \delta^2{}^N_{dk} \; (1 - \rho_{NP})}{\delta^2{}^P_{dk} + \delta^2{}^N_{dk} - 2 \cdot \rho_{NP} \cdot \delta^P_{dk} \cdot \delta^N_{dk}} \qquad (4.23)$$

where

$\delta^2{}^{C*}_{dk}$ = the optimal variance of the composite forecast for CRD d at forecast date k.

The denominator in equation (4.22) is the variance of the difference in the PPM and NASS forecasts. Therefore, the composite forecast variance is smaller than the minimum of either of the variance of the PPM or NASS individual forecasts. The exception to this is when $_{PN} = \delta^2{}^P_{dk}/\delta^2{}^N_{dk}$ or $_{PN} = \delta^2{}^N_{dk}/\delta^2{}^P_{dk}$. In these two cases, the variance of the either the PPM or NASS forecasts. This result shows that combining the PPM and NASS forecasts into a composite forecast will never lead to a worse forecast in the sense of increasing the forecast variance.

Once composite forecasts are obtained for each CRD using the bottom-up approach, these forecasts are aggregated into a composite state-level forecast. The aggregation procedure is the same as that explained in the previous section for aggregating PPM district forecasts. The aggregation expression is:

$$\hat{Y}_{kt} = \sum_{d=1}^{9} \alpha_{dt} \cdot \hat{Y}_{dkt} \tag{4.24}$$

where

$\hat{Y}_{kt}$ = the composite corn yield forecast for the state at forecast date k and year t and

α_{dt} = the weight attached to each CRD forecast in year t.

Again, the weights are proportional to harvested corn acres in each CRD and, therefore, also sum to one.

The primary aim of using this bottom-up approach to developing the composite forecasts was to compare the weights on the PPM with the weights on the NASS district forecasts. For instance, if weights on the PPM forecasts were found to be relatively small, this indicated that the PPM forecasts were not going to contribute much to making more reliable district forecasts. If the weights on the PPM forecasts were relatively large, this may indicate that the PPM would have provided valuable forecasting information. As mentioned, the bottom-up approach can not be used in a real-time implementation of the PPM in Iowa since NASS no longer reports district-level yield forecasts. Real-time implementation will require the top-down approach to deriving composites.

Top-Down Approach Using the top-down approach, PPM and NASS forecasts are combined at the state level. The composite forecasts were obtained as:

$$\hat{Y}^C_{kt} = \pi^P_k \cdot \hat{Y}^P_{kt} + \pi^N_k \cdot \hat{Y}^N_{kt}, \ \pi^P_k + \pi^N_k = 1; \ \pi^P_k, \ \pi^N_k > 0$$

$$= \pi^P_k \cdot \hat{Y}^P_{kt} + (1 - \pi^P_k) \cdot \hat{Y}^N_{kt} \tag{4.25}$$

where

$\hat{Y}^C_{kt}$ = the composite corn yield forecast for the state at forecast day k in year t;

$\hat{Y}^P_{kt}$ = the PPM corn yield forecast for the state at forecast day k in year t;

$\hat{Y}^N_{kt}$ = the NASS corn yield forecast for the state at forecast day k in year t;

π^P_k = the weight on the PPM yield forecast at forecast day k; and

π_k^N = the weight on the NASS yield forecast at forecast day k.

In the same manner as described with the bottom-up approach, the weights on the PPM state yield forecasts were analytically obtained as:

$$\pi_k^P = \frac{\delta^2{}_k^N - \rho_{Np}\cdot\delta_k^P\cdot\delta_k^N}{\delta^2{}_k^P + \delta^2{}_k^N - 2\cdot\rho_{NP}\cdot\delta_k^P\cdot\delta_k^N} \tag{4.26}$$

where

$\delta^2{}_k^P$ = the error variance of the PPM state corn yield forecast at forecast day k;

$\delta^2{}_k^N$ = the error variance of the NASS state corn yield forecast at forecast day k;

δ_k^P = the standard deviation of the PPM state corn yield forecasts at forecast day k;

δ_k^N = the standard deviation of the NASS state corn yield forecast at forecast day k; and

ρ_{NP} = the correlation coefficient between PPM and NASS state forecasts at forecast day k.

The variance of the variance-minimizing composite state forecast is:

$$\delta_K^{2C} = \frac{\delta^2{}_K^P \cdot \delta^2{}_K^N\,(1 - \rho_{NP})}{\delta^2{}_K^P + \delta^2{}_K^N - 2 \cdot \rho_{NP} \cdot \delta_K^P \cdot \delta_K^N} \qquad (4.27)$$

where

δ_K^C = the variance of composite forecast for the state at forecast date k.

Once composite forecasts are obtained at the state level, district composites are calculated. District composite forecasts were obtained from the state composite and from the district yield relationships obtained from the PPM. The district composite forecasts were obtained as:

$$\hat{Y}_{dkt}^{C} = \frac{\hat{Y}_{dkt}^{P}}{Y_{kt}^{P}} \cdot \hat{Y}_{kt}^{C} \qquad (4.28)$$

where

$\hat{Y}_{dkt}^{C}$ = the composite corn yield forecast for CRD d for forecast date k in year t.

The yield relationships between CRD forecasts from the PPM were preserved when calculating the CRD forecasts with the top-down approach.

<u>Deriving Composite Forecasts Directly</u>

The preceeding section described the theoretical framework from which composite corn yield forecasts were derived from individual PPM and NASS forecasts. Analytical solutions to obtaining optimal composite weights are, however, not the most direct way to obtain composite forecasts. A direct approach is to use regression techniques. Two regression approaches were used in this study. In the first approach, simple ordinary least squares (OLS) were applied to equation (4.22). In the second approach, ridge regression techniques were used.

<u>OLS Composite Weights</u> The most direct way to derive the composite weights on the PPM and NASS forecasts was to estimate the composite forecast equation using ordinary least squares procedures. At the district level, for example, the specified equations were:

$$\hat{Y}_{dt} = \pi_{dk} \cdot Y_{dkt} + \pi_{dk} \cdot \hat{Y}_{dkt} + e_{dkt} \tag{4.29}$$

where

$E(e_{dkt}) = 0;$

$E(e_{dkt})^2 = \sigma^2_{dkt}.$

The composite forecasts were obtained as:

$$\hat{Y}_{dkt} = \hat{\pi}_{dk} \cdot \hat{Y}_{dkt} + \hat{\pi}_{dk} \cdot \hat{Y}_{dkt} \tag{4.30}$$

Using OLS, the best linear unbiased estimates of the composite weights were obtained. A problem, however, exists with the estimation equation (4.29). The two independent variables, the PPM forecasts and the NASS forecasts, are likely to be highly correlated. The consequence of this multicollinearity problem is that one or both of the estimated weights may have large standard errors (Fomby, Hill, and Johnson, 1984). Unusually large standard errors have widened the confidence intervals and clouded the confidence that we can place on the estimated weights. An estimation technique called ridge regression can be used to partially offset the problem of multicollinearity and large standard errors.

Ridge Regression Composite Weights Use of ridge regression techniques is a way of reducing the standard error of estimates and increasing the confidence in those estimates. The trade-off is that biased parameter estimates are obtained. In matrix notation, the set of ridge estimates for the vector β is expressed as (Fomby, Hill, and Johnson, 1984):

$$\hat{\beta}(k) = (X'X + kI)^{-1}X'y$$

where

X = the matrix of independent variables;

y = a vector of the dependent variables;

I = an identity matrix;

$\hat{\beta}$ = the estimated parameter vector; and

k = a non-stochastic parameter that is greater than or equal to zero.

The parameter k is referred to as the shrinkage constant. It shrinks the least-squares estimates toward zero by an amount that is proportional to the value of k. The bias in the parameter estimates is directly related to the size of k, and the standard error the estimates is indirectly related to the size of k. Note that when k equals zero, OLS estimates result.

The primary difficulty with using ridge regression is in selecting a value for k. Attempts at determining the appropriate value of k (Casella, 1977; Thisted, 1977; and Strawderman, 1978) have met with limited success. The approach used in this study is to parameterize k and choose the value that seems to give the most desirable trade-off between standard errors and biased estimates. Admittedly, this is a subjective approach but one that is frequently adopted using ridge regression.

Model Performance

All forecasts should be evaluated in terms of their performance and accuracy. Measures of reliability are needed so those who use the forecasts know how much confidence they should put in the forecasts. Several reliability measures are available. The two used in this study are (1) a simple "high-low" count and (2) the root mean square error. The first is an indicator of qualitative performance while the second is a more quantitative indicator.

High-Low Count

The high-low count was a simple, but potentially useful, first step in evaluating the performance of the forecasts. In this study, the high-low count was the frequency that the forecast was correct in predicting an above-average yield or a below-average yield. That is, the high-low count indicated the number of times in the historical period that either of the following occurs:

- The forecast indicated an above-average yield, and the actual yield was above-average.
- The forecast indicated a below-average yield, and the actual yield was below-average.

The high-low count was a first-step indicator of the reliability of yield forecasts. The limitation of the high-low count, however, is that it indicates nothing about how accurate the forecast is in predicting the magnitude of the yield above or below average.

Root Mean Square Error

A more quantitative measure of forecast reliability is the root mean square error (RMSE). The RMSE is a measure of the average percent deviation of a forecast from actual values over a historical period. The RMSE is currently used by NASS to report the reliability of their forecasts. These reliability measures are used to derive confidence intervals for their forecasts. In this study, RMSEs are calculated at the district and state levels for the calibrated PPI and for the composite forecasts. Also, RMSEs are calculated for NASS forecasts for the same 10-year period. The district and state RMSEs are defined as:

$$RMSE_{dk} = \sqrt{(1/N-1) \sum_{t=1}^{T} (Y_{dkt} - Y_{dt})^2} \tag{4.31}$$

and

$$RMSE_{k} = \sqrt{(1/N-1) \sum_{t=1}^{T} (Y_{kt} - Y_{t})^2} \tag{4.32}$$

where

$RMSE_{dk}$ = the root mean square error for the corn yield forecast in district d at forecast date k;

$RMSE_{k}$ = the root mean square error for the state corn yield forecast at forecast date k; and

T = the number of years of forecast.

The RMSE estimates for all of the forecasts are reported and compared in Chapter V.

V. IOWA CORN YIELD FORECASTS

This chapter reports results of generating corn yield forecasts in Iowa using a plant-process model (PPM) and the results of combining these with NASS forecasts. State and district corn yield forecasts are reported and compared for the NASS, PPM, and composite forecasts. Forecast reliability results for the three different types of forecasts are also given.

NASS Corn Yield Forecasts

Before reporting PPM forecasts, NASS Iowa corn yield forecasts are reviewed for the period 1975 through 1984. NASS forecasts are made in August, September, October, and November based upon conditions on the first day of the month. A final yield estimate is reported the following January and is based upon the December enumerative survey. A revised final estimate is reported the following January.

Iowa corn yield forecasts made at the crop reporting district (CRD) level were begun in the early 1970s. As mentioned previously, CRD yield forecasts were discontinued in 1987 due to budget cuts. Currently, only state level forecasts are made. NASS forecasts reported here include state and CRD forecasts for the period 1975 through 1984.

Tables 11 through 20 show NASS corn yield forecasts for Iowa and its nine crop reporting districts for years 1975 through 1984, respectively. Also shown in the tables are actual yields for Iowa and the CRDs. Actual yields are based on the revised final yield estimates that are reported approximately one year after harvest. CRD forecasts are not available for August of 1975 and 1976. The yield forecasts are plotted for each CRD in Figures 10 through 19, respectively.

The high-low count was the first indicator used to evaluate NASS forecast performance. The high-low count is simply an indicator of the number of times that the NASS forecast correctly predicted an above-average corn yield when the actual yield was above-average or predicted a below-average corn yield when the actual yield was below average. This count was made for all four forecast dates -- August, September, October, and November -- and all nine crop reporting districts and the state. High-low counts for the NASS forecasts are shown in Table 21.

The high-low count indicates that NASS forecasts do a reasonably good job of accurately predicting either an above-average or a below-average yield for CRDs in Iowa. The forecasts do an even better job at the state level. As expected, later season forecasts are more accurate than early season forecasts although no forecast was incorrect more than

Table 11. NASS corn yield forecasts for four forecast dates and actual corn yields by crop reporting district, 1975

Crop Reporting District	Forecast Date Aug. 1	Sept. 1	Oct. 1	Nov. 1	Actual[a] Yield
		bushels per acre[b]			
Northwest	N.A.	84	84	88	88.0
North Central	N.A.	93	96	98	95.0
Northeast	N.A.	90	90	92	93.0
West Central	N.A.	84	88	89	85.0
Central	N.A.	93	97	100	98.0
East Central	N.A.	92	97	102	100.0
Southwest	N.A.	70	74	76	68.0
South Central	N.A.	69	69	75	74.0
Southeast	N.A.	82	87	94	93.0
Iowa	91	86	89	92	90.0

[a]Based on revised final estimate.
[b]As reported by the NASS, final estimates are rounded to nearest tenth of a bushel while other forecasts and estimates are rounded to nearest bushel.

Table 12. NASS corn yield forecasts for four forecast dates and actual corn yields by crop reporting district, 1976

Crop Reporting District	Forecast Date Aug. 1	Sept. 1	Oct. 1	Nov. 1	Actual[a] Yield
		bushels per acre[b]			
Northwest	N.A.	60	63	69	73.0
North Central	N.A.	88	88	93	93.0
Northeast	N.A.	82	82	88	91.0
West Central	N.A.	59	60	66	71.0
Central	N.A.	98	98	104	104.0
East Central	N.A.	100	99	99	102.0
Southwest	N.A.	97	95	97	99.0
South Central	N.A.	99	96	97	95.0
Southeast	N.A.	109	109	106	107.0
Iowa	93	85	85	89	91.0

[a]Based on revised final estimate.
[b]As reported by the NASS, final estimates are rounded to nearest tenth of a bushel while other forecasts and estimates are rounded to nearest bushel.

Table 13. NASS corn yield forecasts and estimates for four forecast dates and actual corn yields by Crop Forecasting District, 1977

Crop Reporting District	Forecast Date Aug. 1	Sept. 1	Oct. 1	Nov. 1	Actual[a] Yield
	bushels per acre[b]				
Northwest	104	106	107	107	103.0
North Central	98	100	102	105	102.0
Northeast	100	101	105	108	112.0
West Central	77	76	75	75	74.0
Central	68	68	69	69	66.0
East Central	94	98	99	101	103.0
Southwest	73	73	69	69	68.0
South Central	36	36	39	40	40.0
Southeast	74	75	75	76	76.0
Iowa	85	86	87	88	86.0

[a]Based on revised final estimate.
[b]As reported by the NASS, final estimates are rounded to nearest tenth of a bushel while other forecasts and estimates are rounded to nearest bushel.

Table 14. NASS corn yield forecasts for four forecast dates and actual corn yields by crop reporting district, 1978

Crop Reporting District	Forecast Date Aug. 1	Sept. 1	Oct. 1	Nov. 1	Actual[a] Yield
	bushels per acre[b]				
Northwest	120	120	120	122	119.5
North Central	115	115	115	118	121.0
Northeast	108	108	107	110	118.0
West Central	117	117	118	120	115.0
Central	122	122	122	123	116.1
East Central	114	114	115	118	117.8
Southwest	111	111	110	110	104.7
South Central	99	99	100	103	99.7
Southeast	114	114	114	114	106.6
Iowa	115	115	115	117	115.0

[a]Based on revised final estimate.
[b]As reported by the NASS, final estimates are rounded to nearest tenth of a bushel while other forecasts and estimates are rounded to nearest bushel.

Table 15. NASS corn yield forecasts for four forecast dates and actual corn yields by crop reporting district, 1979

Crop Reporting District	Forecast Date Aug. 1	Sept. 1	Oct. 1	Nov. 1	Actual[a] Yield
	bushels per acre[b]				
Northwest	113	117	121	124	123.9
North Central	122	124	124	133	130.0
Northeast	119	121	121	124	130.4
West Central	109	112	113	118	119.1
Central	117	120	123	134	135.3
East Central	114	118	120	124	132.3
Southwest	108	111	114	119	120.0
South Central	103	104	106	110	110.5
Southeast	112	115	119	125	133.0
Iowa	114	117	119	125	127.0

[a]Based on revised final estimate.

[b]As reported by the NASS, final estimates are rounded to nearest tenth of a bushel while other forecasts and estimates are rounded to nearest bushel.

Table 16. NASS corn yield forecasts for four forecast dates and actual corn yields by crop reporting district, 1980

Crop Reporting District	Forecast Date Aug. 1	Sept. 1	Oct. 1	Nov. 1	Actual[a] Yield
	bushels per acre[b]				
Northwest	106	110	113	116	116.8
North Central	118	121	123	127	125.3
Northeast	119	122	122	118	121.4
West Central	87	90	87	87	86.8
Central	112	111	115	118	116.0
East Central	119	117	119	118	117.9
Southwest	89	87	86	87	88.0
South Central	98	85	87	90	88.5
Southeast	120	114	113	112	112.9
Iowa	108	108	109	110	110.0

[a]Based on revised final estimate.

[b]As reported by the NASS, final estimates are rounded to nearest tenth of a bushel while other forecasts and estimates are rounded to nearest bushel.

Table 17. NASS corn yield forecasts for four forecast dates and actual corn yields by crop reporting district, 1981

Crop Reporting District	Forecast Date: Aug. 1	Sept. 1	Oct. 1	Nov. 1	Actual[a] Yield
	bushels per acre[b]				
Northwest	132	129	126	127	125.1
North Central	128	131	134	134	133.5
Northeast	132	133	134	133	129.2
West Central	111	112	112	111	109.7
Central	126	131	132	132	129.5
East Central	132	136	138	138	132.5
Southwest	117	121	121	122	116.7
South Central	116	121	125	125	118.9
Southeast	126	128	132	132	125.7
Iowa	125	127	128	128	125.0

[a]Based on revised final estimate.

[b]As reported by the NASS, final estimates are rounded to nearest tenth of a bushel while other forecasts and estimates are rounded to nearest bushel.

Table 18. NASS corn yield forecasts for four forecast dates and actual corn yields by crop reporting district, 1982

Crop Reporting District	Forecast Date: Aug. 1	Sept. 1	Oct. 1	Nov. 1	Actual[a] Yield
	bushels per acre[b]				
Northwest	133	125	125	118	117.9
North Central	126	128	130	128	127.2
Northeast	119	124	124	124	121.5
West Central	121	123	122	122	115.8
Central	128	131	130	129	128.1
East Central	132	133	132	131	129.3
Southwest	96	109	107	108	102.5
South Central	80	88	92	94	90.9
Southeast	128	129	127	128	122.7
Iowa	122	124	124	122	120.0

[a]Based on revised final estimate.

[b]As reported by the NASS, final estimates are rounded to nearest tenth of a bushel while other forecasts and estimates are rounded to nearest bushel.

Table 19. NASS corn yield forecasts for four forecast dates and actual corn yields by crop reporting district, 1983

Crop Reporting District	Forecast Date: Aug. 1	Sept. 1	Oct. 1	Nov. 1	Actual[a] Yield
	bushels per acre[b]				
Northwest	114	105	98	92	86.5
North Central	131	112	106	101	101.4
Northeast	125	100	101	99	102.4
West Central	113	93	91	85	86.1
Central	126	100	103	99	103.5
East Central	118	84	85	80	85.3
Southwest	97	72	80	75	78.9
South Central	86	40	40	38	47.2
Southeast	80	44	45	43	47.9
Iowa	114	90	89	85	87.0

[a]Based on revised final estimate.

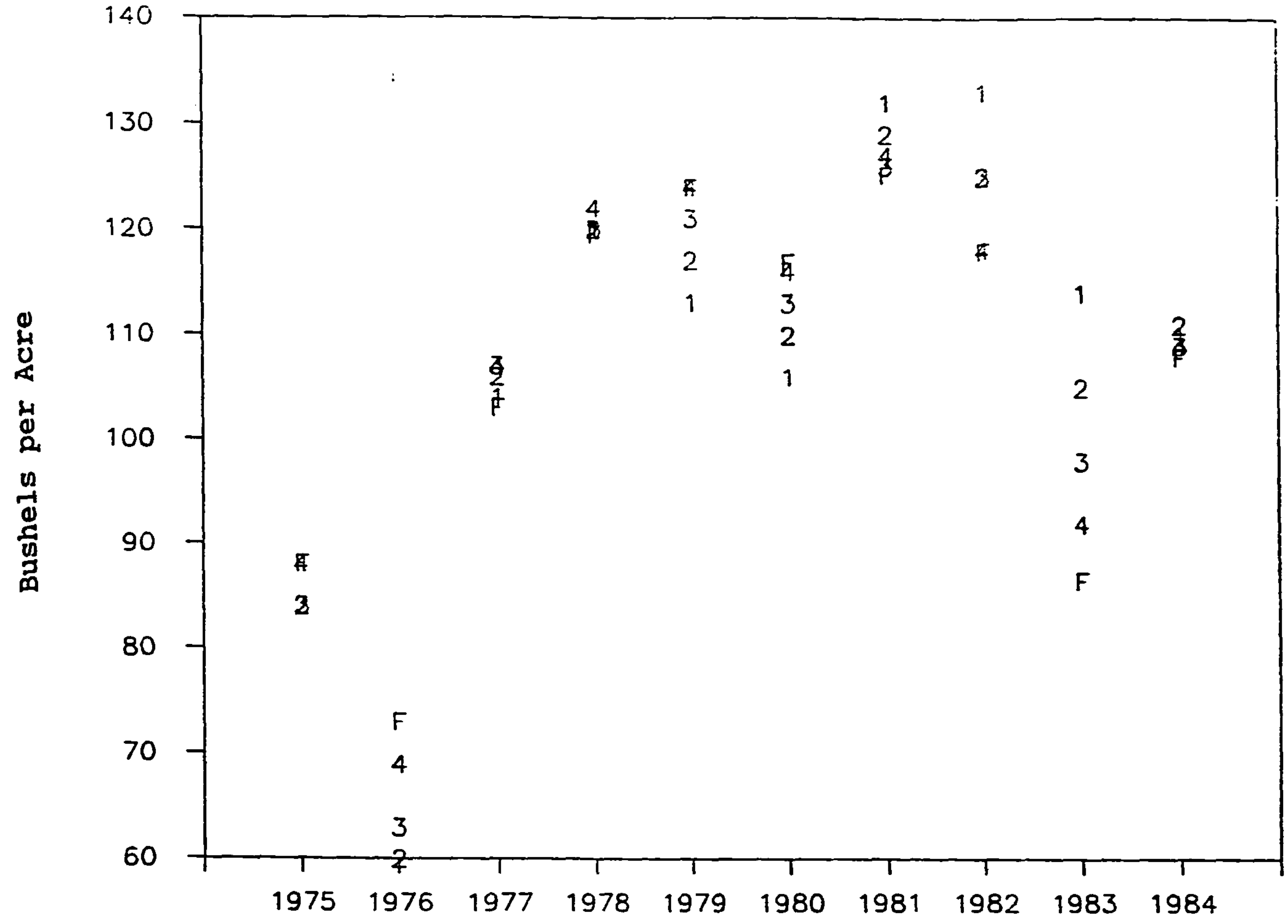
[b]As reported by the NASS, final estimates are rounded to nearest tenth of a bushel while other forecasts and estimates are rounded to nearest bushel.

Table 20. NASS corn yield forecasts for four forecast dates and actual corn yields by crop reporting district, 1984

Crop Reporting District	Forecast Date: Aug. 1	Sept. 1	Oct. 1	Nov. 1	Actual[a] Yield
	bushels per acre[b]				
Northwest	110	111	109	109	107.9
North Central	128	117	115	115	115.0
Northeast	132	118	120	114	114.1
West Central	111	105	103	108	109.3
Central	130	128	125	123	118.2
East Central	138	127	123	122	123.2
Southwest	102	91	90	95	95.8
South Central	95	92	88	88	85.5
Southeast	138	128	126	123	120.7
Iowa	122	115	113	113	112.0

[a]Based on revised final estimate.

[b]As reported by the NASS, final estimates are rounded to nearest tenth of a bushel while other forecasts and estimates are rounded to nearest bushel.



1 - Aug. 1   2 - Sept. 1   3 - Oct. 1   4 - Nov. 1   F - Final Estimate

Figure 10. NASS corn yield forecasts for four forecast dates and actual corn yields for 1975 through 1984, Northwest district

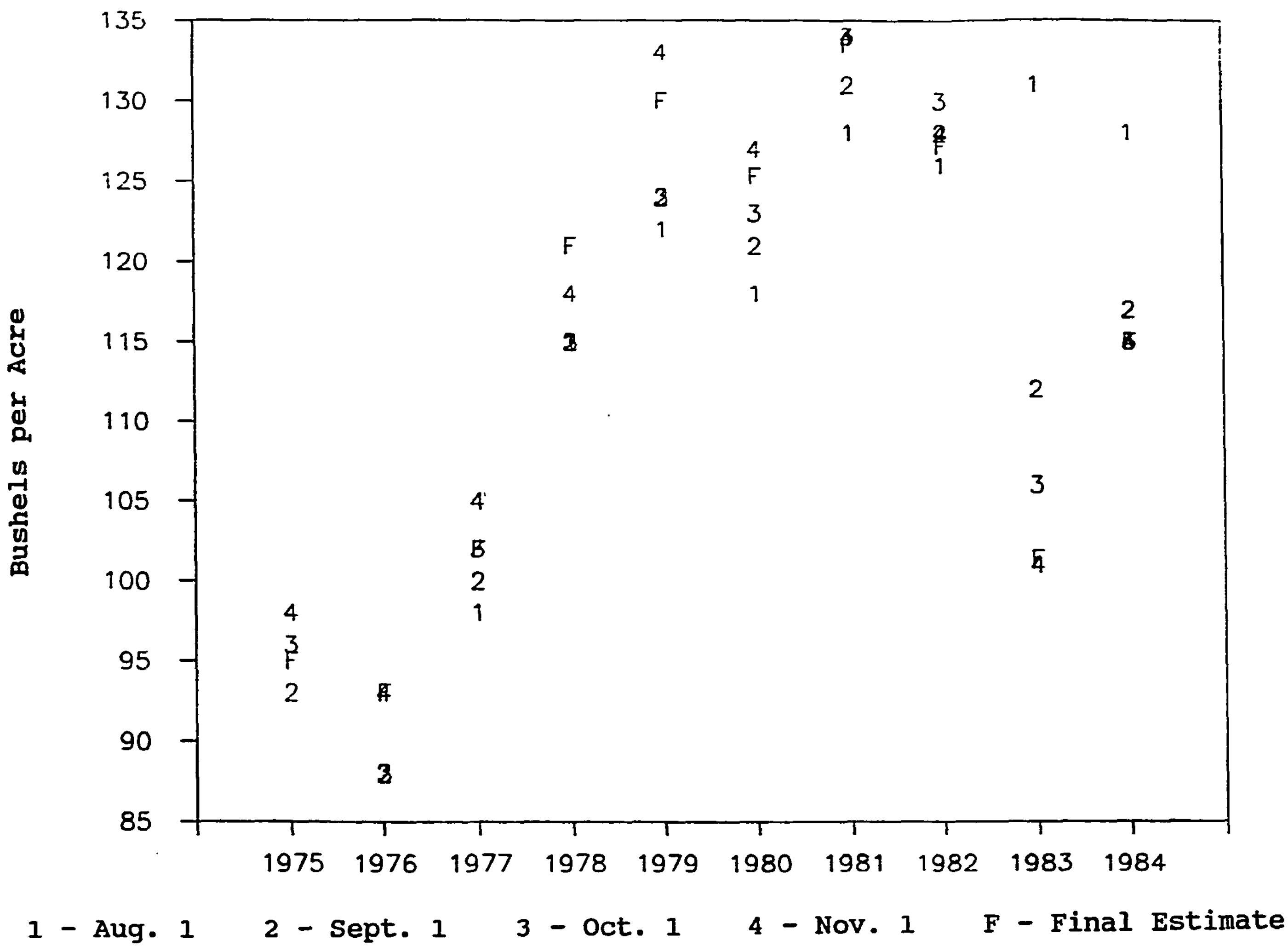


Figure 11. NASS corn yield forecasts for four forecast dates and actual corn yields for 1975 through 1984, North Central district

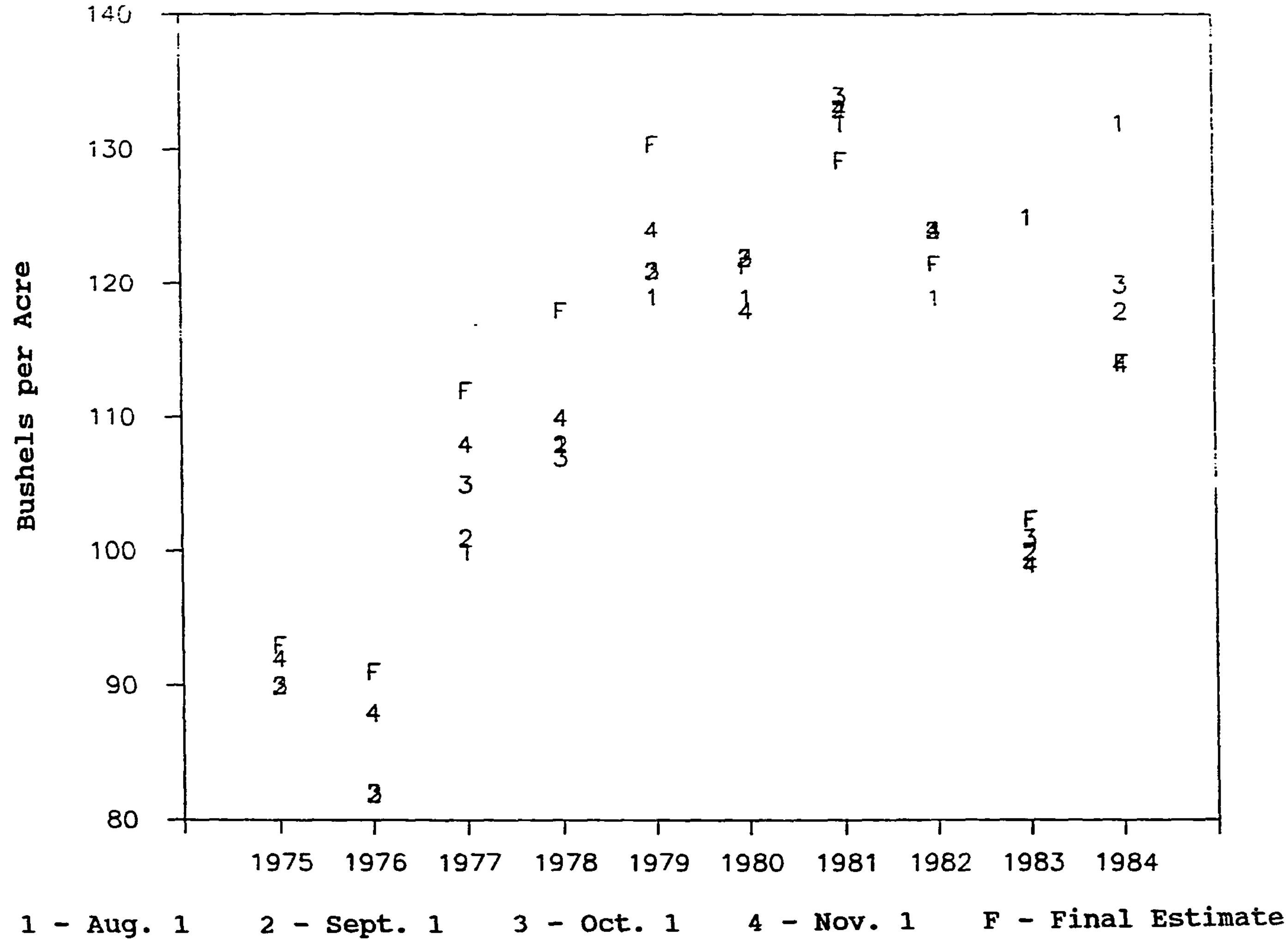
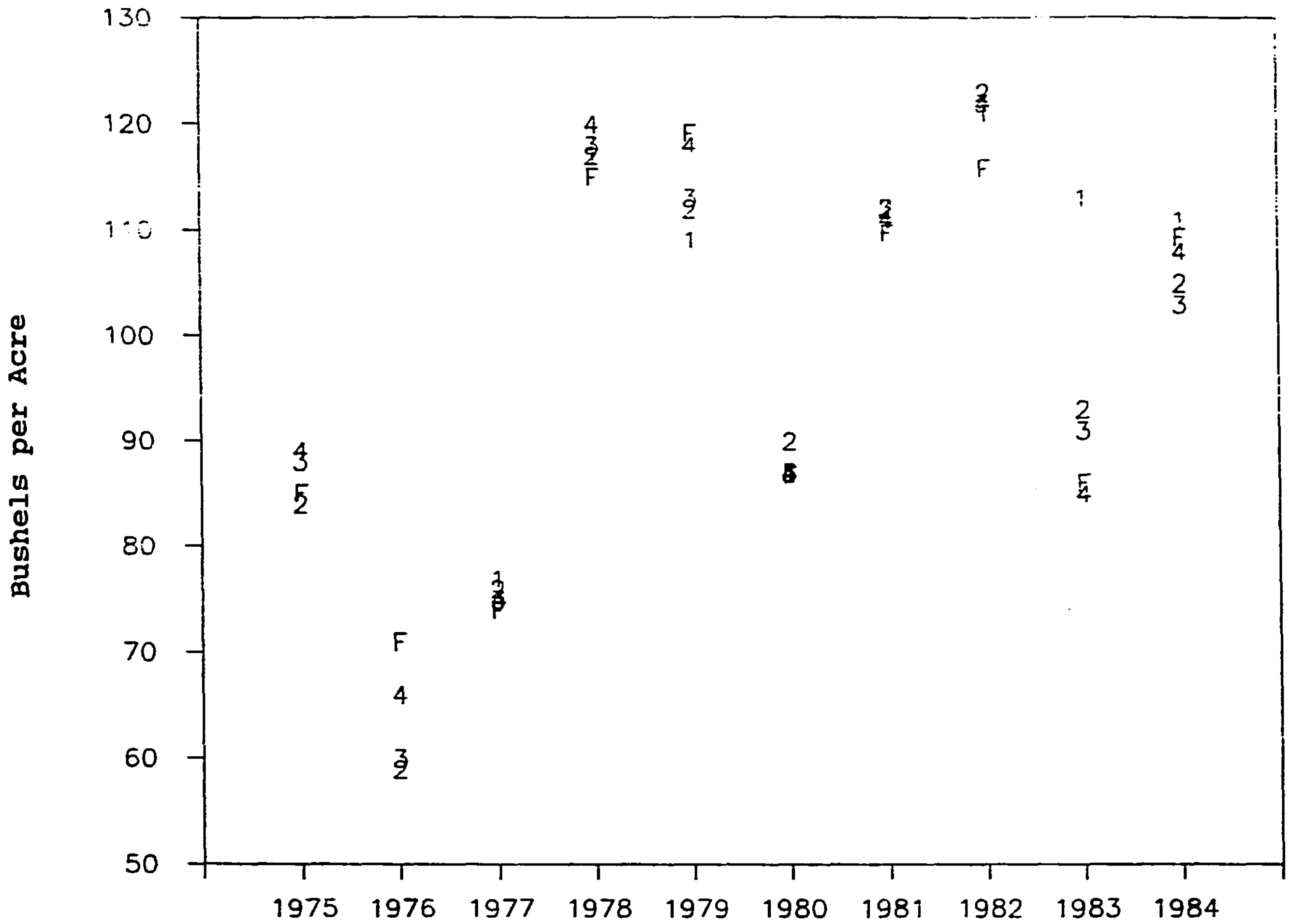
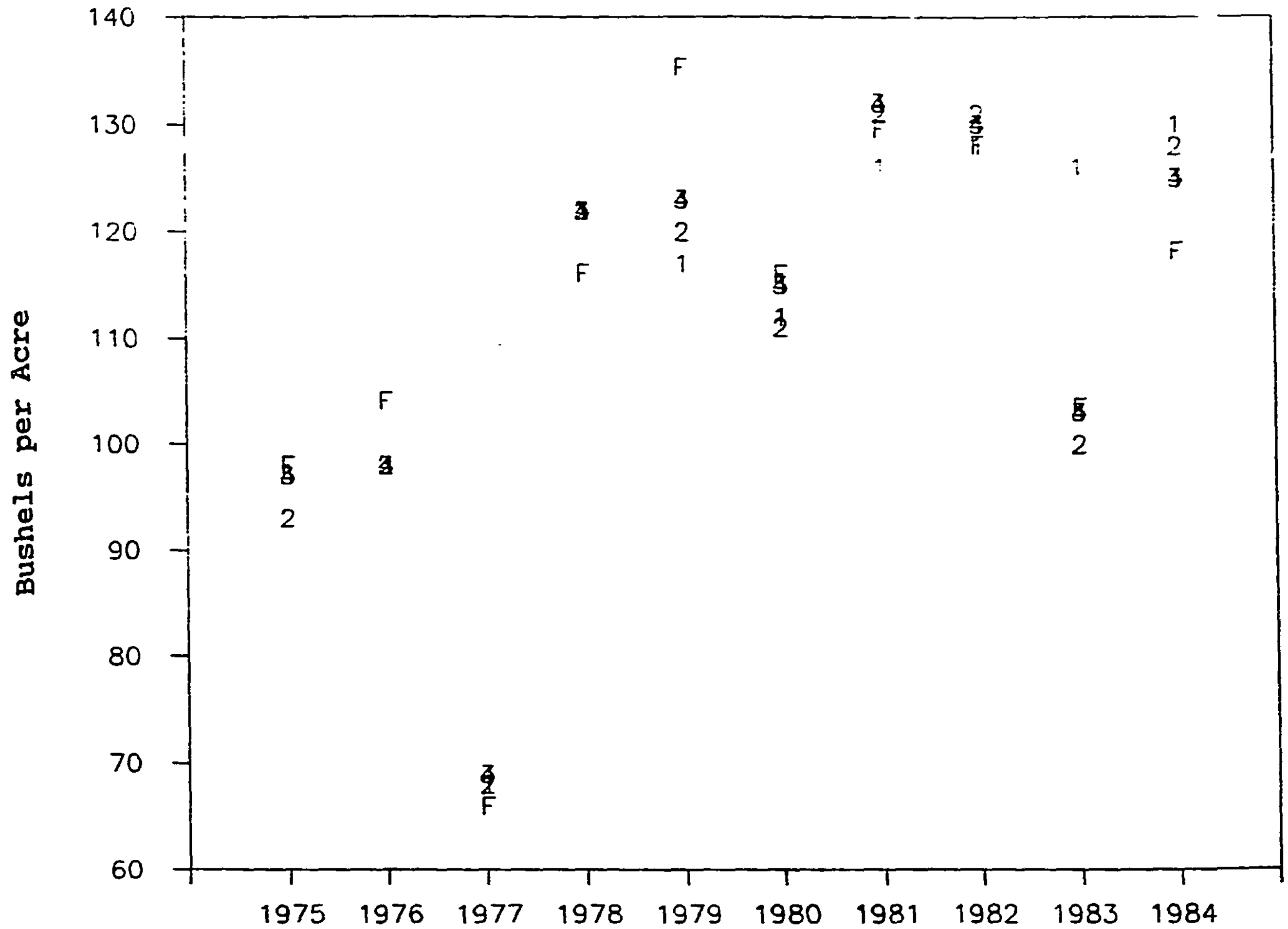


Figure 12. NASS corn yield forecasts for four forecast dates and actual corn yields for 1975 through 1984, Northeast district



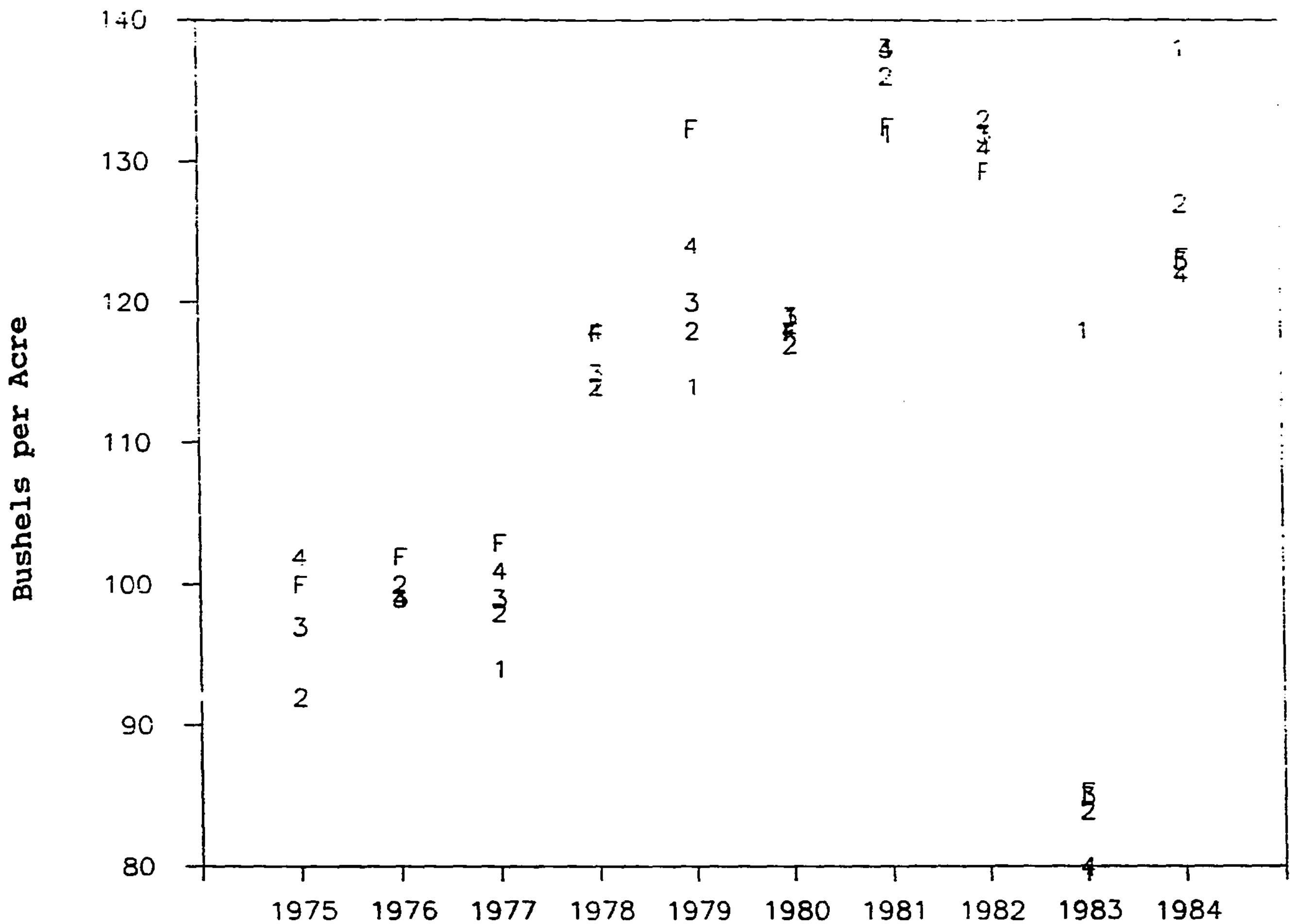
1 - Aug. 1   2 - Sept. 1   3 - Oct. 1   4 - Nov. 1   F - Final Estimate

Figure 13. NASS corn yield forecasts for four forecast dates and actual corn yields for 1975 through 1984, West Central district



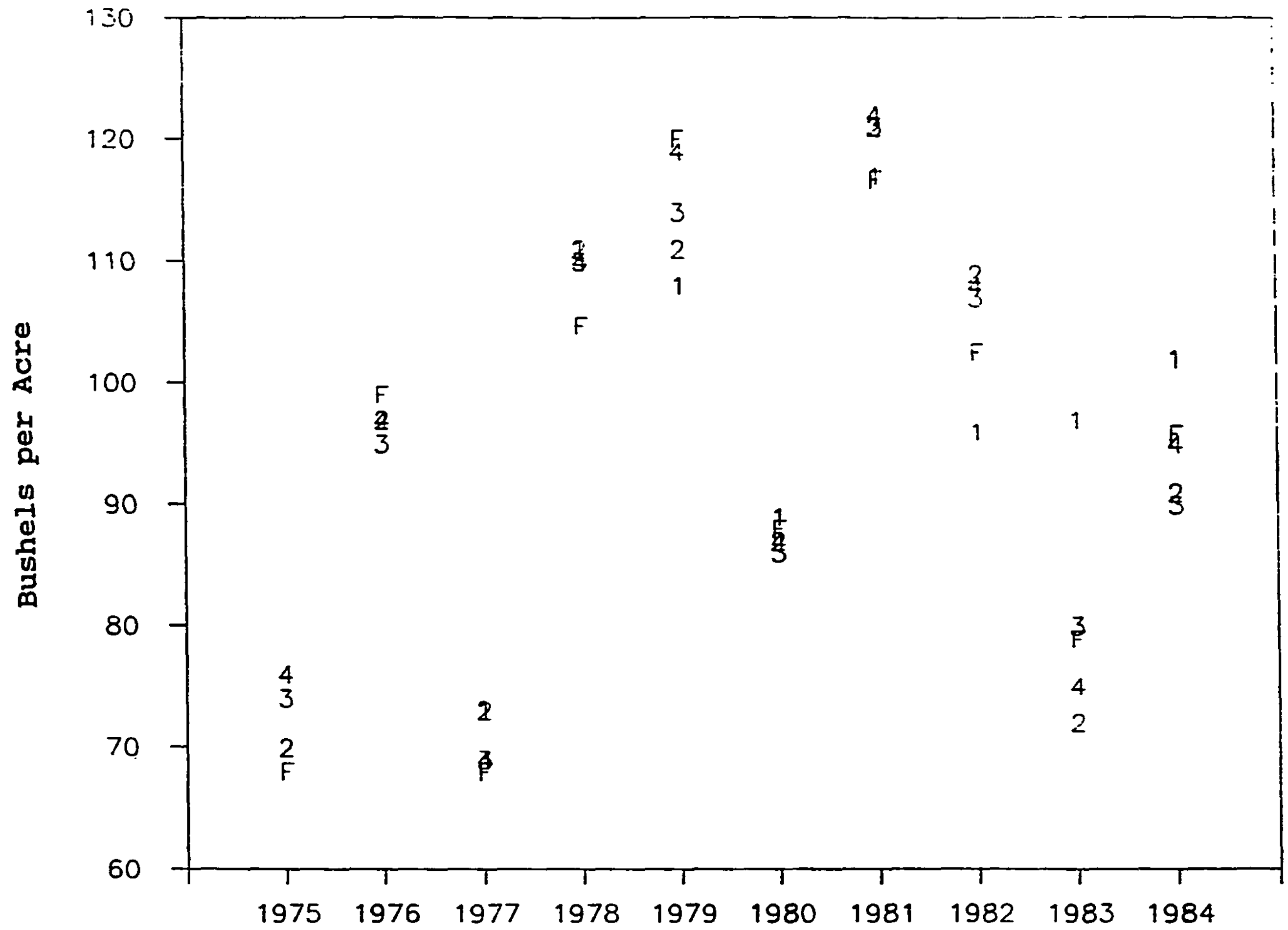
1 - Aug. 1   2 - Sept. 1   3 - Oct. 1   4 - Nov. 1   F - Final Estimate

Figure 14. NASS corn yield forecasts for four forecast dates and actual corn yields for 1975 through 1984, Central district



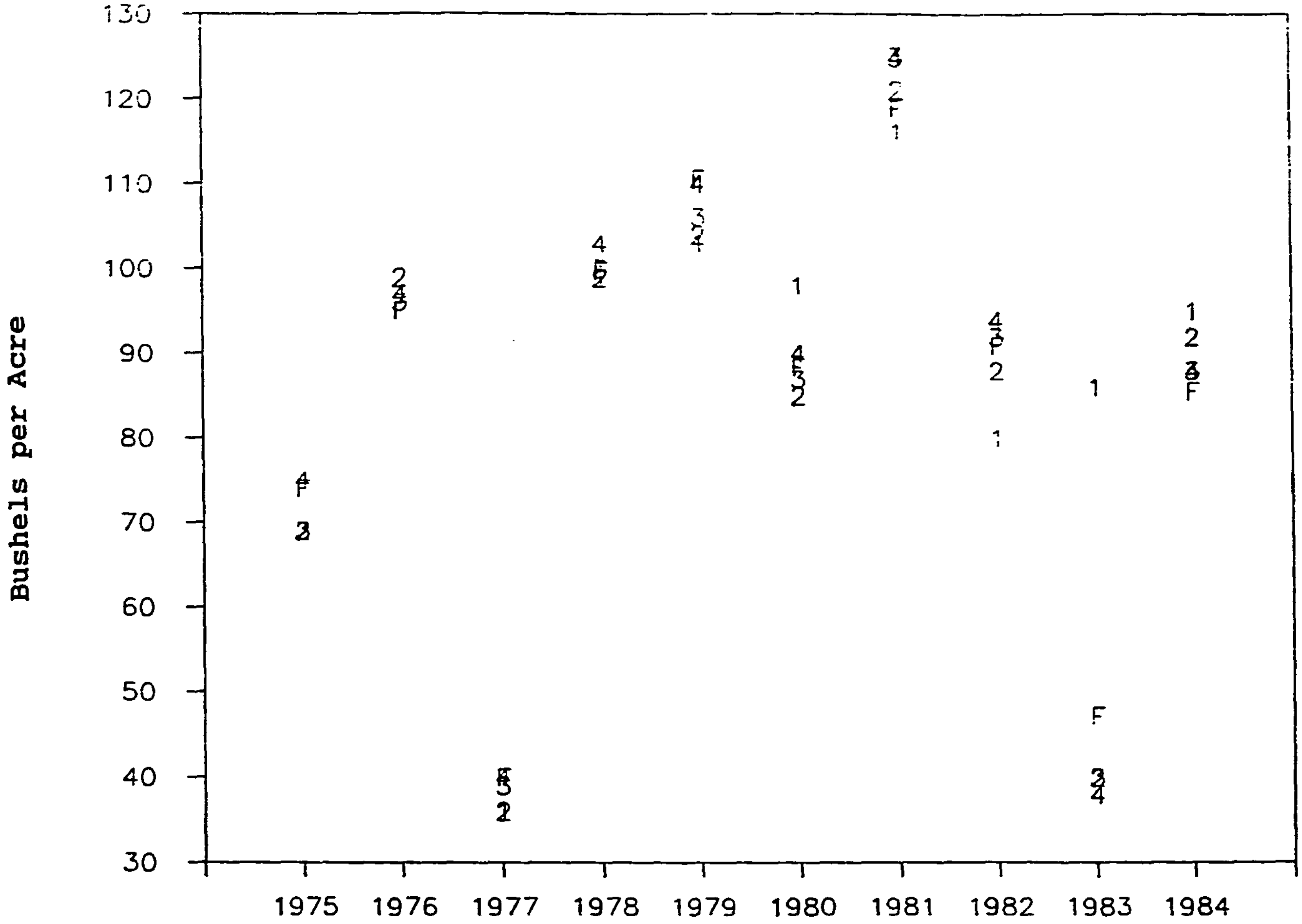
1 - Aug. 1   2 - Sept. 1   3 - Oct. 1   4 - Nov. 1   F - Final Estimate

Figure 15. NASS corn yield forecasts for four forecast dates and actual corn yields for 1975 through 1984, East Central district



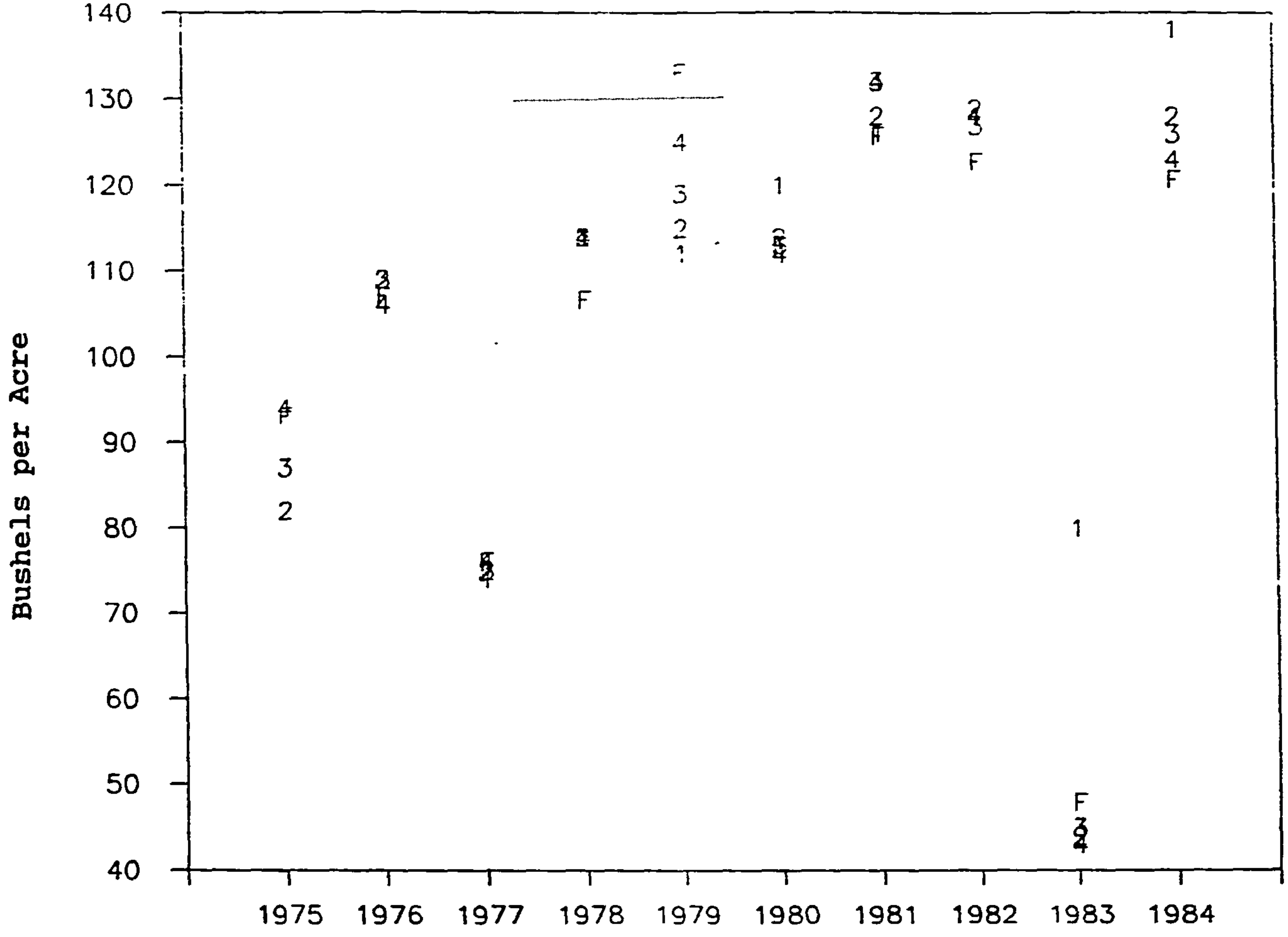
1 - Aug. 1 2 - Sept. 1 3 - Oct. 1 4 - Nov. 1 F - Final Estimate

Figure 16. NASS corn yield forecasts for four forecast dates and actual corn yields for 1975 through 1984, Southwest district



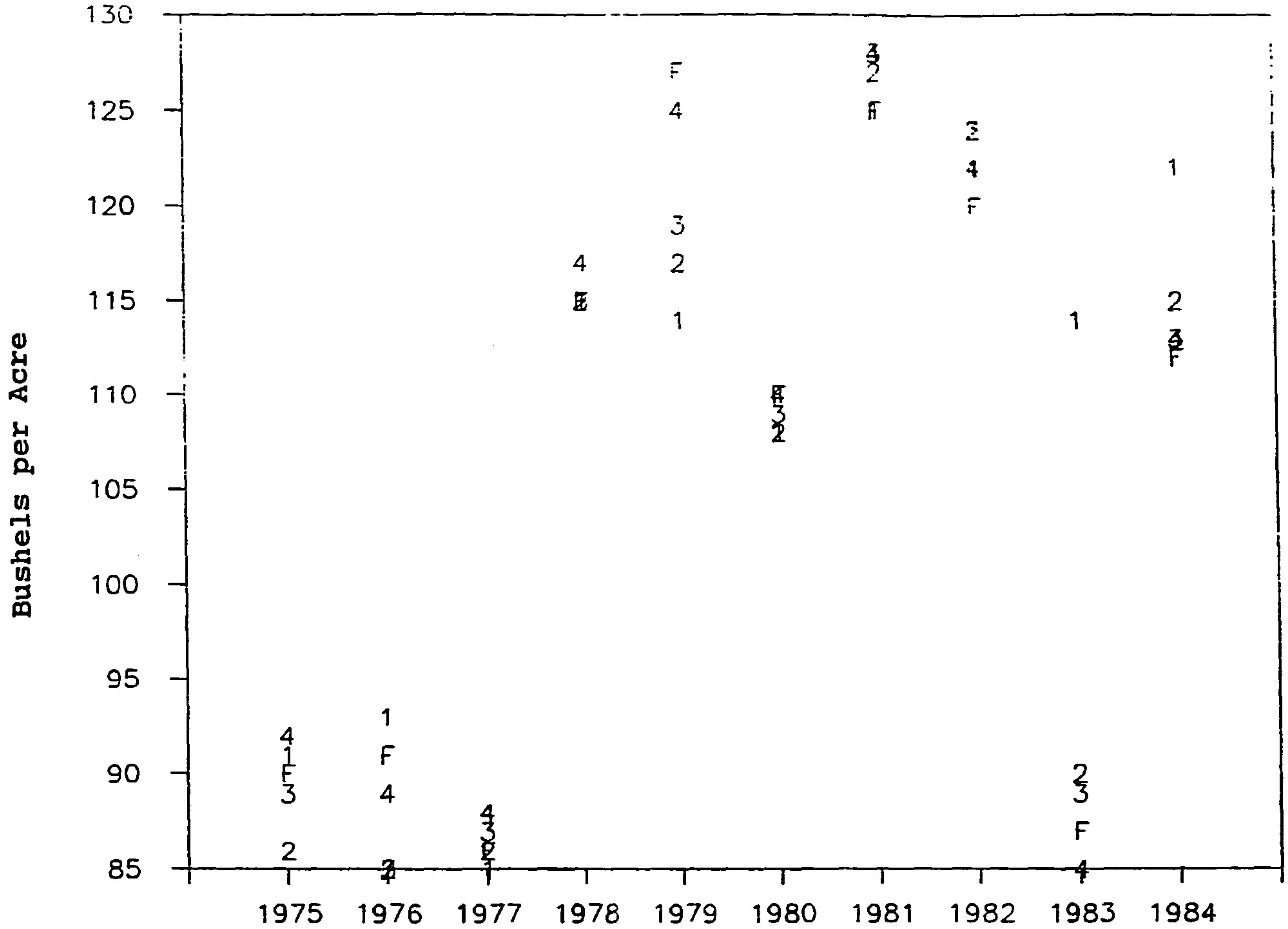
1 - Aug. 1   2 - Sept. 1   3 - Oct. 1   4 - Nov. 1   F - Final Estimate

Figure 17. NASS corn yield forecasts for four forecast dates and actual corn yields for 1975 through 1984, South Central district



1 - Aug. 1   2 - Sept. 1   3 - Oct. 1   4 - Nov. 1   F - Final Estimate

Figure 18. NASS corn yield forecasts for four forecast dates and actual corn yields for 1975 through 1984, Southeast district



1 - Aug. 1 2 - Sept. 1 3 - Oct. 1 4 - Nov. 1 F - Final Estimate

Figure 19. NASS corn yield forecasts for four forecast dates and actual corn yields for 1975 through 1984, Iowa

Table 21. Number of years out of ten that the NASS forecast correctly predicted an above or a below average actual yield

Crop Reporting District	Forecast Date			
	Aug. 1	Sept. 1	Oct. 1	Nov. 1
Northwest	8	10	9	9
North Central	9	10	10	10
Northeast	8	9	9	9
West Central	9	10	10	10
Central	9	9	10	10
East Central	7	9	10	10
Southwest	9	9	9	10
South Central	8	9	10	10
Southeast	10	10	10	10
Iowa	9	10	10	10

three years out of ten. As qualitative predictors (i.e., ability to predict higher than average or lower than average yields), NASS forecasts seem to do well. Although a good first indication of a forecasts performance, the high-low count has limited use for users of these forecasts. A more quantitative measure of performance is generally desired.

As discussed in Chapter IV, the root mean square error (RMSE) is one quantitative measure of forecast reliability. Since 1979, NASS has reported RMSEs along with all of its crop yield forecasts. NASS calculates RMSEs based upon twenty years of past forecast history. In this study, NASS forecast reliability is determined for only the ten year period, 1975 through 1984. The shorter period corresponds to years that plant-process model yield forecasts have been generated. RMSE values were calculated for each of the four forecast dates and the nine CRDs and for Iowa. The NASS forecast RMSEs are shown in Table 22.

The RMSEs indicate some of the same performance characteristics that were shown by the high-low count. That is, reliability of NASS forecasts improves as the growing season progresses. This, of course, comes as no surprise since weather and other uncertainties decrease as the growing season progresses. It is interesting, however, that the August forecasts were much less reliable than even the September forecasts. One of the extreme cases was the North

Table 22. Root mean square errors for NASS corn yield forecasts for four forecast dates by crop reporting district in Iowa

Crop Reporting District	Forecast Dates			
	Aug. 1	Sept. 1	Oct. 1	Nov.1
Northwest	12.07	8.40	5.83	2.72
North Central	11.29	4.97	3.64	2.10
Northeast	11.47	6.64	6.44	4.18
West Central	10.20	5.80	5.34	3.34
Central	10.52	6.91	5.71	3.60
East Central	13.40	5.96	4.83	3.98
Southwest	7.91	5.70	4.50	4.41
South Central	13.89	4.67	3.82	3.95
Southeast	14.26	7.87	6.41	4.76
Iowa	11.36	4.23	3.48	1.98

Central district which has a RMSE value of over 11 percent in August but less than 5 percent in September. Even the state forecast reliability was much lower for the August compared to September forecast. Problems associated with low reliability of the August forecasts have been recognized by NASS and work is underway to improve these forecasts (Warren and Cook, 1988).

In general across districts, reliability of the November forecasts are high. Remember that the November forecast was based primarily upon objective yield samples in the field. That is, the crop is usually fully matured by the November survey (and by the October survey in some years) and corn samples can be taken from the field and weighed. This is compared to using proxy measurements for earlier forecasts (see Tables 3 and 4). The only forecast to be made in November is for the harvesting losses. The forecast error in the November forecast is made up of only a small error associated with harvest losses, a small measurement error, and sampling error. This is compared to earlier forecasts that also have model error.

Differences did exist in forecast reliability between the nine crop reporting districts. The most noticeable difference was in the August and November forecasts. August and November forecasts had somewhat lower reliabilities in the South Central and Southeast districts. Lower reliabilities in these districts can be partially attributed to sample size used by the objective survey. Sample size was proportional to corn acreage and the southern districts have had lower corn acres than other districts in the state (see Table 7).

The more quantitative RMSE is a better indicator of forecast performance than the high-low count. It is interesting to note that the August forecast in the Southeast district was correct in predicting above- or below-average yields in all ten years. However, this forecast had the lowest RMSE value of any forecast in any district. Similarly, the forecast with one of the lowest RMSEs (Northwest district forecast for November) was wrong in only one year out of ten in predicting an above- or below-average corn yield. Both performance measures were also used to assess reliability of the plant-process model and the composite forecasts. Interpretation of these measures should be done while remembering that they are based upon only ten years of forecast history.

Plant-Process Model Corn Yield Forecasts

This section reports results of the plant-process model (PPM) corn yield forecasts. Forecasts were made for July 1, August 1, September 1, October 1, and November 1 for each of the years 1975 through 1984. Forecasts were made at the county, CRD, and state level. The focus of the discussion is on district and state forecasts although county yield forecasts are discussed briefly in the next section.

County Corn Yield Forecasts

Yield forecasts are made for all counties in which historical weather information was available from one or more cooperative weather stations. There were a total of ninety of these counties. One or more yield samples were generated for each of these counties depending upon the number of weather station locations, soils, varieties, and planting dates selected. Table 23 shows that only one soil, variety, and planting date per county was selected for the simulations while up to three weather stations per county were used. As described in Chapter IV, weighted averages of the yield samples were calculated in order to arrive at county yields. Multiple weather locations in a given county were assigned equal weight. Soil, variety, and planting dates were all assigned a weight of one.

PPM yield forecasts were made at five times during the growing season. The forecast dates are July 1, August 1, September 1, October 1, and November 1. Forecasts were made over the ten year period 1975 through 1984. Forecasts were based upon actual weather conditions and events up to the time of the forecast and upon twenty-five years of historical

Table 23. Number of different weather station locations, soils, varieties, and planting dates used in each Iowa county

County Name	County No.	Number of: Weather Station Locations	Soils	Varieties	Planting Dates
Northwest District					
Buena Vista	21	2	1	1	1
Cherokee	35	1	1	1	1
Clay	41	1	1	1	1
Dickinson	59	2	1	1	1
Emmet	63	1	1	1	1
Lyon	119	1	1	1	1
O'Brien	141	1	1	1	1
Osceola	143	1	1	1	1
Palo Alto	147	1	1	1	1
Plymouth	149	2	1	1	1
Pocahontas	151	1	1	1	1
Sioux	167	2	1	1	1
North Central District					
Butler	23	2	1	1	1
Cerro Gordo	33	2	1	1	1
Floyd	67	1	1	1	1
Franklin	69	1	1	1	1
Hancock	81	1	1	1	1
Humboldt	91	0	1	1	1
Kossuth	109	1	1	1	1
Mitchell	131	1	1	1	1
Winnebago	189	1	1	1	1
Worth	195	1	1	1	1
Wright	197	1	1	1	1
Northeast District					
Allamakee	5	1	1	1	1
Black Hawk	13	0	1	1	1
Bremer	17	1	1	1	1
Buchanan	19	0	1	1	1
Chickasaw	37	1	1	1	1
Clayton	43	2	1	1	1
Delaware	55	0	1	1	1
Dubuque	61	2	1	1	1
Fayette	65	2	1	1	1
Howard	89	1	1	1	1
Winneshiek	191	1	1	1	1

Table 23. (continued)

County Name	County No.	Number of Weather Station Locations	Soils	Varieties	Planting Dates
West Central District					
Audubon	9	1	1	1	1
Calhoun	25	1	1	1	1
Carroll	27	1	1	1	1
Crawford	47	1	1	1	1
Greene	73	1	1	1	1
Guthrie	77	1	1	1	1
Harrison	85	1	1	1	1
Ida	93	1	1	1	1
Monona	133	2	1	1	1
Sac	161	1	1	1	1
Shelby	165	1	1	1	1
Woodbury	193	3	1	1	1
Central District					
Boone	15	0	1	1	1
Dallas	49	1	1	1	1
Grundy	75	1	1	1	1
Hamilton	79	1	1	1	1
Hardin	83	1	1	1	1
Jasper	99	1	1	1	1
Marshall	127	1	1	1	1
Polk	153	1	1	1	1
Poweshiek	157	1	1	1	1
Story	169	0	1	1	1
Tama	171	1	1	1	1
Webster	187	1	1	1	1
East Central District					
Benton	11	2	1	1	1
Cedar	31	1	1	1	1
Clinton	45	1	1	1	1
Iowa	95	1	1	1	1
Jackson	97	1	1	1	1
Johnson	103	1	1	1	1
Jones	105	1	1	1	1
Linn	113	1	1	1	1
Muscatine	139	1	1	1	1
Scott	163	1	1	1	1

Table 23. (continued)

County Name	County No.	Number of Weather Station Locations	Soils	Varieties	Planting Dates
Southwest District					
Adair	1	1	1	1	1
Adams	3	1	1	1	1
Cass	29	1	1	1	1
Fremont	71	0	1	1	1
Mills	129	1	1	1	1
Montgomery	137	1	1	1	1
Page	145	2	1	1	1
Pottawattamie	155	1	1	1	1
Taylor	173	1	1	1	1
South Central District					
Appanoose	7	1	1	1	1
Clarke	39	1	1	1	1
Decatur	53	1	1	1	1
Lucas	117	1	1	1	1
Madison	121	1	1	1	1
Marion	125	1	1	1	1
Monroe	135	1	1	1	1
Ringgold	159	1	1	1	1
Union	175	1	1	1	1
Warren	181	1	1	1	1
Wayne	185	0	1	1	1
Southeast District					
Davis	51	1	1	1	1
Des Moines	57	0	1	1	1
Henry	87	1	1	1	1
Jefferson	101	1	1	1	1
Keokuk	107	1	1	1	1
Lee	111	1	1	1	1
Louisa	115	1	1	1	1
Mahaska	123	1	1	1	1
Van Buren	177	1	1	1	1
Wapello	179	1	1	1	1
Washington	183	1	1	1	1

weather information beyond the forecast date. Historical weather from the years 1960 through 1984 are used to make the forecasts. A yield forecast is the mean of the twenty-five yield estimates made using the historical weather information.

Due to space limitations, county-level PPM forecasts are not reported here. In general, however, these forecasts were assumed to be biased and contain systematic errors. The bias was collectively a result of data, model, and aggregation errors. Since the focus of the study is on district and state forecasts, no attempt was made to correct for bias and systematic error in the county forecasts. That is, PPM forecasts were not calibrated at the county level. Calibrations were done at the crop reporting district level.

Crop Reporting District and State Yield Forecasts

PPM corn yield forecasts were obtained for each of the nine Iowa crop reporting districts and also for the state. The CRD forecasts were obtained by aggregating appropriate county forecasts. Counties where no PPM forecasts were made were treated as if their yields were the same as the average for the district. Aggregations were simply weighted averages of county yields.

In Chapter IV, two CRD aggregation approaches were discussed. The first approach gave equal weight to each county forecast within respective districts. The second approach weighted each county within a district with a weight proportional to harvested corn acreage in each county. CRD-level forecasts were found not to be significantly different under the two approaches. As a consequence, only forecast results generated with the acreage weights are reported here. Harvested corn acres by county for the years 1975 through 1984 are shown in Tables A.1 and A.2 in the Appendix.

State corn yield forecasts are obtained by aggregating CRD forecasts. Weighted averages of the district forecasts are calculated using district harvested corn acreage for weights. CRD weights are shown in Table 24.

The CRD corn yield forecasts derived from aggregating county forecasts are shown in Tables A.3 through A.12 of the Appendix. These are referred to as the PPM uncalibrated corn yield forecasts. *A priori* these forecasts were expected to contain systematic error. Steps were taken to eliminate systematic error in the CRD forecasts. Calibration models discussed in Chapter IV were specified and estimated for each district and each forecast date.

PPM calibration model estimation results are shown in Table A.13 of the Appendix. These results confirmed the notion that CRD forecasts contained systematic error. With only a few exceptions, the slope parameters in the calibration models are positive and between zero and one.

Table 24. Crop reporting district aggregation weights, 1975-1984

Crop Reporting District	Year									
	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Northwest	0.145	0.138	0.140	0.146	0.145	0.142	0.142	0.144	0.140	0.141
North Central	0.133	0.134	0.130	0.132	0.130	0.131	0.130	0.133	0.128	0.132
Northeast	0.107	0.106	0.109	0.112	0.111	0.114	0.116	0.117	0.121	0.122
West Central	0.146	0.147	0.145	0.148	0.149	0.147	0.145	0.146	0.143	0.142
Central	0.148	0.151	0.150	0.147	0.143	0.144	0.141	0.141	0.139	0.137
East Central	0.109	0.112	0.113	0.116	0.113	0.112	0.115	0.119	0.124	0.120
Southwest	0.080	0.079	0.081	0.081	0.081	0.080	0.079	0.076	0.078	0.077
South Central	0.047	0.051	0.048	0.050	0.050	0.049	0.052	0.046	0.046	0.050
Southeast	0.084	0.082	0.084	0.080	0.079	0.080	0.081	0.079	0.081	0.079

Also, the intercepts are generally positive. These results indicate that the PPM was generally under-predicting yields in bad years and over-predicting in good years. Results also indicate that the July PPM forecasts may not be very useful. For practically all districts, t-statistics showed that the coefficient on the uncalibrated PPM forecast was insignificantly different from zero. Further, as indicated by the R-square values for July models, the PPM forecasts explained little variation in actual yields from year to year. All calibration equations were used to obtain calibrated PPM corn yield forecasts.

Calibrated PPM yield forecasts are shown in Tables 25 through 34 for the years 1975 through 1984, respectively. Also, the forecasts are plotted along with actual yields in Figures 20 through 29 for each CRD and for Iowa. The "calibrated" state forecast is an aggregation of calibrated district forecasts.

PPM forecast performance was assessed using the high-low counts and RMSEs. High-low counts are shown in Table 35. The PPM's ability to predict above-average and below-average corn yields is similar to that of the NASS forecasts. The exception is that PPM forecasts are qualitatively not as accurate in November as the NASS forecasts. The July PPM high-low counts are noticeably lower than August counts. This is not totally surprising given the results of

Table 25. Calibrated PPM corn yield forecasts for five forecasting dates and actual corn yields by crop reporting district, 1975

Crop Reporting District	Forecast Date					Actual Yield
	July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	
	bushels per acre					
Northwest	104.8	98.2	90.3	90.4	90.4	88.0
North Central	116.3	107.8	105.1	105.0	105.0	95.0
Northeast	113.0	97.7	94.1	95.0	95.0	93.0
West Central	101.3	87.0	89.8	89.8	89.8	85.0
Central	117.9	108.7	107.3	107.3	107.3	98.0
East Central	115.0	112.4	117.7	117.6	117.6	100.0
Southwest	95.5	74.3	75.9	75.6	75.6	68.0
South Central	89.7	74.4	72.3	72.7	72.7	74.0
Southeast	107.9	88.1	86.7	86.6	86.6	93.0
Iowa	108.6	97.0	95.6	92.1	92.1	90.0

Table 26. Calibrated PPM corn yield forecasts for five forecasting dates and actual corn yields by crop reporting district, 1976

Crop Reporting District	Forecast Date					Actual Yield
	July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	
	bushels per acre					
Northwest	108.2	94.2	72.2	72.2	72.2	73.0
North Central	111.2	88.0	87.8	87.8	87.8	93.0
Northeast	112.8	99.0	105.2	105.7	105.7	91.0
West Central	91.4	70.2	64.5	64.7	64.7	71.0
Central	111.0	101.4	91.6	91.2	91.2	104.0
East Central	113.5	101.2	103.9	103.7	103.7	102.0
Southwest	93.5	84.8	87.6	87.7	87.7	99.0
South Central	92.8	75.5	80.4	80.6	80.6	95.0
Southeast	105.1	101.2	107.3	107.2	107.2	107.0
Iowa	105.4	91.1	87.6	84.3	84.3	91.0

Table 27. Calibrated PPM corn yield forecasts for five forecasting dates and actual corn yields by crop reporting district, 1977

Crop Reporting District	Forecast Date: July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	Actual Yield
	bushels per acre					
Northwest	111.1	102.9	101.9	102.0	102.0	103.0
North Central	103.8	103.7	103.2	103.1	103.1	102.0
Northeast	106.5	99.8	109.7	109.5	109.5	112.0
West Central	86.9	83.1	87.6	87.6	87.6	74.0
Central	71.7	75.3	76.5	76.4	76.4	66.0
East Central	104.8	98.6	107.8	107.9	107.9	103.0
Southwest	80.4	73.3	80.8	80.7	80.7	68.0
South Central	109.0	57.2	40.0	40.0	40.0	40.0
Southeast	73.7	67.7	69.0	69.0	69.0	76.0
Iowa	93.8	87.6	90.3	86.7	86.7	86.0

Table 28. Calibrated PPM corn yield forecasts for five forecasting dates and actual corn yields by crop reporting district, 1978

Crop Reporting District	Forecast Date: July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	Actual Yield
	bushels per acre					
Northwest	104.2	117.4	127.0	126.8	126.8	119.5
North Central	116.7	123.6	123.2	122.4	122.4	121.0
Northeast	115.4	118.3	115.8	114.0	114.0	118.0
West Central	98.6	113.3	112.9	112.6	112.6	115.0
Central	118.2	123.2	127.2	127.0	127.0	116.1
East Central	116.0	118.5	119.4	119.1	119.1	117.8
Southwest	96.1	109.6	107.1	107.4	107.4	104.7
South Central	87.9	103.0	103.6	102.9	102.9	99.7
Southeast	111.9	120.5	125.5	125.5	125.5	106.6
Iowa	108.8	117.6	119.5	114.9	114.9	115.0

Table 29. Calibrated PPM corn yield forecasts for five forecasting dates and actual corn yields by crop reporting district, 1979

Crop Reporting District	Forecast Date: July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	Actual Yield
	bushels per acre					
Northwest	106.4	110.6	120.4	120.1	120.1	123.9
North Central	113.6	123.9	128.5	128.7	128.7	130.0
Northeast	114.3	124.6	127.0	127.3	127.3	130.4
West Central	100.1	111.0	109.4	109.1	109.1	119.1
Central	123.2	127.7	133.7	133.1	133.1	135.3
East Central	115.6	126.8	126.2	125.5	125.5	132.3
Southwest	96.7	116.8	111.3	112.1	112.1	120.0
South Central	88.8	99.7	95.8	95.5	95.5	110.5
Southeast	109.6	120.8	126.1	126.1	126.1	133.0
Iowa	109.3	119.0	121.6	117.5	117.5	127.0

Table 30. Calibrated PPM corn yield forecasts for five forecasting dates and actual corn yields by crop reporting district, 1980

Crop Reporting District	Forecast Date: July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	Actual Yield
	bushels per acre					
Northwest	109.1	95.3	103.5	103.8	103.8	116.8
North Central	114.2	112.5	125.0	124.6	124.6	125.3
Northeast	113.6	109.5	116.4	115.7	115.7	121.4
West Central	92.2	76.2	83.8	83.9	83.9	86.8
Central	112.7	102.7	109.7	109.7	109.7	116.0
East Central	115.0	104.1	105.5	105.7	105.7	117.9
Southwest	87.9	77.8	82.1	82.0	82.0	88.0
South Central	96.0	77.7	79.1	79.3	79.3	88.5
Southeast	104.5	98.9	95.9	95.8	95.8	112.9
Iowa	106.3	96.4	102.5	99.0	99.0	110.0

Table 31. Calibrated PPM corn yield forecasts for five forecasting dates and actual corn yields by crop reporting district, 1981

Crop Reporting District	Forecast Date: July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	Actual Yield
	bushels per acre					
Northwest	108.7	105.9	115.3	115.8	115.8	125.1
North Central	116.5	121.6	129.6	129.6	129.6	133.5
Northeast	114.6	126.8	130.0	132.3	132.3	129.2
West Central	89.8	103.8	114.0	114.0	114.0	109.7
Central	106.2	109.8	124.1	125.0	125.0	129.5
East Central	115.2	119.9	131.6	132.0	132.0	132.5
Southwest	91.0	106.4	112.0	112.5	112.5	116.7
South Central	90.5	102.1	107.4	106.8	106.8	118.9
Southeast	110.2	112.9	121.6	121.5	121.5	125.7
Iowa	105.8	112.6	121.6	117.4	117.4	125.0

Table 32. Calibrated PPM corn yield forecasts for five forecasting dates and actual corn yields by crop reporting district, 1982

Crop Reporting District	Forecast Date: July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	Actual Yield
	bushels per acre					
Northwest	108.0	110.0	114.4	114.7	114.7	117.9
North Central	115.0	122.6	128.6	129.3	129.3	127.2
Northeast	113.6	122.9	128.2	126.4	126.4	121.5
West Central	98.6	112.4	118.4	119.0	119.0	115.8
Central	113.8	121.0	124.5	124.7	124.7	128.1
East Central	115.4	123.0	129.4	130.0	130.0	129.3
Southwest	103.6	107.4	117.1	116.5	116.5	102.5
South Central	86.3	101.6	110.4	111.1	111.1	90.9
Southeast	107.3	115.5	119.9	119.8	119.8	122.7
Iowa	108.5	116.5	122.1	116.6	116.6	120.0

Table 33. Calibrated PPM corn yield forecasts for five forecasting dates and actual corn yields by crop reporting district, 1983

Crop Reporting District	Forecast Date					Actual Yield
	July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	
	bushels per acre					
Northwest	100.9	111.4	99.9	99.9	99.9	86.5
North Central	118.0	116.5	101.2	101.2	101.2	101.4
Northeast	115.2	116.4	100.1	100.6	100.6	102.4
West Central	106.7	100.9	89.6	89.6	89.6	86.1
Central	118.8	112.9	97.8	97.8	97.8	103.5
East Central	117.0	106.8	86.5	87.1	87.1	85.3
Southwest	99.4	90.3	80.5	80.4	80.4	78.9
South Central	87.7	78.3	73.6	74.0	74.0	47.2
Southeast	106.9	86.0	68.3	68.3	68.3	47.9
Iowa	109.9	105.6	91.4	87.5	87.5	87.0

Table 34. Calibrated PPM corn yield forecasts for five forecasting dates and actual corn yields by crop reporting district, 1984

Crop Reporting District	Forecast Date					Actual Yield
	July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	
	bushels per acre					
Northwest	100.4	115.8	116.2	115.9	115.9	107.9
North Central	118.2	123.2	111.4	111.6	111.6	115.0
Northeast	113.9	118.0	106.6	106.6	106.6	114.1
West Central	106.1	113.9	101.9	101.9	101.9	109.3
Central	121.3	132.0	122.5	122.0	122.0	118.2
East Central	115.7	131.9	115.1	114.5	114.5	123.2
Southwest	97.6	101.9	87.2	87.3	87.3	95.8
South Central	90.5	97.9	87.4	87.3	87.3	85.5
Southeast	108.4	133.8	125.3	125.2	125.2	120.7
Iowa	109.8	120.4	110.1	105.0	105.0	112.0

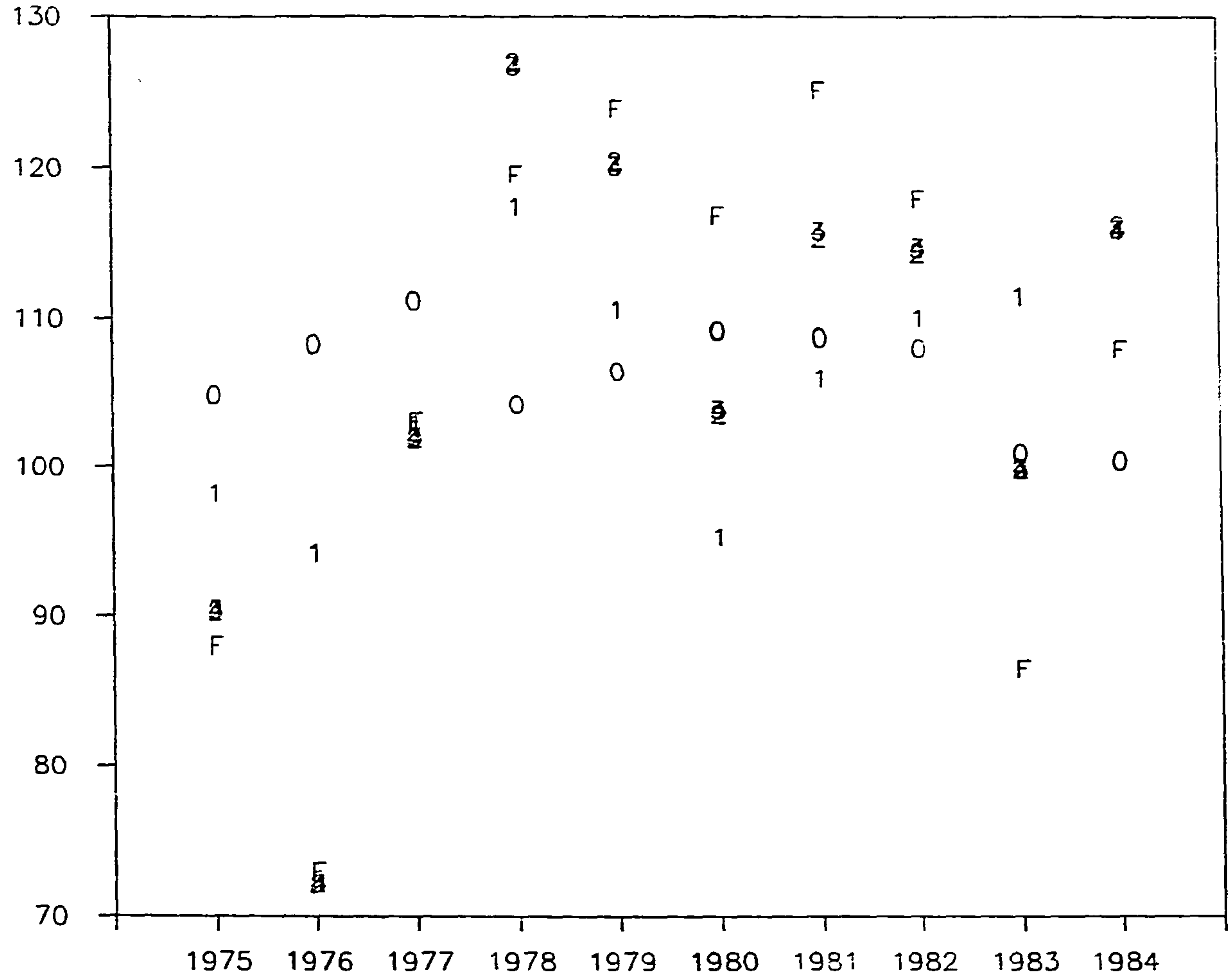
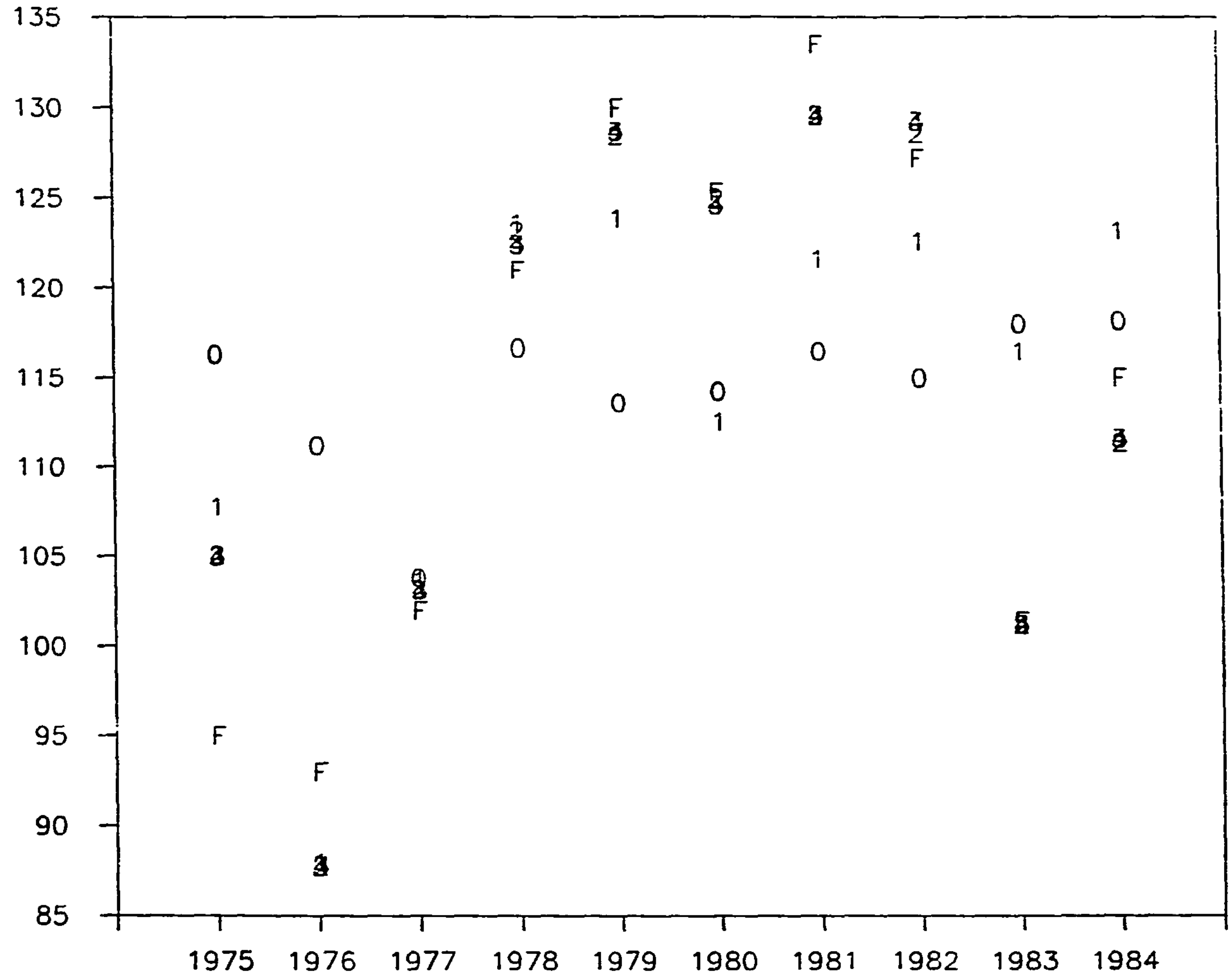
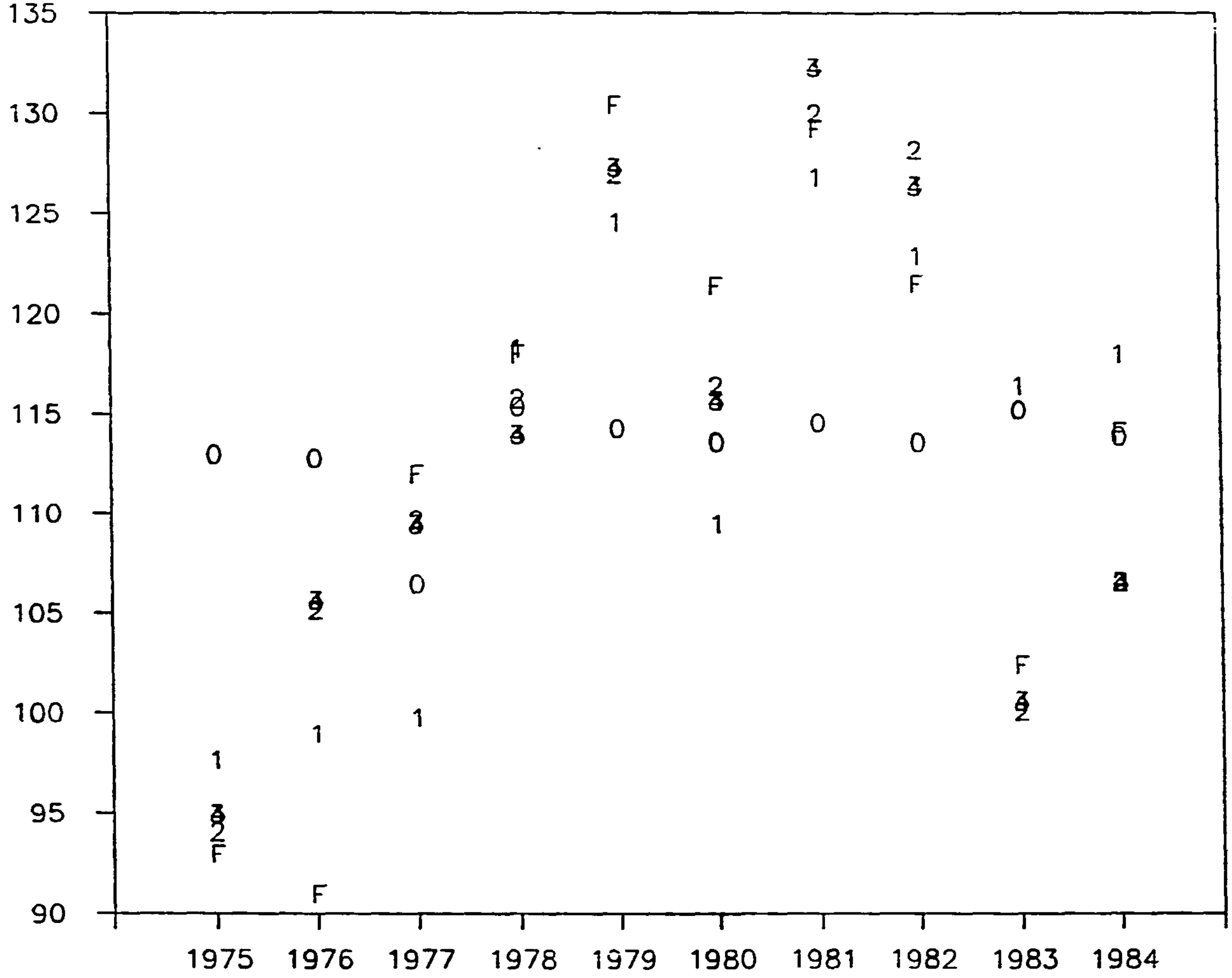


Figure 20. PPM corn yield forecasts for five forecast dates and actual corn yields for 1975 and 1984, Northwest district



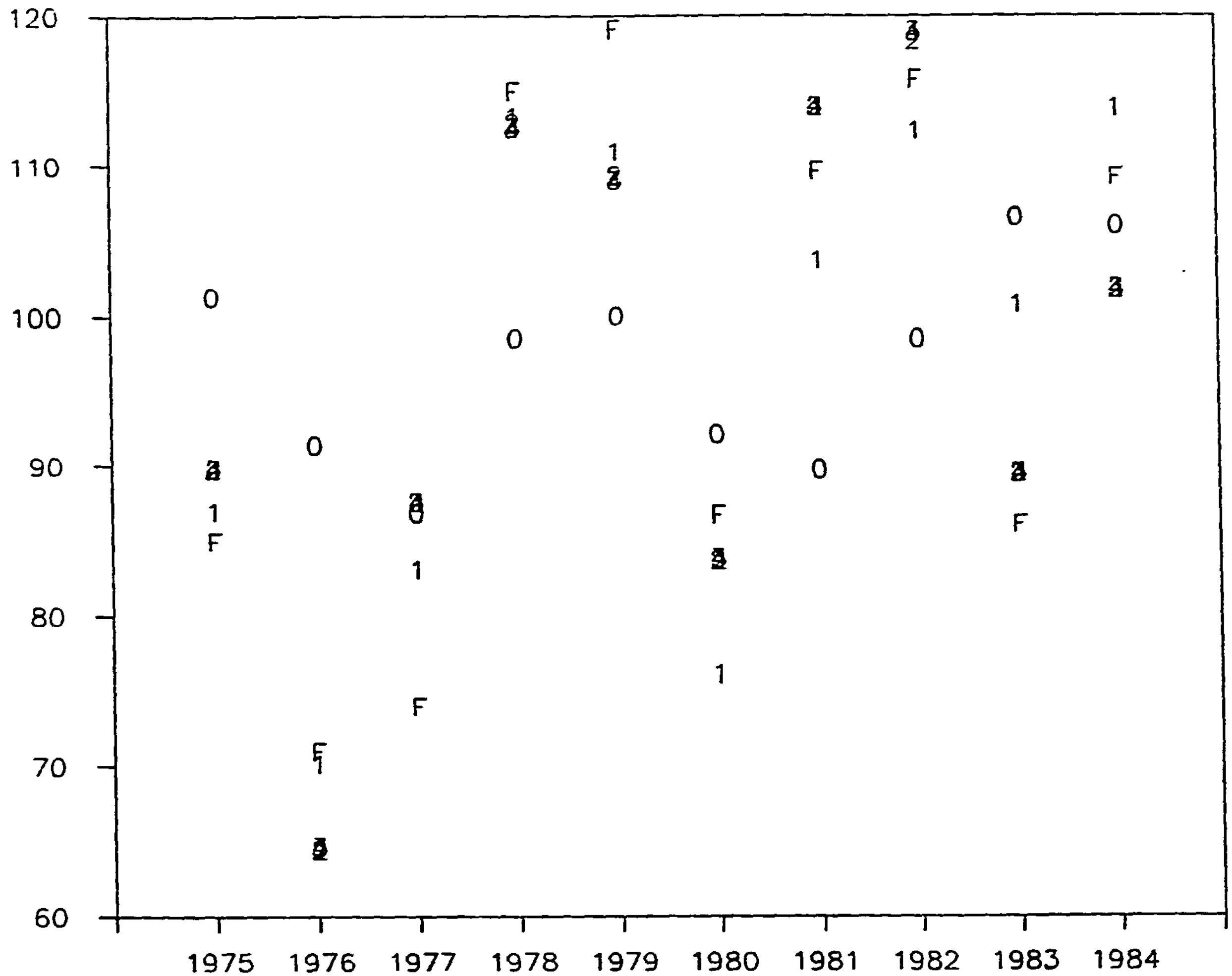
0 - July 1 1 - Aug. 1 2 - Sept. 1 3 - Oct. 1 4 - Nov. 1 F - Final Estimate

Figure 21. PPM corn yield forecasts for five forecast dates and actual corn yields for 1975 and 1984, North Central district



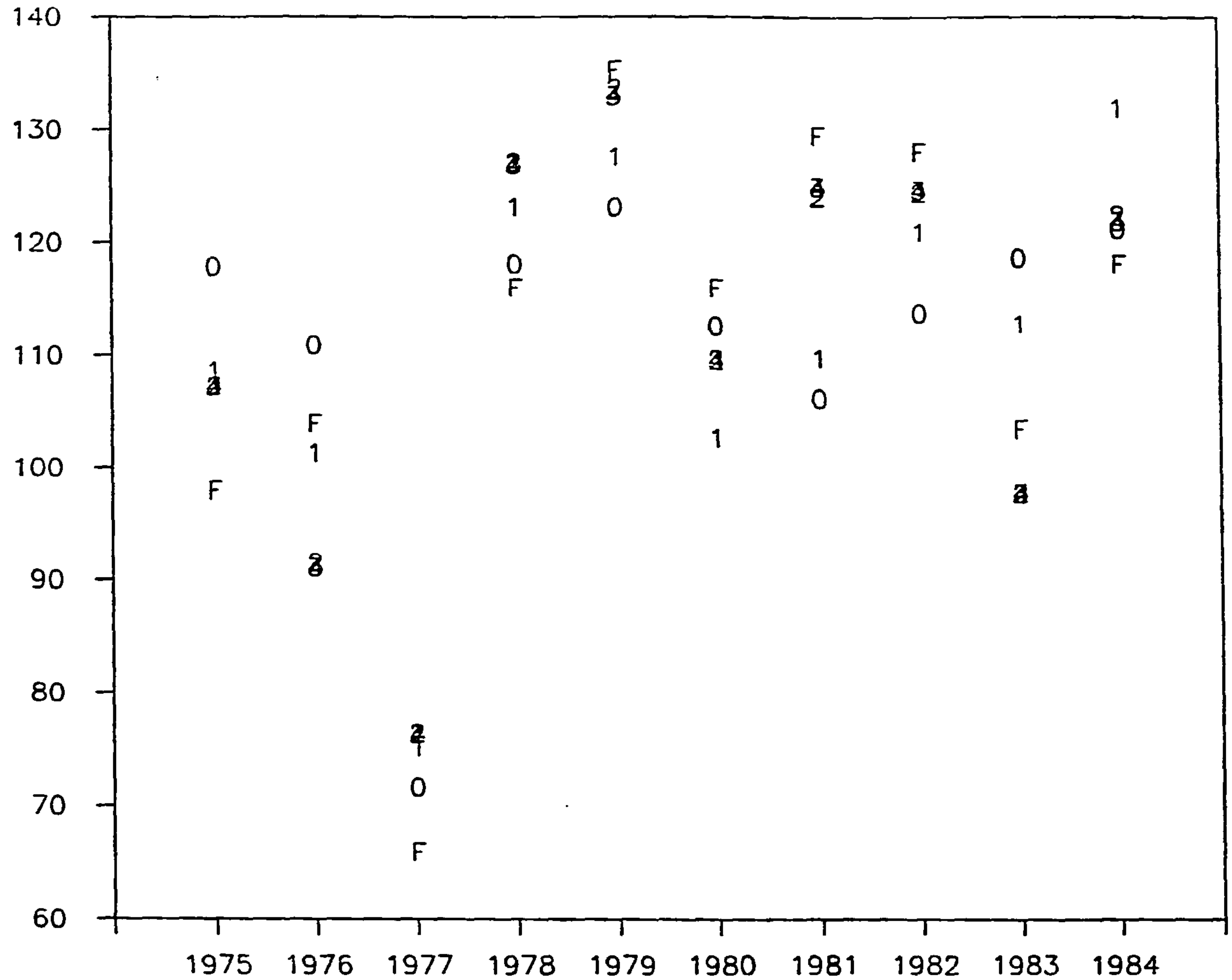
0 - July 1 1 - Aug. 1 2 - Sept. 1 3 - Oct. 1 4 - Nov. 1 F - Final Estimate

Figure 22. PPM corn yield forecasts for five forecast dates and actual corn yields for 1975 and 1984, Northeast district



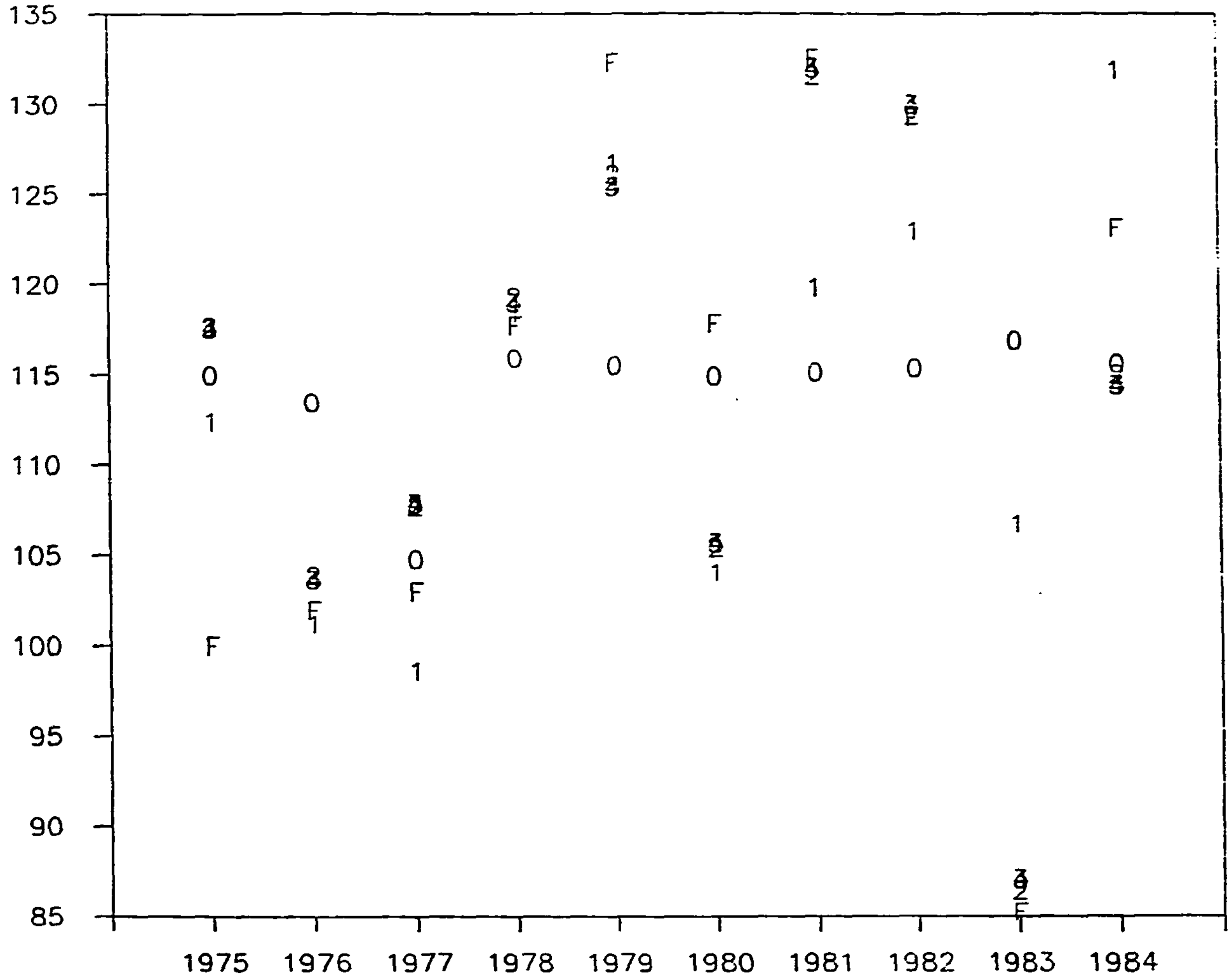
0 - July 1 1 - Aug. 1 2 - Sept. 1 3 - Oct. 1 4 - Nov. 1 F - Final Estimate

Figure 23. PPM corn yield forecasts for five forecast dates and actual corn yields for 1975 and 1984, West Central district



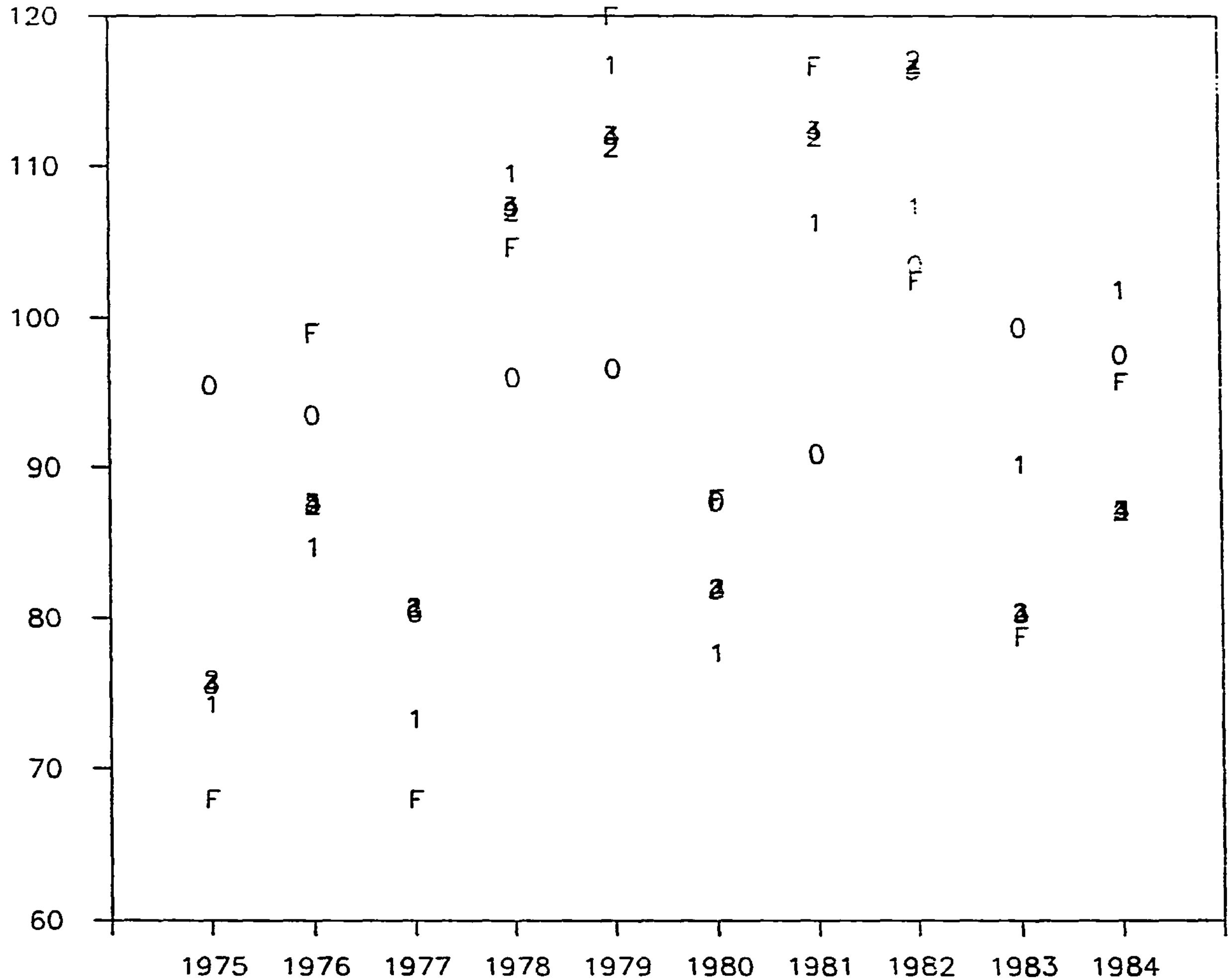
0 - July 1 1 - Aug. 1 2 - Sept. 1 3 - Oct. 1 4 - Nov. 1 F - Final Estimate

Figure 24. PPM corn yield forecasts for five forecast dates and actual corn yields for 1975 and 1984, Central district



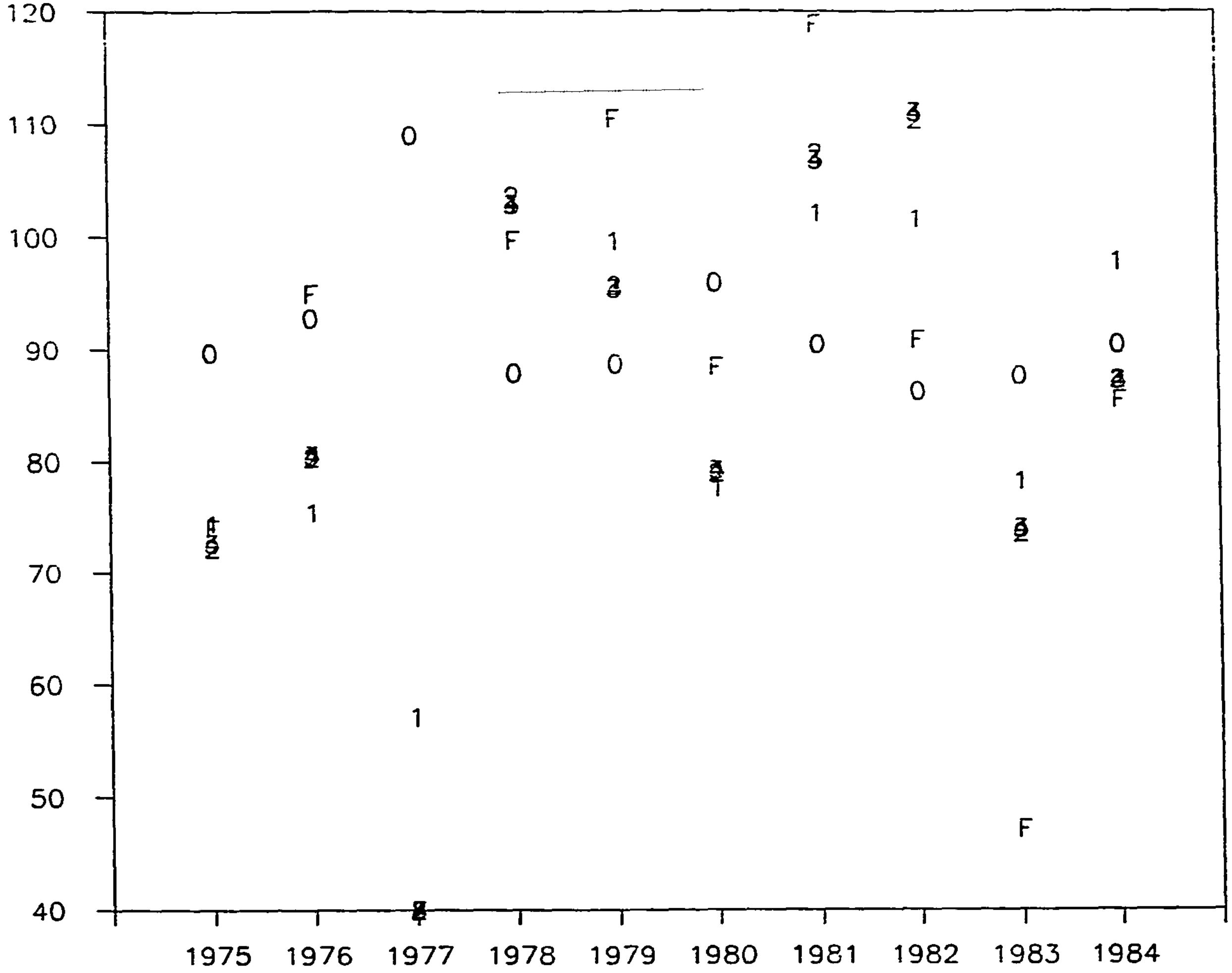
0 - July 1 1 - Aug. 1 2 - Sept. 1 3 - Oct. 1 4 - Nov. 1 F - Final Estimate

Figure 25. PPM corn yield forecasts for five forecast dates and actual corn yields for 1975 and 1984, East Central district



0 - July 1 1 - Aug. 1 2 - Sept. 1 3 - Oct. 1 4 - Nov. 1 F - Final Estimate

Figure 26. PPM corn yield forecasts for five forecast dates and actual corn yields for 1975 and 1984, Southwest district



0 - July 1 1 - Aug. 1 2 - Sept. 1 3 - Oct. 1 4 - Nov. 1 F - Final Estimate

Figure 27. **PPM corn yield forecasts for five forecast dates and actual corn yields for 1975 and 1984, South Central district**

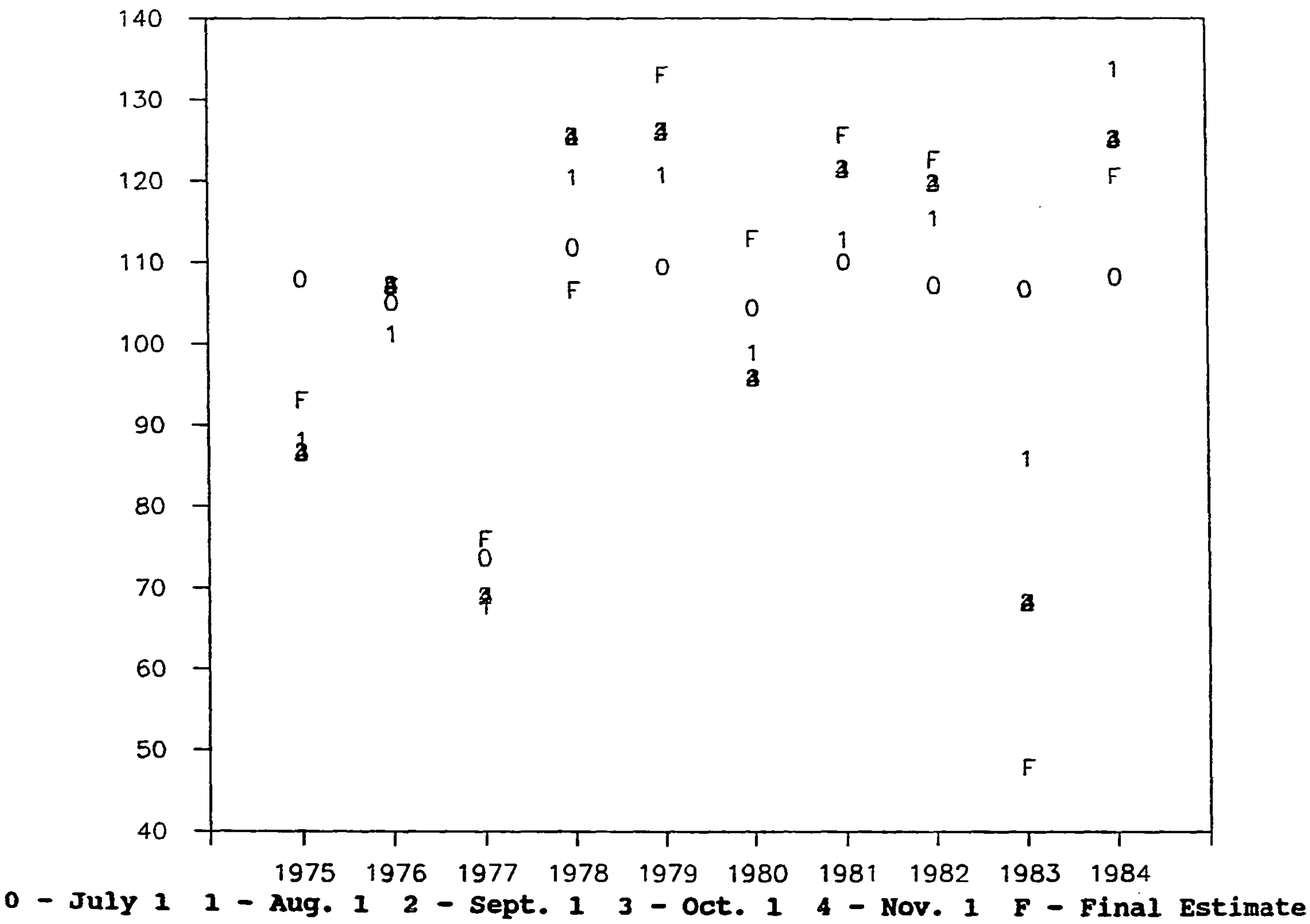
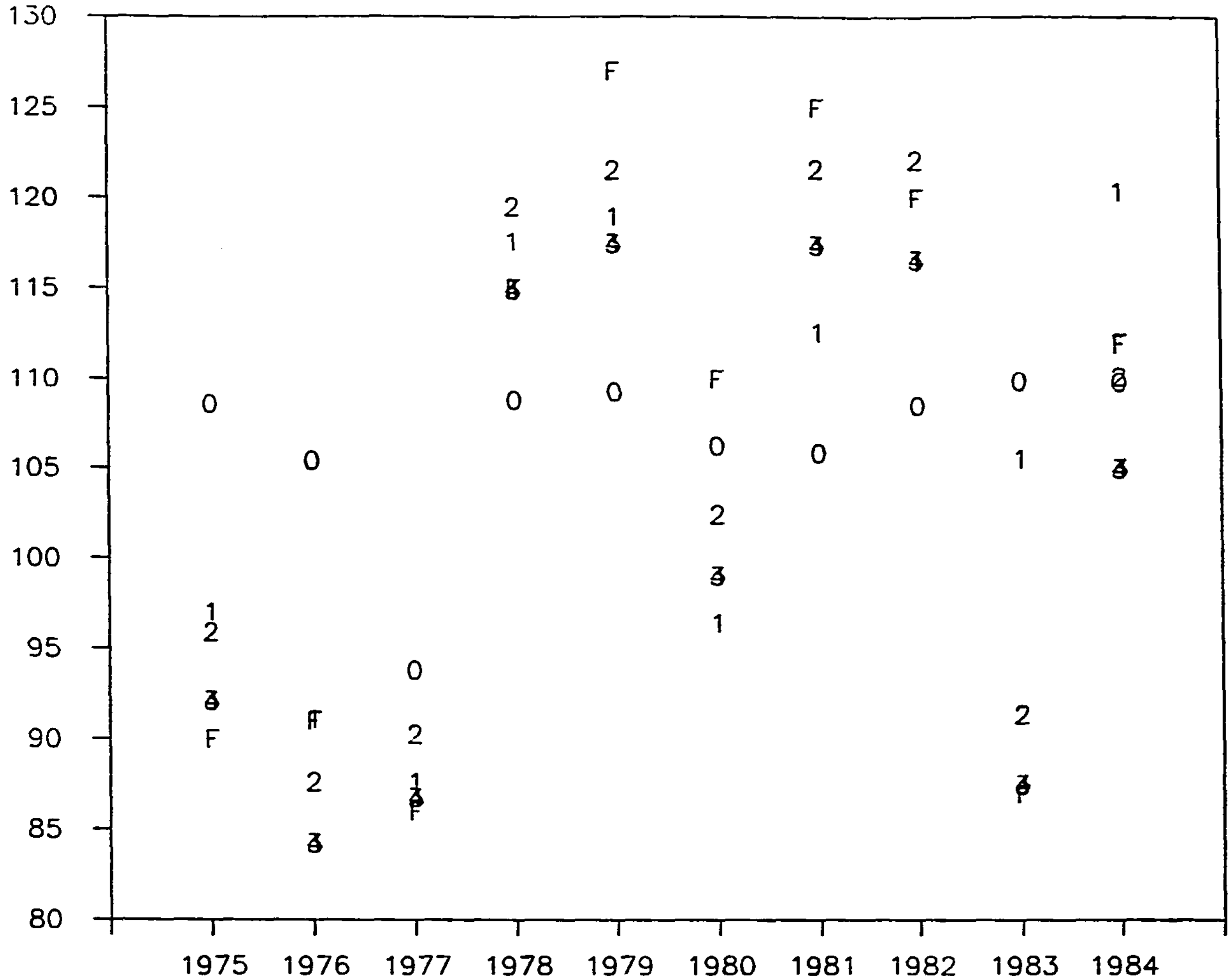


Figure 28. PPM corn yield forecasts for five forecast dates and actual corn yields for 1975 and 1984, Southeast district



0 - July 1 1 - Aug. 1 2 - Sept. 1 3 - Oct. 1 4 - Nov. 1 F - Final Estimate

Figure 29. PPM corn yield forecasts for five forecast dates and actual corn yields for 1975 and 1984, Iowa

Table 35. Number of years out of ten that the PPM forecast correctly predicted an above or a below average actual yield

Crop Reporting District	Forecast Date				
	July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1
Northwest	6	8	8	10	10
North Central	6	9	8	9	9
Northeast	9	8	10	9	9
West Central	7	9	10	10	10
Central	7	8	9	9	9
East Central	8	9	8	8	8
Southwest	6	9	10	10	10
South Central	7	7	10	10	10
Southeast	7	10	10	10	10
Iowa	8	9	9	10	10

estimating the calibration models. Again, the high-low count is only a first indication of forecast performance.

The RMSE values for the PPM forecasts are shown in Table 36. As expected, RMSE values are highest for the July forecasts and generally lowest for the October and November forecasts. In general, PPM forecast reliability does not improve significantly beyond the September 1 forecast. The reason for this is that once the simulated plants reach maturity, no factors in the model will alter the yield forecast, and maturity usually occurs sometime in September. Like with NASS forecasts, PPM forecasts for the Southern districts are generally less reliable than for other districts. Compared to NASS forecasts, however, the forecast errors are relatively larger. This result can likely be attributed to relatively larger errors in the PPM input data for the Southern districts. For example, the soil information used in the PPM may not accurately reflect the diversity and variability of soils in the South. Improvements on these forecasts may require simulating the PPM under a wider variety of growing conditions.

Other interesting comparisons between NASS and PPM forecast reliability are seen. For the August forecast, the PPM does better (i.e., lower RMSEs) than NASS forecasts in four of the nine districts (North Central, Northeast, West Central, and East Central). Even September RMSE values are

Table 36. Root mean square errors for PPM corn yield forecasts for five forecast dates by crop reporting district in Iowa

Crop Reporting District	Forecast Dates				
	July 1	Aug. 1	Sept. 1	Oct. 1	Nov.1
Northwest	18.77	17.01	8.72	8.54	8.54
North Central	15.52	10.36	4.57	4.52	4.52
Northeast	14.46	8.86	6.68	6.90	6.90
West Central	18.13	8.33	7.49	7.56	7.56
Central	14.28	12.31	8.72	8.66	8.66
East Central	16.57	11.89	8.68	8.77	8.77
Southwest	18.18	9.34	9.89	9.63	9.63
South Central	22.09	17.49	15.80	16.04	16.04
Southeast	24.96	17.70	12.48	12.49	12.49
Iowa	14.97	9.89	4.71	5.78	5.78

similar between NASS and PPM forecasts except for the southern districts where the NASS forecasts are more reliable. October and November NASS forecasts are consistently, and for the southern districts significantly, more reliable than PPM forecasts. These results seems to indicate that the PPM may contribute useful yield forecasting information during the early season (August and September), but usefulness later in the season may be limited.

In making comparisons between NASS and PPM forecast reliability, an important point should be kept in mind. NASS recalibrates its forecasting models (Models I and Models II from the discussion in Chapter IV) every year using the lastest year's information. These calibrations are done prior to the forecasts, however. That is, NASS model calibrations are done ex ante. On the other hand, PPM calibration models have been estimated ex post. This is to say, the reliability tests on the PPM forecasts are done over the same period from which the calibrations models were fit. In short, comparisons are being made between the reliability of ex ante NASS forecasts and ex post PPM forefasts. This might be an unfair comparison. Future comparisons could be made using out-of-sample PPM forecasts. Out-of-sample PPM forecasts were not done in this study.

Composite Corn Yield Forecasts

This section reviews results of combining PPM forecasts with NASS forecasts to obtain composite corn yield forecasts. The theoretical framework for combining individual forecasts was discussed in Chapter IV. Also discussed were the two different approaches taken to deriving the composite forecasts. Selected results from both the bottom-up approach and the top-down approach are reported and discussed.

Regression analysis was used to derive optimal composite forecasting weights on the PPM and NASS forecasts. Two approaches were used to derive these weights. Ordinary Least Squares (OLS) as well as ridge regressions were used. Ridge regression was used in order to address the problem of multi-collinearity between the PPM and NASS forecasts. The results reported here focus on OLS-derived weights. Selected ridge regression results, however, are also reported.

Bottom-up Approach Recall that with the bottom-up approach to deriving composite forecasts, PPM and NASS forecasts are combined at the district level. The state "composite" forecasts are then obtained by aggregating the CRD composites. This approacch was taken in order that comparison could be made with the weights on the two forecasts. If weights on the PPM forecasts were small or insignificantly different from zero, the PPM forecasts would be considered poor predictors of CRD corn yields relative to

NASS forecasts. On the other hand, if weights on the PPM forecasts were high, they would be considered as good predictors of CRD yields relative to NASS forecasts. Recall also that optimal composite weights are those that minimize the variance of the composite forecast. Therefore, if there were "diversification" advantages in using a combination of PPM and NASS forecasts, the composite weights on both would likely be significantly different from zero. On the other hand, if there was little or no diversification advantage, one of the forecast weights would dominate.

Results of the OLS composite estimations are shown in Table A.14 of the Appendix. Recall that since both the calibrated PPM and NASS forecats are assumed to be unbiased, the two composite weights were restricted so that they sum to one. Further, no non-negativity restriction was put on the weights. The interpretation on a negative weight was that the forecast with the negative weight is an inferior forecast but if it is highly correlated with the other forecast, the inferior forecast still provides useful information. Results here show that negative weights are insignificantly different from zero (α = 0.05).

The composite weights are derived from OLS regressions are summarized in Table 37a. NASS did not make yield forecasts in July and, therefore, the entire composite weight for each of the July forecasts was on the PPM forecast. For

Table 37a. Bottom-up composite forecast weights (OLS) on the PPM and NASS forecasts for nine CRDs and five forecast dates

Crop Reporting District	Forecast Date				
	July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1
Northwest					
PPM	1.00	0.34	0.57	0.27	-0.04
NASS	0.00	0.66	0.43	0.73	1.04
North Central					
PPM	1.00	0.82	0.60	0.43	0.10
NASS	0.00	0.18	0.40	0.57	0.90
Northeast					
PPM	1.00	0.89	0.55	0.52	0.26
NASS	0.00	0.11	0.45	0.48	0.74
West Central					
PPM	1.00	0.87	0.32	0.16	0.05
NASS	0.00	0.13	0.68	0.84	0.95
Central					
PPM	1.00	0.45	0.40	0.18	-0.07
NASS	0.00	0.55	0.60	0.82	1.07
East Central					
PPM	1.00	0.77	0.40	0.28	0.12
NASS	0.00	0.23	0.60	0.72	0.88
Southwest					
PPM	1.00	0.45	-0.05	-0.20	-0.01
NASS	0.00	0.55	1.05	1.20	1.01
South Central					
PPM	1.00	0.43	0.17	0.14	0.17
NASS	0.00	0.57	0.83	0.86	0.83
Southeast					
PPM	1.00	0.28	0.27	0.15	0.11
NASS	0.00	0.72	0.73	0.85	0.89

the other forecasts, weights varied from district to district but, in general, weights on PPM forecasts dropped as the forecast date moved closer to the end of the season.

For the August forecast, more weight was put on the PPM forecast in four of the nine districts (North Central, Northeast, West Central, and East Central). These weights were also significant ($\alpha = 0.05$). The five other districts had weights ranging from 0.28 to 0.45. These weights were insignificant, but this could be due to the multi-collinearity problem.

Weights on the PPM forecasts are generally lower in September compared to August. However, for the northern three districts, the September weights are larger than NASS weights and also statistically significant. Comparatively, PPM weights are small and insignificantly different from zero for other districts.

The October and November forecasts put only small weight on the PPM forecasts. The exception was for the Northeast district which had a statistically significant weight of 0.52 in the October composite forecast. In the other districts, PPM weights are small and insignificant from zero. This result was not surprising given the RMSE results obtained for the PPM and NASS forecast for October and November.

As shown in Table A.14 of the Appendix, many of the estimated composite weights are insignificantly different from zero. This is not generally a concern when only one of the two weights is insignificant, but it is a concern when both weights are insignificantly different from zero. When standard errors on both weights are high, confidence intervals on the parameter estimates are wide and little faith can be placed in the estimates. Large standard errors can generally be attributed to a multi-collinearity problem between the two forecast variables. Ridge regression procedures discussed in Chapter IV were followed in order to ameliorate the multi-collinearity problem.

Ridge regression estimation results are shown in Table A.15 of the Appendix. Ridge regression weights are summarized in Table 37b. In general, ridge regression weights are significantly different from zero (α=0.05) except for weights that are below 0.10. Weights are somewhat different than OLS weights. The ridge regression weights are, as mentioned in Chapter IV, biased estimates with smaller standard errors. In general, using ridge regression, PPM weights are lower on the early season forecasts and higher on the later season forecasts. Ridge regression results show a trade-off between biased parameter estimates and lower standard errors on the estimates. The gain from lower standard errors did not seem to justify using biased weights and, therefore, composite forecasts reported here are only those derived from OLS regression results.

Table 37b. Bottom-up composite forecast weights (ridge regression) on the PPM and NASS forecasts for nine CRDs and five forecast dates

Crop Reporting District	Forecast Date				
	July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1
Northwest					
PPM	1.00	0.37	0.54	0.38	0.22
NASS	0.00	0.63	0.46	0.62	0.78
North Central					
PPM	1.00	0.68	0.53	0.47	0.41
NASS	0.00	0.32	0.47	0.53	0.59
Northeast					
PPM	1.00	0.74	0.51	0.50	0.37
NASS	0.00	0.26	0.49	0.50	0.63
West Central					
PPM	1.00	0.73	0.42	0.37	0.27
NASS	0.00	0.27	0.58	0.63	0.73
Central					
PPM	1.00	0.47	0.44	0.35	0.23
NASS	0.00	0.53	0.56	0.65	0.77
East Central					
PPM	1.00	0.69	0.42	0.34	0.29
NASS	0.00	0.31	0.58	0.66	0.71
Southwest					
PPM	1.00	0.46	0.20	0.14	0.18
NASS	0.00	0.54	0.80	0.86	0.82
South Central					
PPM	1.00	0.54	0.21	0.18	0.21
NASS	0.00	0.46	0.79	0.82	0.79
Southeast					
PPM	1.00	0.33	0.33	0.24	0.21
NASS	0.00	0.67	0.67	0.76	0.79

The bottom-up composite forecast equations were used to derive composite corn yield forecasts at the district level. These forecasts are shown in Tables 38 through 47 and Figures 30 through 39. State-level forecasts are aggregations of the district forecasts. Note that the July composite forecasts were identical to the PPM forecasts. This, of course, was because a weight of one was assigned to the July PPM forecast. Performance indicators for July composites were also the same as those for the PPM forecasts.

The high-low count (Table 48) for the August through November composite forecasts were not significantly different than the counts for the NASS forecasts. Somewhat surprisingly, however, the counts were slightly lower for the composites in August. This only points out the high-low counts should be interpreted with some caution. As indicated by the RMSE values, the forecast errors on average were lower for the composite forecasts than for the NASS forecasts.

RMSE values for the bottom-up composite forecasts are shown in Table 49. Again, July values were the same as those for the PPM. Similar observations were made on the composite forecast RMSEs as for the PPM and NASS forecasts. That is, average forecast errors fall as the growing season progresses and, in general, the southern districts' forecasts perform the poorest. All composite forecasts, however, perform better than either the PPM or NASS forecasts.

Table 38. Corn yield bottom-up composite forecasts for five forecast dates and actual corn yields by crop reporting district, 1975

Crop Reporting District	Forecast Date July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	Actual Yield
	bushels per acre					
Northwest	104.8	98.2	86.6	84.5	87.8	88.0
North Central	116.3	107.8	103.1	102.8	101.2	95.0
Northeast	113.0	97.7	93.1	93.7	93.5	93.0
West Central	101.3	87.0	84.6	88.0	89.0	85.0
Central	117.9	108.7	101.0	100.6	99.5	98.0
East Central	115.0	112.4	105.0	105.2	106.1	100.0
Southwest	95.5	74.3	70.2	73.8	76.0	68.0
South Central	89.7	74.4	69.5	69.5	74.6	74.0
Southeast	107.9	88.1	83.1	87.0	93.2	93.0
Iowa	108.6	97.0	91.0	91.8	93.0	90.0

Table 39. Corn yield bottom-up composite forecasts for five forecast dates and actual corn yields by crop reporting district, 1976

Crop Reporting District	Forecast Date July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	Actual Yield
	bushels per acre					
Northwest	108.2	94.2	65.2	63.7	68.8	73.0
North Central	111.2	88.0	87.8	87.9	90.6	93.0
Northeast	112.8	99.0	99.9	99.7	97.4	91.0
West Central	91.4	70.2	59.6	59.9	65.9	71.0
Central	111.0	101.4	94.4	95.0	104.9	104.0
East Central	113.5	101.2	102.0	100.9	100.2	102.0
Southwest	93.5	84.8	96.7	95.9	96.8	99.0
South Central	92.8	75.5	96.2	93.9	94.1	95.0
Southeast	105.1	101.2	108.6	108.6	106.1	107.0
Iowa	105.4	91.1	87.2	86.9	89.8	91.0

Table 40. Corn yield bottom-up composite forecasts for five forecast dates and actual corn yields by crop reporting district, 1977

Crop Reporting District	Forecast Date					Actual Yield
	July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	
	bushels per acre					
Northwest	111.1	103.6	104.3	106.6	107.3	103.0
North Central	103.8	104.7	102.7	102.9	104.1	102.0
Northeast	106.5	99.8	107.7	108.3	108.8	112.0
West Central	86.9	82.2	77.2	74.7	75.9	74.0
Central	71.7	91.4	72.7	71.6	68.5	66.0
East Central	104.8	98.4	102.9	102.5	102.8	103.0
Southwest	80.4	73.2	73.2	67.6	69.2	68.0
South Central	109.0	47.6	40.0	40.0	40.0	40.0
Southeast	73.7	72.6	73.6	74.1	75.2	76.0
Iowa	93.8	90.1	87.5	86.9	87.2	86.0

Table 41. Corn yield bottom-up composite forecasts for five forecast dates and actual corn yields by crop reporting district, 1978

Crop Reporting District	Forecast Date					Actual Yield
	July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	
	bushels per acre					
Northwest	104.2	119.2	122.9	120.5	121.7	119.5
North Central	116.7	125.1	121.8	120.6	120.1	121.0
Northeast	115.4	119.7	114.0	112.2	112.1	118.0
West Central	98.6	113.9	116.6	118.1	119.5	115.0
Central	118.2	122.6	124.9	123.8	122.7	116.1
East Central	116.0	118.3	116.7	116.6	118.3	117.8
Southwest	96.1	110.1	110.9	110.3	109.9	104.7
South Central	87.9	101.2	99.7	100.4	103.0	99.7
Southeast	111.9	115.5	116.7	115.7	115.2	106.6
Iowa	108.8	117.7	117.8	117.1	117.5	115.0

Table 42. Corn yield bottom-up composite forecasts for five forecast dates and actual corn yields by crop reporting district, 1979

Crop Reporting District	Forecast Date					Actual Yield
	July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	
	bushels per acre					
Northwest	106.4	112.2	118.4	120.9	124.3	123.9
North Central	113.6	124.3	127.8	127.5	131.0	130.0
Northeast	114.3	125.3	125.7	125.7	125.7	130.4
West Central	100.1	110.7	111.7	113.1	117.4	119.1
Central	123.2	122.0	127.6	126.6	134.1	135.3
East Central	115.6	126.3	122.1	122.2	124.4	132.3
Southwest	96.7	113.9	111.0	114.2	118.9	120.0
South Central	88.8	101.2	102.8	104.6	107.4	110.5
Southeast	109.6	114.0	117.6	120.0	125.1	133.0
Iowa	109.3	117.7	119.7	120.7	124.5	127.0

Table 43. Corn yield bottom-up composite forecasts for five forecast dates and actual corn yields by crop reporting district, 1980

Crop Reporting District	Forecast Date					Actual Yield
	July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	
	bushels per acre					
Northwest	109.1	102.5	107.3	112.3	116.8	116.8
North Central	114.2	111.5	124.4	124.2	125.9	125.3
Northeast	113.6	108.3	117.6	117.3	116.8	121.4
West Central	92.2	77.8	89.4	87.1	86.8	86.8
Central	112.7	107.6	110.3	113.2	118.6	116.0
East Central	115.0	104.7	111.2	113.7	114.8	117.9
Southwest	87.9	81.5	86.9	86.5	86.9	88.0
South Central	96.0	86.8	84.1	85.9	88.1	88.5
Southeast	104.5	115.3	109.7	110.5	110.3	112.9
Iowa	106.3	100.2	106.4	107.5	109.3	110.0

Table 44. Corn yield bottom-up composite forecasts for five forecast dates and actual corn yields by crop reporting district, 1981

Crop Reporting District	Forecast Date					Actual Yield
	July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	
	bushels per acre					
Northwest	108.7	123.6	123.4	125.2	127.8	125.1
North Central	116.5	120.4	129.8	130.7	132.0	133.5
Northeast	114.6	126.1	130.7	132.7	132.6	129.2
West Central	89.8	104.9	112.2	112.0	111.2	109.7
Central	106.2	118.4	127.1	129.6	132.5	129.5
East Central	115.2	120.4	133.8	135.6	136.4	132.5
Southwest	91.0	109.9	120.7	122.0	121.8	116.7
South Central	90.5	108.4	119.0	122.5	121.7	118.9
Southeast	110.2	123.1	126.5	130.5	130.9	125.7
Iowa	105.8	117.8	125.0	126.7	127.6	125.0

Table 45. Corn yield bottom-up composite forecasts for five forecast dates and actual corn yields by crop reporting district, 1982

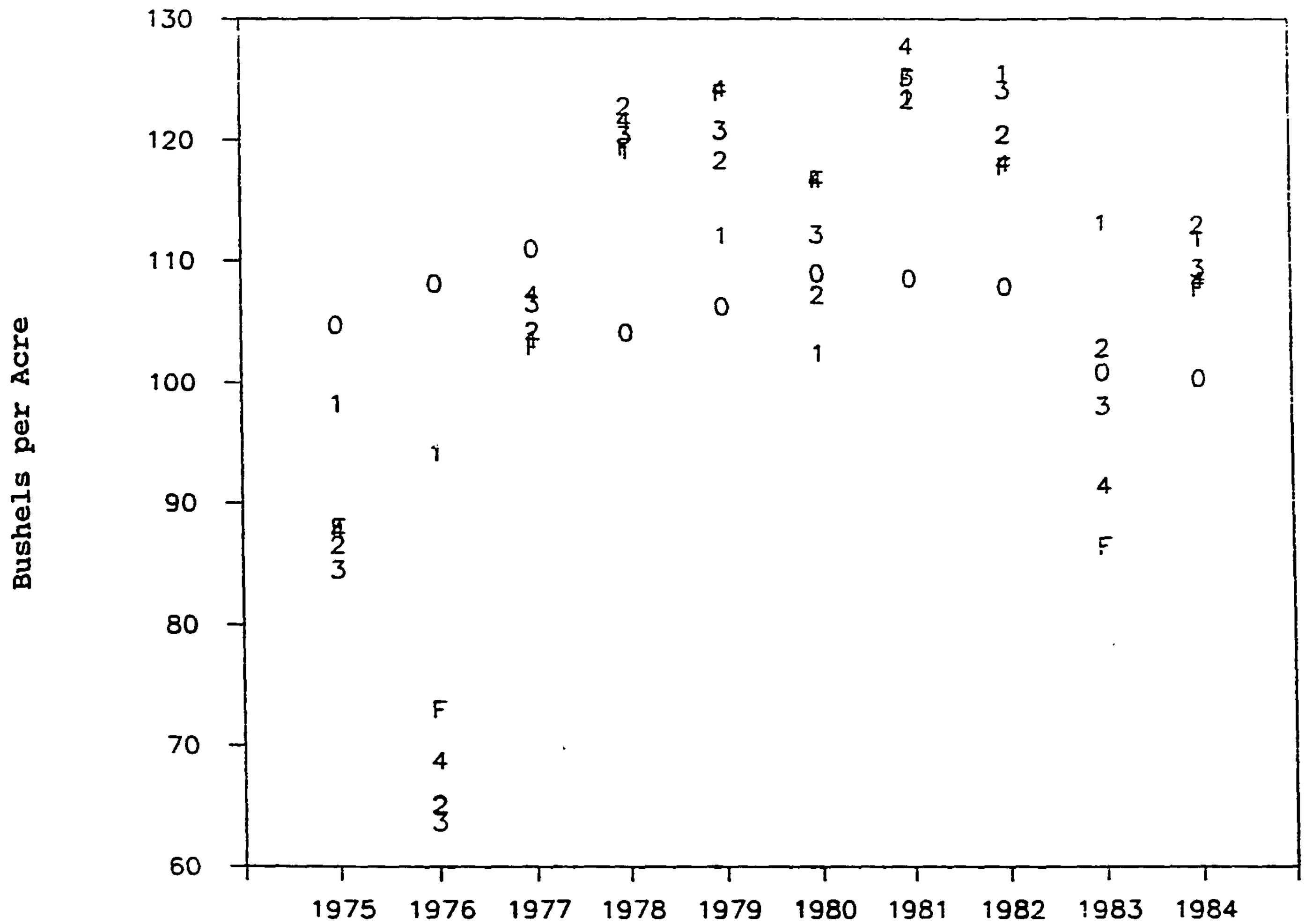
Crop Reporting District	Forecast Date					Actual Yield
	July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	
	bushels per acre					
Northwest	108.0	125.6	120.6	124.2	118.2	117.9
North Central	115.0	122.0	128.5	129.5	128.6	127.2
Northeast	113.6	123.4	127.2	125.8	125.3	121.5
West Central	98.6	113.6	122.5	122.1	121.8	115.8
Central	113.6	124.7	127.4	128.1	129.3	128.1
East Central	115.4	123.4	131.2	131.2	130.8	129.3
Southwest	103.6	103.6	109.2	105.8	108.2	102.5
South Central	86.3	91.8	91.4	94.6	97.0	90.9
Southeast	107.3	125.2	126.9	126.0	127.1	122.7
Iowa	108.5	119.5	123.2	123.5	123.0	120.0

Table 46. Corn yield bottom-up composite forecasts for five forecast dates and actual corn yields by crop reporting district, 1983

Crop Reporting District	Forecast Date July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	Actual Yield
	bushels per acre					
Northwest	100.9	113.2	102.9	98.1	91.5	86.5
North Central	118.0	114.0	102.9	102.3	101.1	101.4
Northeast	115.2	115.3	100.1	100.7	99.8	102.4
West Central	106.7	102.7	92.6	91.0	85.3	86.1
Central	118.8	119.8	98.8	101.2	99.1	103.5
East Central	117.0	107.3	85.3	85.8	81.9	85.3
Southwest	99.4	92.6	72.3	80.0	75.1	78.9
South Central	87.7	81.8	45.1	44.7	44.4	47.2
Southeast	106.9	81.4	49.7	48.4	45.7	47.9
Iowa	109.9	106.6	89.0	88.9	85.6	87.0

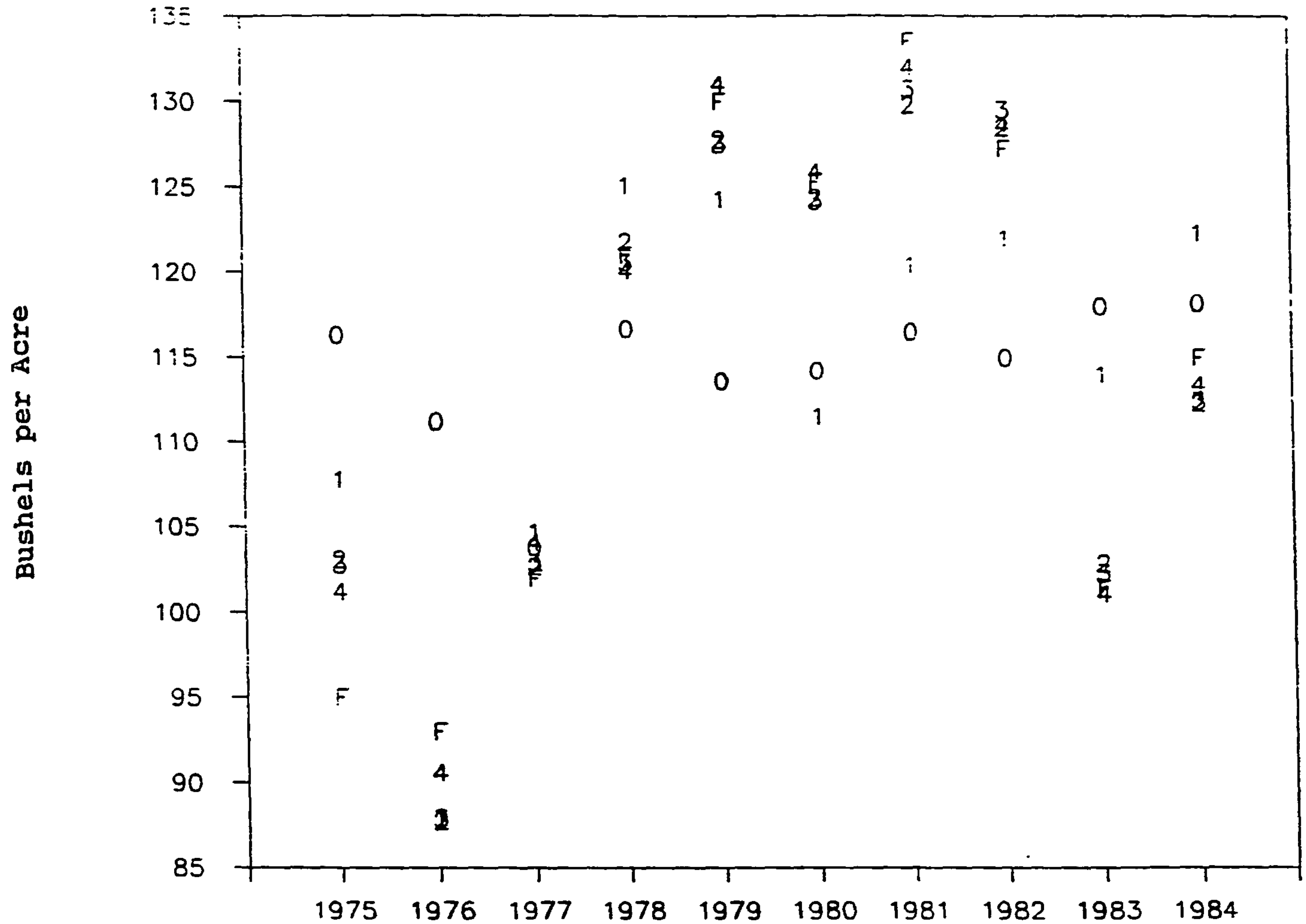
Table 47. Corn yield bottom-up composite forecasts for five forecast dates and actual corn yields by crop reporting district, 1984

Crop Reporting District	Forecast Date July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	Actual Yield
	bushels per acre					
Northwest	100.4	111.9	113.1	109.5	108.5	107.9
North Central	118.2	122.3	112.3	112.4	113.4	115.0
Northeast	113.9	116.1	109.2	110.0	110.0	114.1
West Central	106.1	113.5	104.7	103.0	107.6	109.3
Central	121.3	130.9	124.9	124.0	123.0	118.2
East Central	115.7	132.2	121.0	119.6	120.0	123.2
Southwest	97.6	101.3	90.9	90.3	94.8	95.8
South Central	90.5	96.6	91.3	87.9	87.9	85.5
Southeast	108.4	137.1	127.4	125.9	123.2	120.7
Iowa	109.8	119.5	112.2	111.0	111.6	112.0



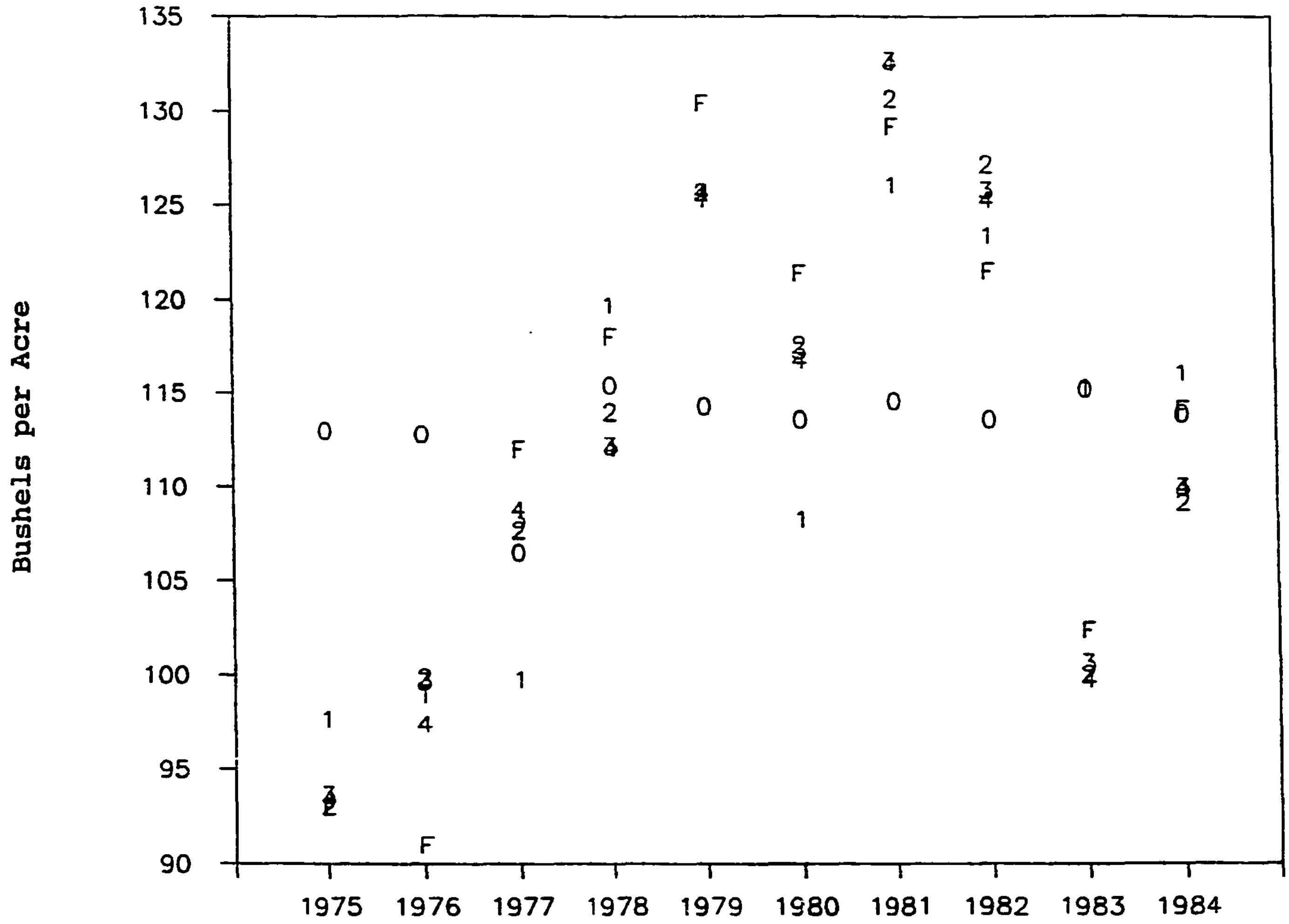
0 - July 1 1 - Aug. 1 2 - Sept. 1 3 - Oct. 1 4 - Nov. 1 F - Final Estimate

Figure 30. Composite corn yield forecasts for five forecast dates and actual corn yields for 1975 through 1984, Northwest district



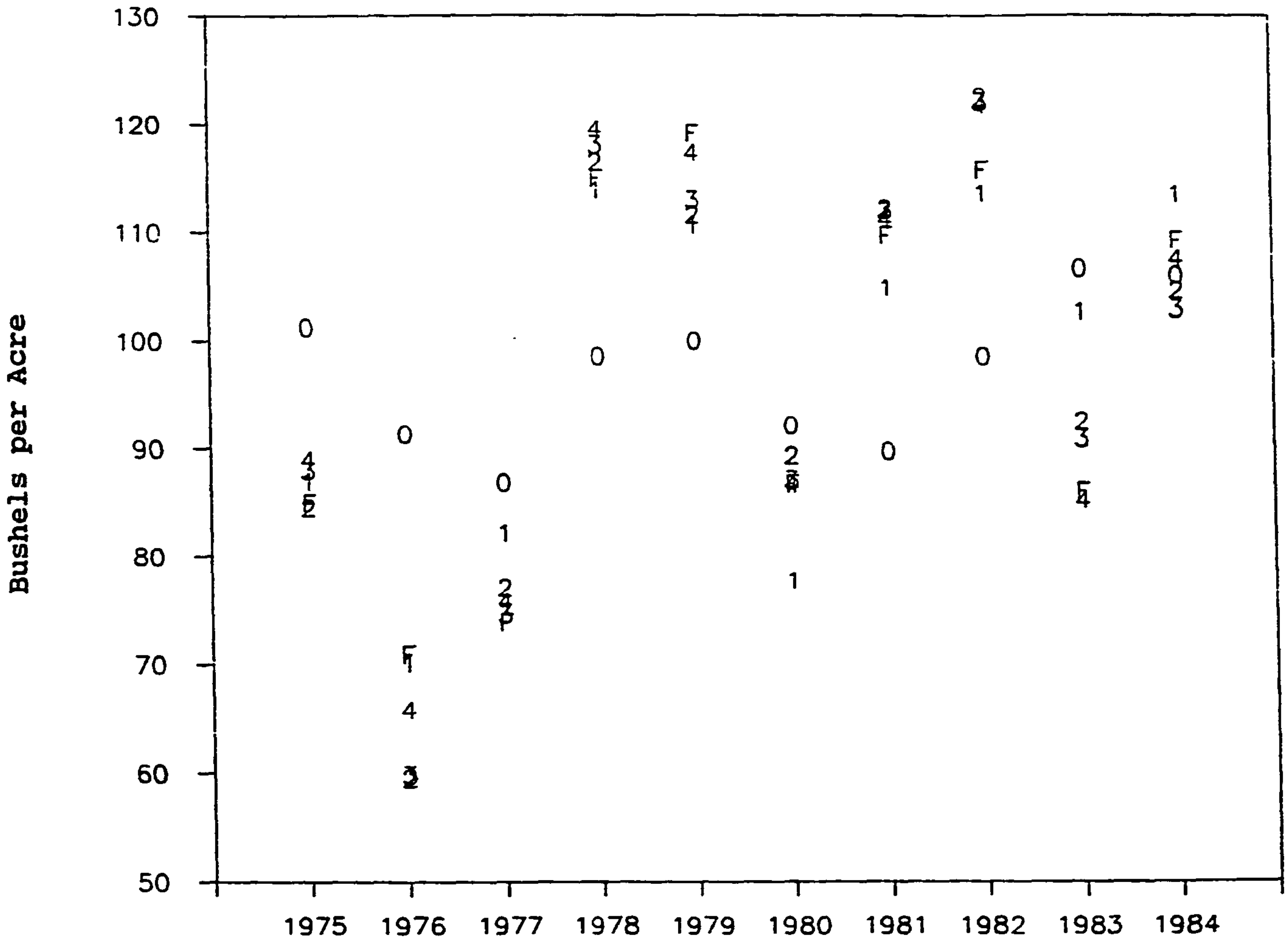
0 - July 1 1 - Aug. 1 2 - Sept. 1 3 - Oct. 1 4 - Nov. 1 F - Final Estimate

Figure 31. Composite corn yield forecasts for five forecast dates and actual corn yields for 1975 through 1984, North Central district



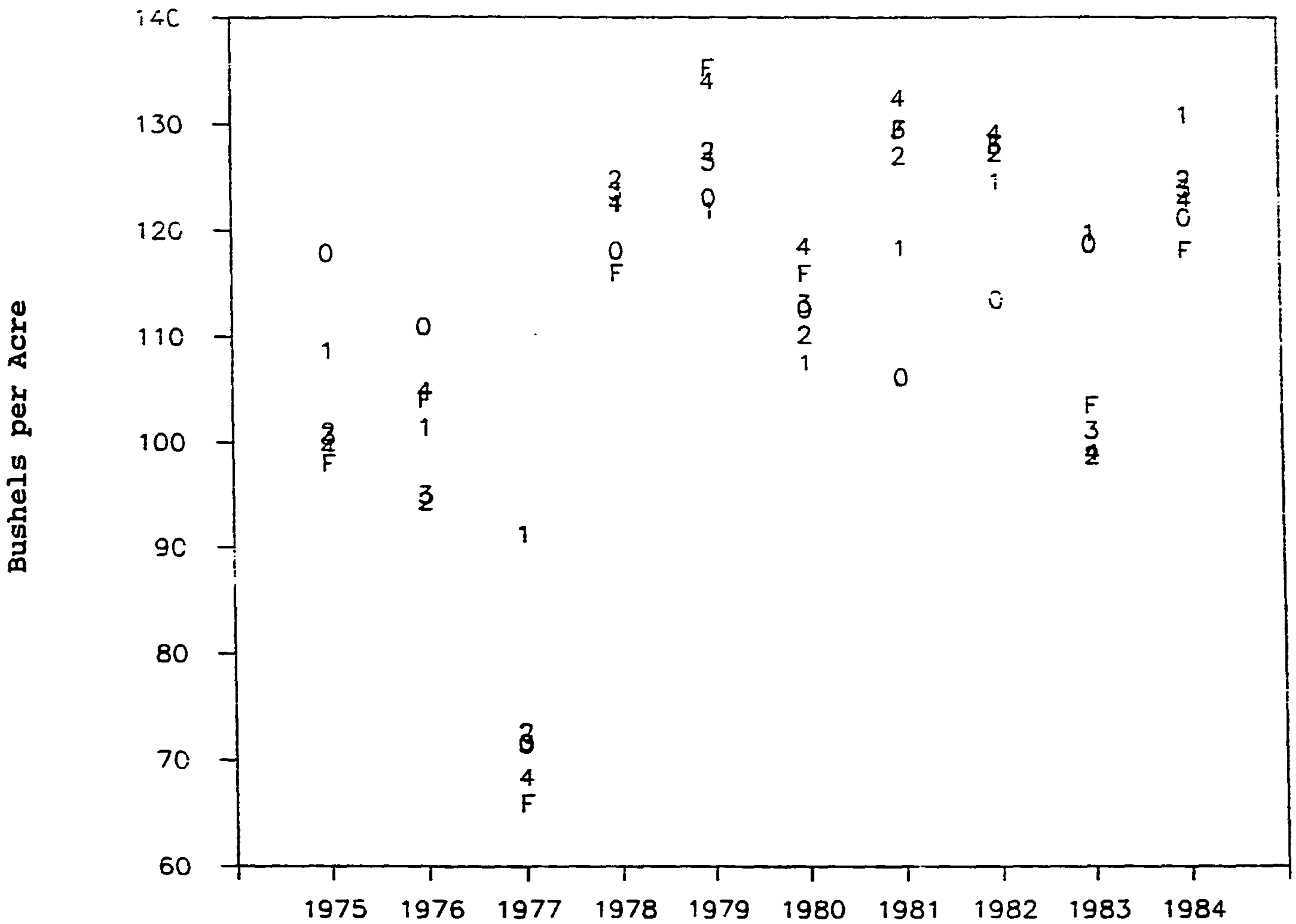
0 - July 1 1 - Aug. 1 2 - Sept. 1 3 - Oct. 1 4 - Nov. 1 F - Final Estimate

Figure 32. Composite corn yield forecasts for five forecast dates and actual corn yields for 1975 through 1984, Northeast district



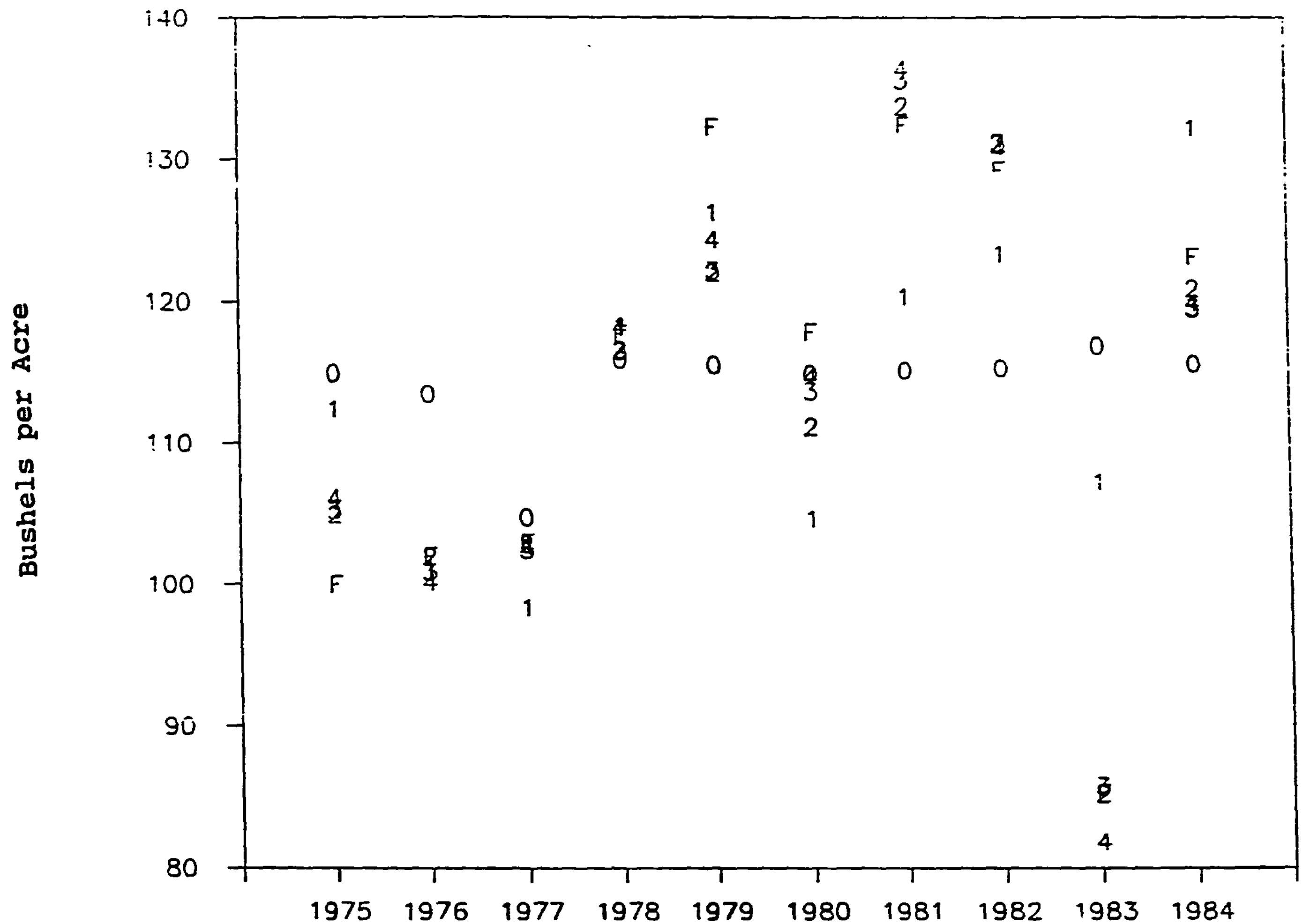
0 - July 1 1 - Aug. 1 2 - Sept. 1 3 - Oct. 1 4 - Nov. 1 F - Final Estimate

Figure 33. Composite corn yield forecasts for five forecast dates and actual corn yields for 1975 through 1984, West Central district



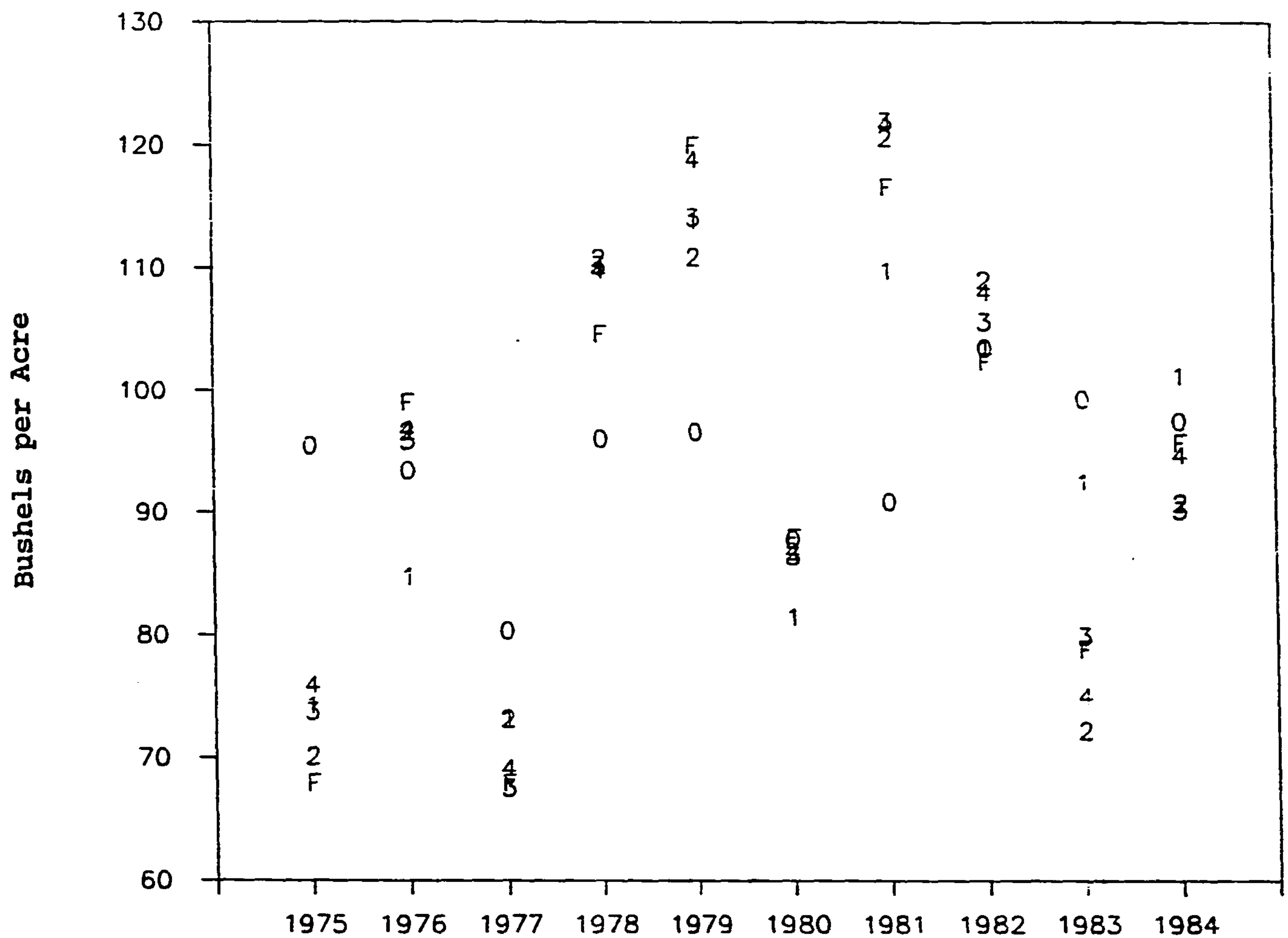
0 - July 1 1 - Aug. 1 2 - Sept. 1 3 - Oct. 1 4 - Nov. 1 F - Final Estimate

Figure 34. Composite corn yield forecasts for five forecast dates and actual corn yields for 1975 through 1984, Central district



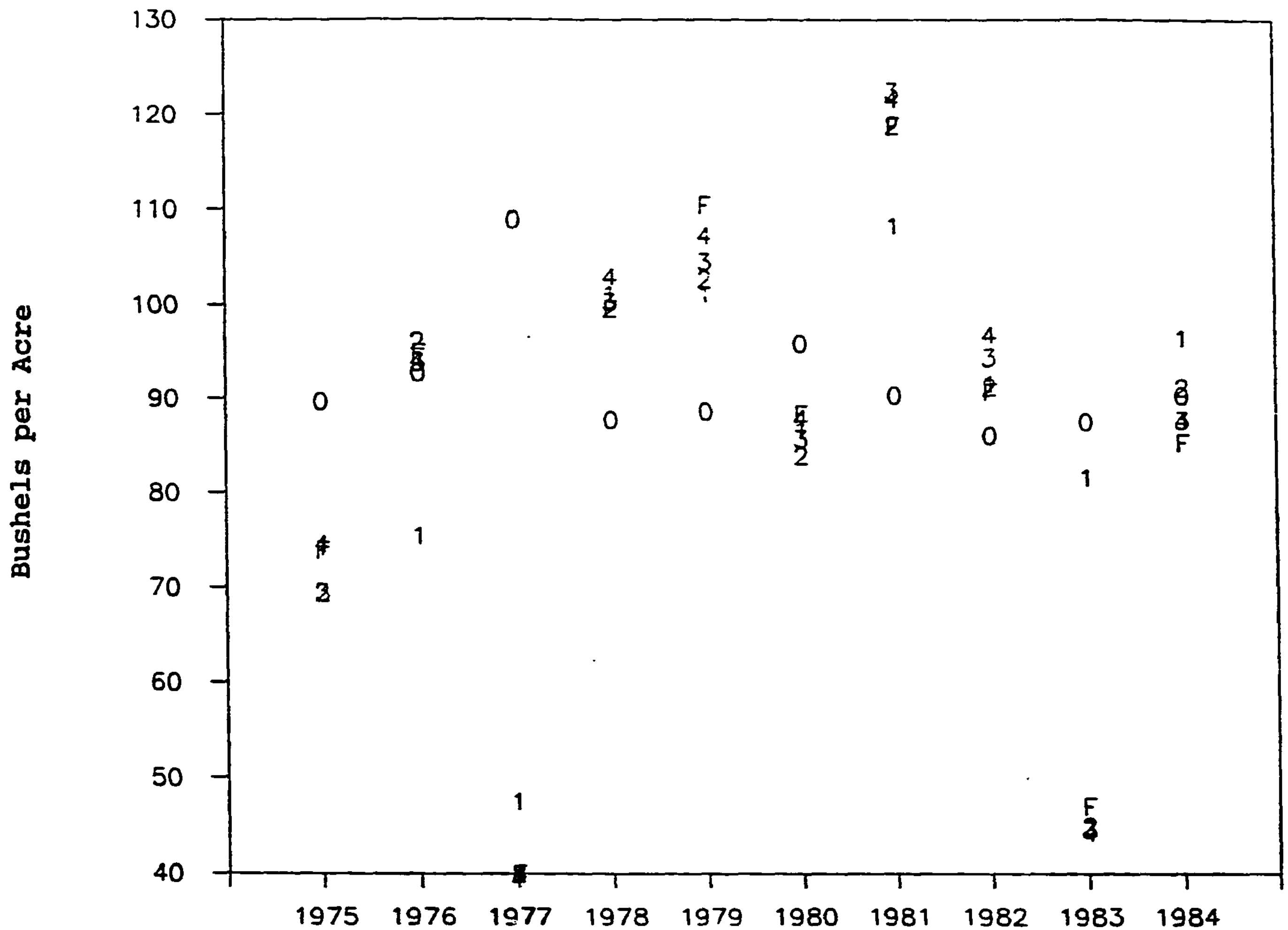
0 - July 1 1 - Aug. 1 2 - Sept. 1 3 - Oct. 1 4 - Nov. 1 F - Final Estimate

Figure 35. Composite corn yield forecasts for five forecast dates and actual corn yields for 1975 through 1984, East Central district



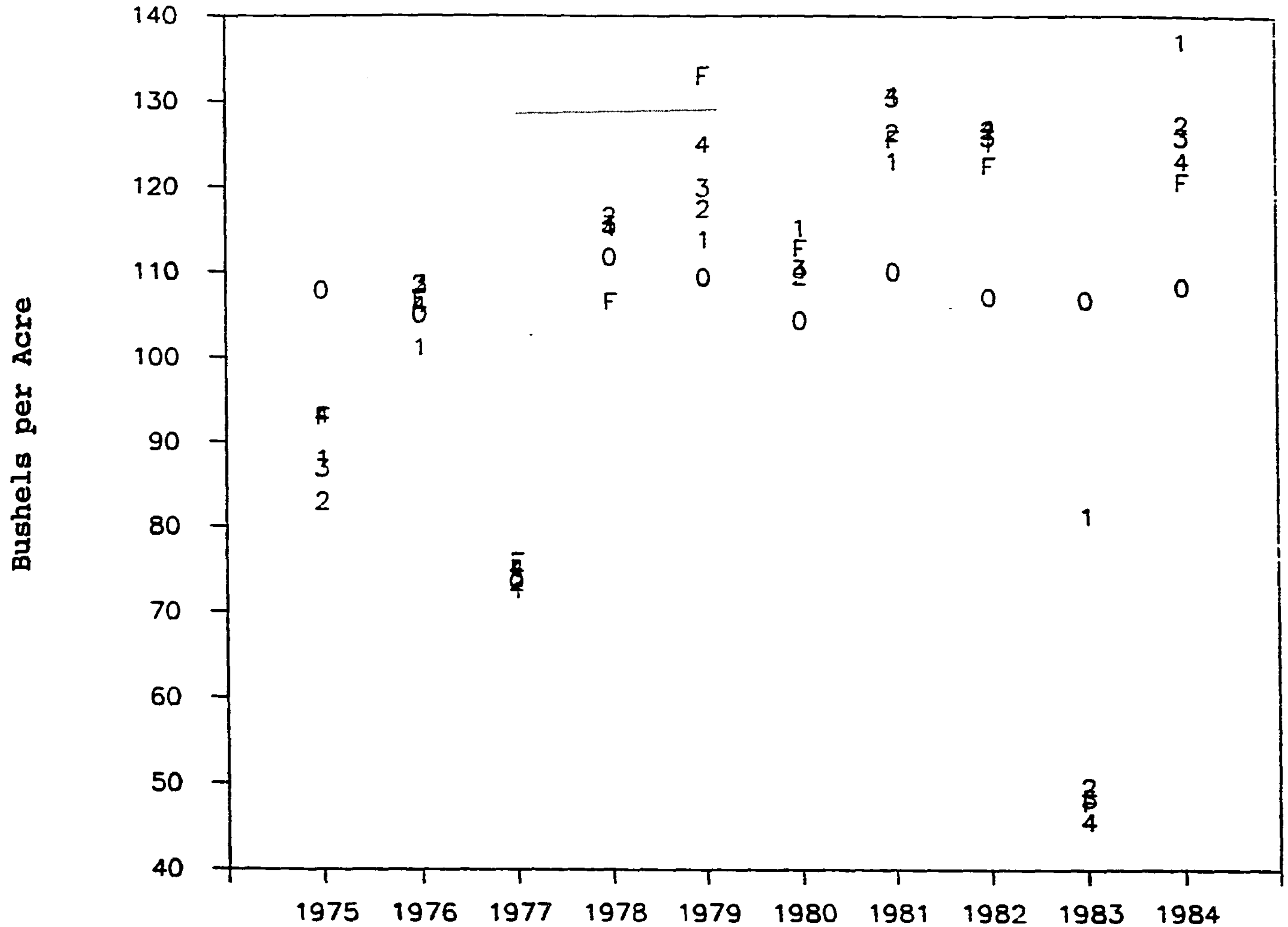
0 - July 1 1 - Aug. 1 2 - Sept. 1 3 - Oct. 1 4 - Nov. 1 F - Final Estimate

Figure 36. Composite corn yield forecasts for five forecast dates and actual corn yields for 1975 through 1984, Southwest district



0 - July 1 1 - Aug. 1 2 - Sept. 1 3 - Oct. 1 4 - Nov. 1 F - Final Estimate

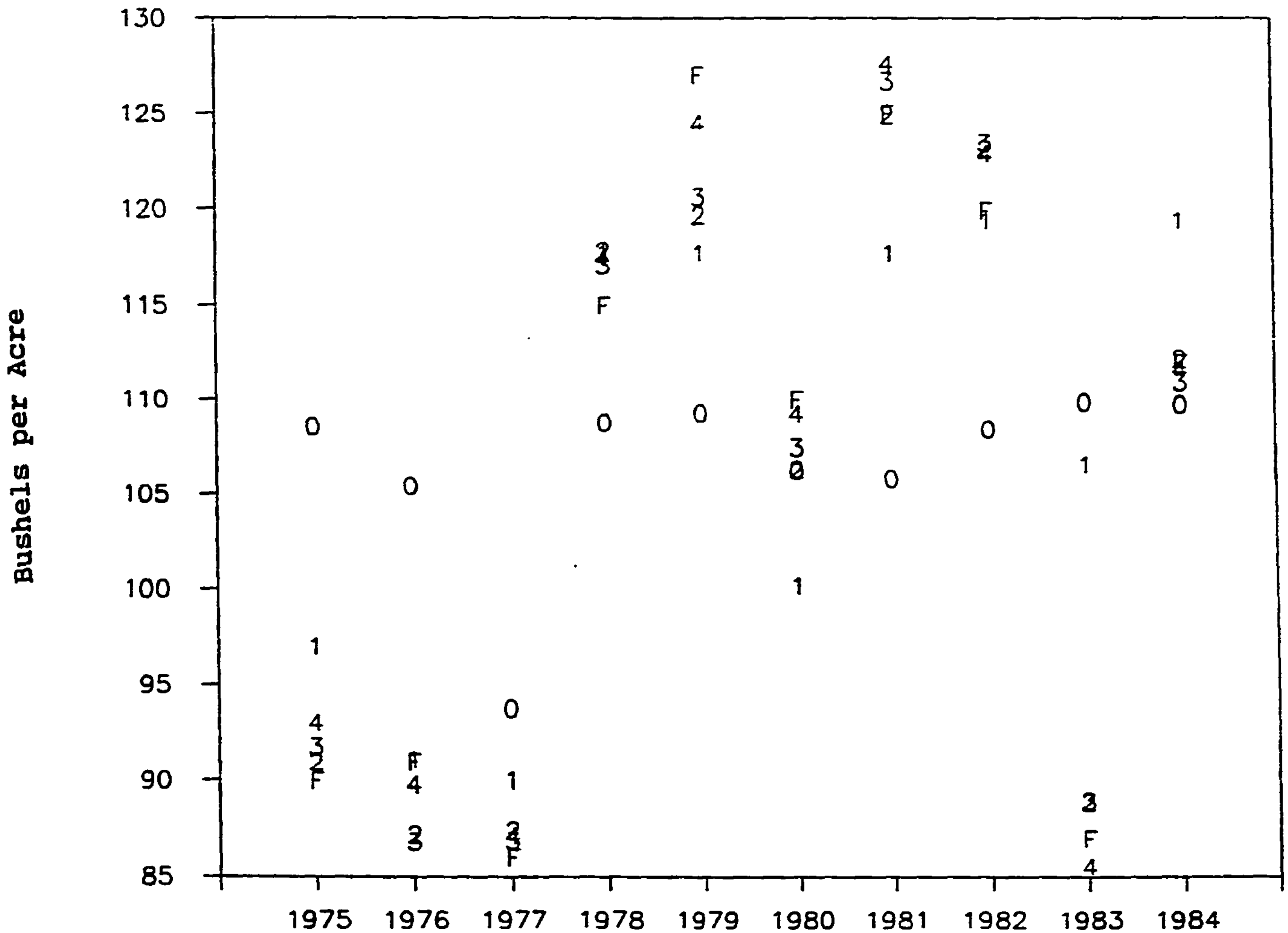
Figure 37. Composite corn yield forecasts for five forecast dates and actual corn yields for 1975 through 1984, South Central district



0 - July 1 1 - Aug. 1 2 - Sept. 1 3 - Oct. 1 4 - Nov. 1 F - Final Estimate

Figure 38. Composite corn yield forecasts for five forecast dates and actual corn yields for 1975 through 1984, Southeast district

158



0 - July 1 1 - Aug. 1 2 - Sept. 1 3 - Oct. 1 4 - Nov. 1 F - Final Estimate

Figure 39. Composite corn yield forecasts for five forecast dates and actual corn yields for 1975 through 1984, Iowa

Table 48. Number of years out of ten that the bottom-up composite forecast correctly predicted an above or a below average actual yield

Crop Reporting District	Forecast Date				
	July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1
Northwest	6	8	9	10	9
North Central	6	8	9	9	10
Northeast	9	8	9	9	10
West Central	7	9	8	10	10
Central	7	8	8	10	10
East Central	8	8	7	10	10
Southwest	6	9	7	9	10
South Central	7	8	7	10	10
Southeast	7	9	8	10	10
Iowa	8	9	1	10	10

Table 49. Root mean square errors for the bottom-up composite corn yield forecasts for five forecast dates by crop reporting district in Iowa

Crop Reporting District	Forecast Dates				
	July 1	Aug. 1	Sept. 1	Oct. 1	Nov.1
Northwest	18.77	11.21	7.34	5.76	2.85
North Central	15.52	9.65	3.35	3.21	2.06
Northeast	14.46	8.28	4.32	4.29	4.04
West Central	18.13	7.78	5.83	5.56	3.50
Central	14.27	10.04	6.43	5.65	3.57
East Central	16.58	10.88	4.36	4.28	3.96
Southwest	18.20	7.41	5.63	4.46	4.39
South Central	22.10	14.07	4.15	3.57	3.18
Southeast	24.96	14.71	7.59	6.33	4.75
Iowa	14.97	9.86	5.79	4.43	3.34

The difference between composite and NASS forecasts are shown in Table 50. Also shown are differences between PPM and NASS forecasts. Clearly, when PPM forecasts were better than NASS forecasts (a negative difference in Table 50), composite forecasts were better than NASS forecasts alone. But even when PPM forecasts were not better than NASS forecasts (a positive difference in Table 50), combinations of PPM and NASS forecasts were still better than NASS forecasts alone. This result was consistent with the theoretical concepts discussed in Chapter IV. The improvement in forecast performance came from the "diversification" effect. The diversification effect was significantly greater in the August and September forecasts compared to the October and November forecasts, however. In fact, very little benefit was shown using the composite forecasts in October and November. For a better picture of the comparison between reliability of the three different forecasts, the RMSE values are graphed for each of the nine crop reporting districts in Tables 40 through 48, respectively.

Top-Down Approach With the top-down approach of deriving composite forecasts, PPM and NASS forecasts were combined at the state level. District forecasts were obtained using the state composite forecasts and the relative yield relationship between districts that was obtained from

Table 50. Difference in root mean square error for the PPM and composite corn yield forecasts relative to NASS corn yield forecasts

Crop Reporting District	Forecast Date			
	Aug. 1	Sept. 1	Oct. 1	Nov. 1
Northwest				
PPM	+4.94	+0.32	+2.71	+5.82
Composite	-0.86	-1.06	-0.07	-0.02
North Central				
PPM	-0.93	-0.40	+0.88	+2.42
Composite	-1.64	-1.62	-0.43	-0.10
Northeast				
PPM	-2.61	+0.04	+0.46	+2.72
Composite	-3.19	-2.32	-2.15	-0.14
West Central				
PPM	-1.87	+1.69	+2.22	+4.22
Composite	-2.42	-0.03	-0.02	-0.04
Central				
PPM	+1.79	+1.81	+2.95	+5.06
Composite	-0.48	-0.48	-0.06	-0.03
East Central				
PPM	-1.51	+2.72	+3.94	+4.79
Composite	-2.52	-1.60	-0.55	-0.02
Southwest				
PPM	+1.43	+4.19	+5.13	+5.22
Composite	-0.50	-0.07	-0.04	-0.02
South Central				
PPM	+3.60	+11.13	+12.20	+12.09
Composite	-0.12	-0.52	-0.25	-0.77
Southeast				
PPM	+3.40	+4.61	+6.08	+7.73
Composite	-0.05	-0.28	-0.08	-0.01

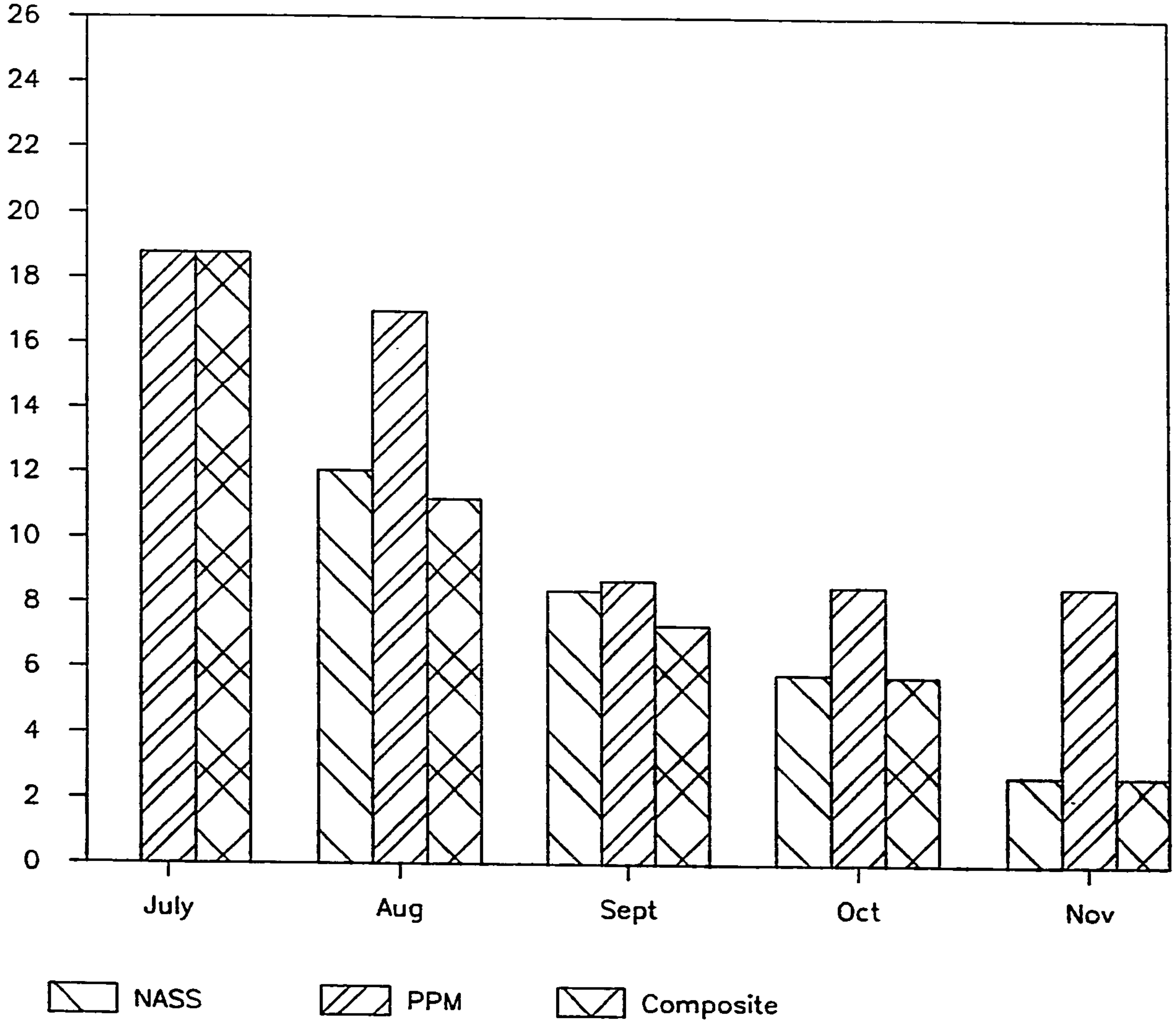


Figure 40. Root mean square error comparisons, Northwest district

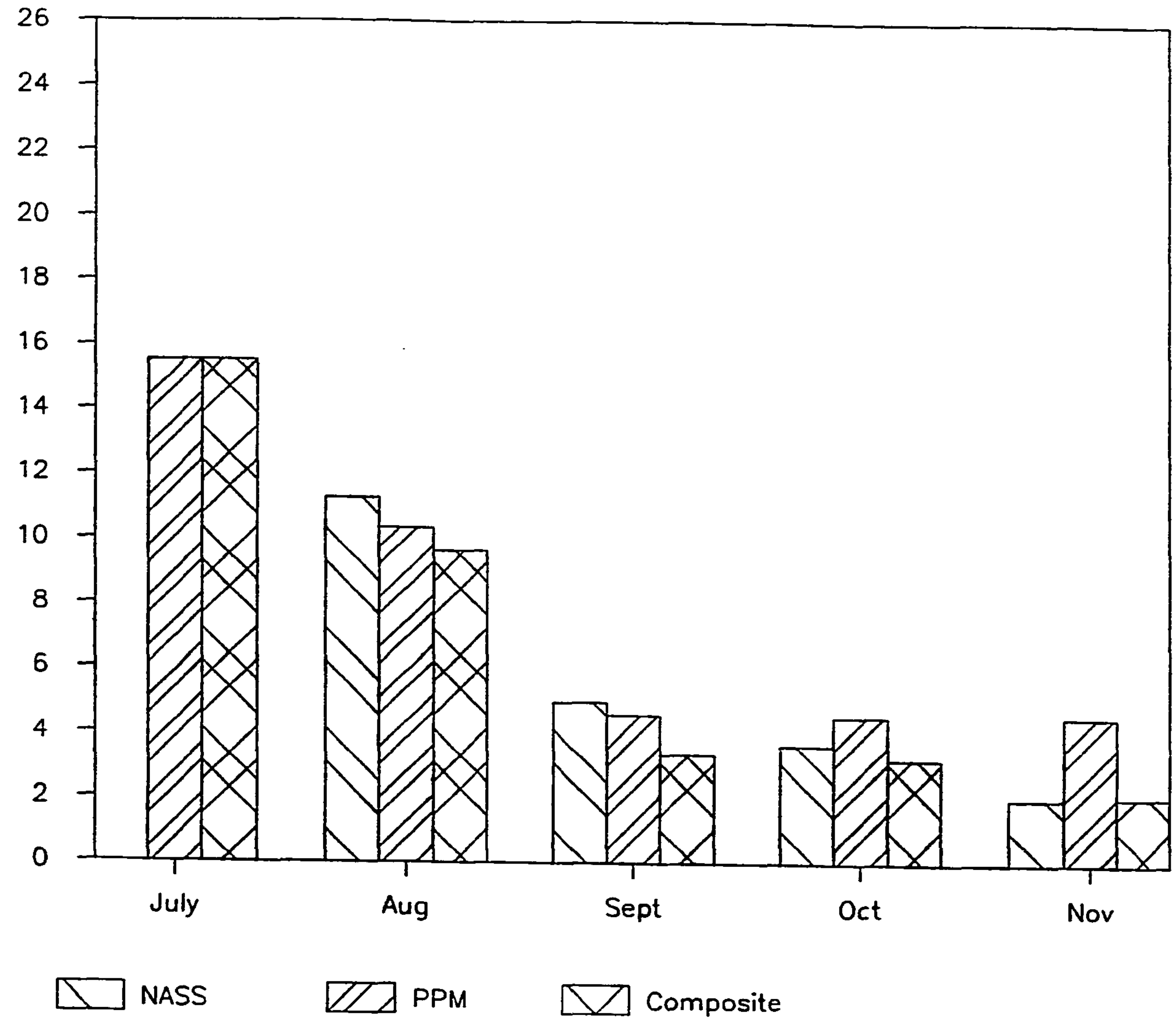


Figure 41. Root mean square error comparisons, North Central district

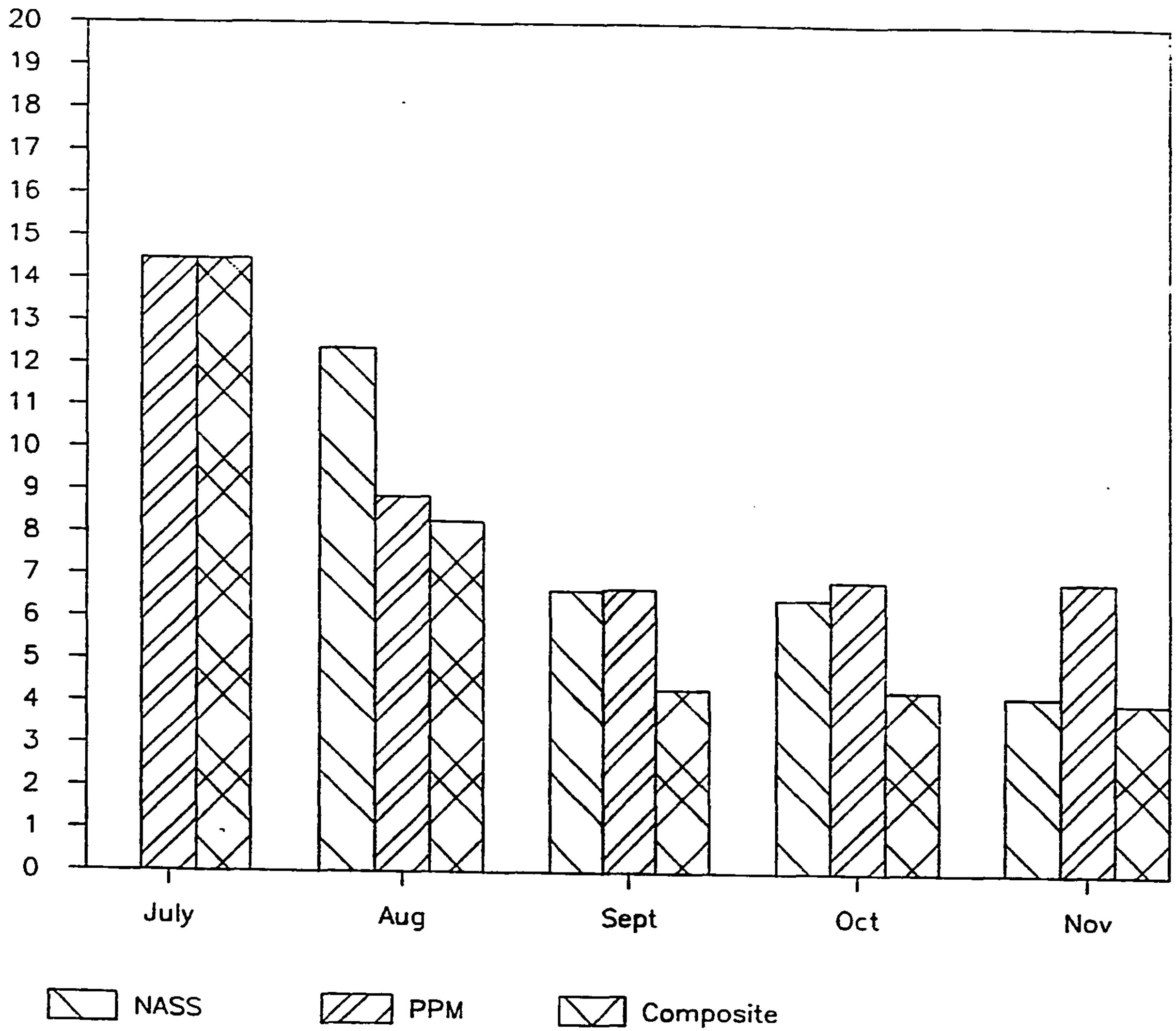


Figure 42. Root mean square error comparisons, Northeast district

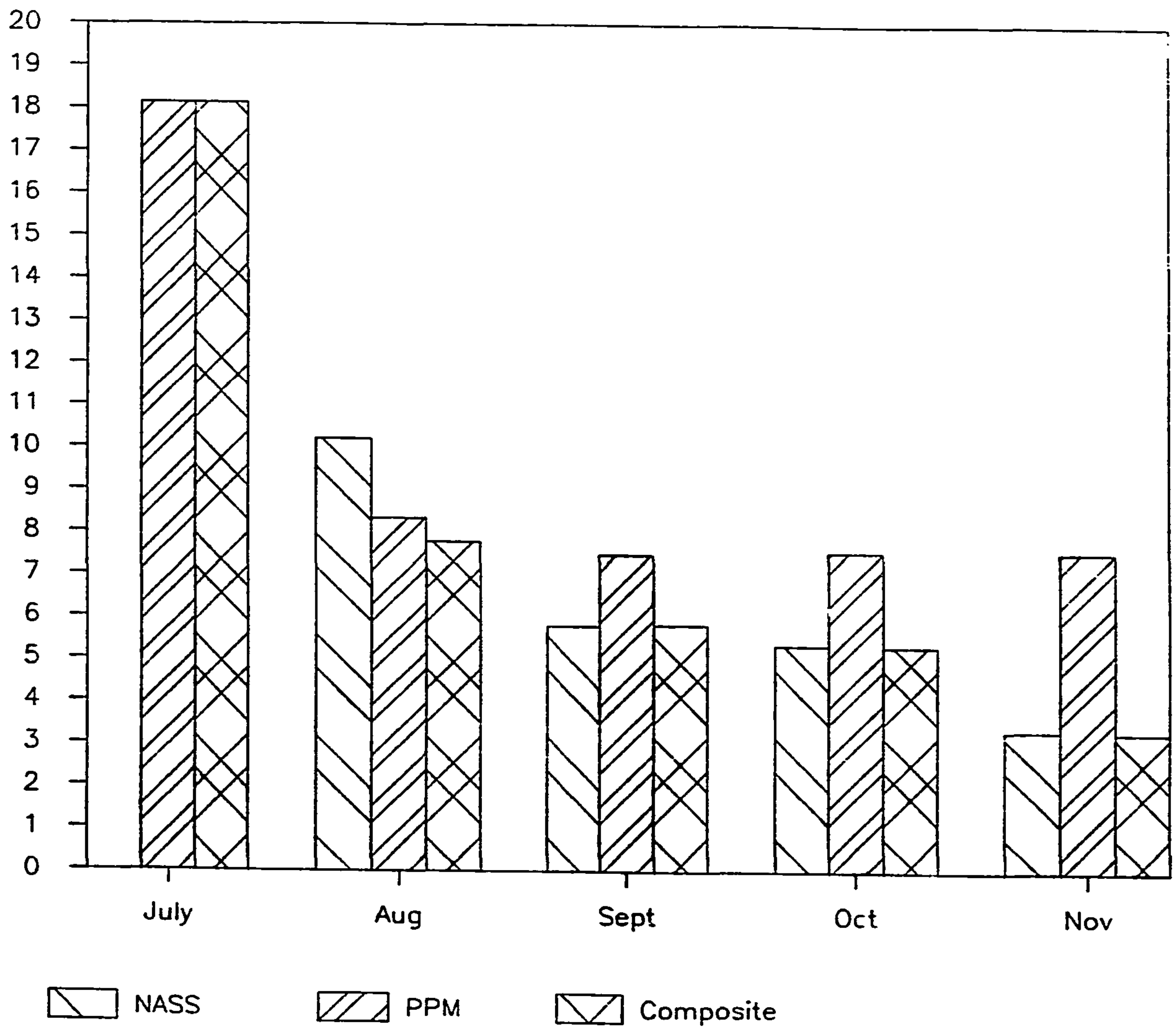


Figure 43. Root mean square error comparisons, West Central district

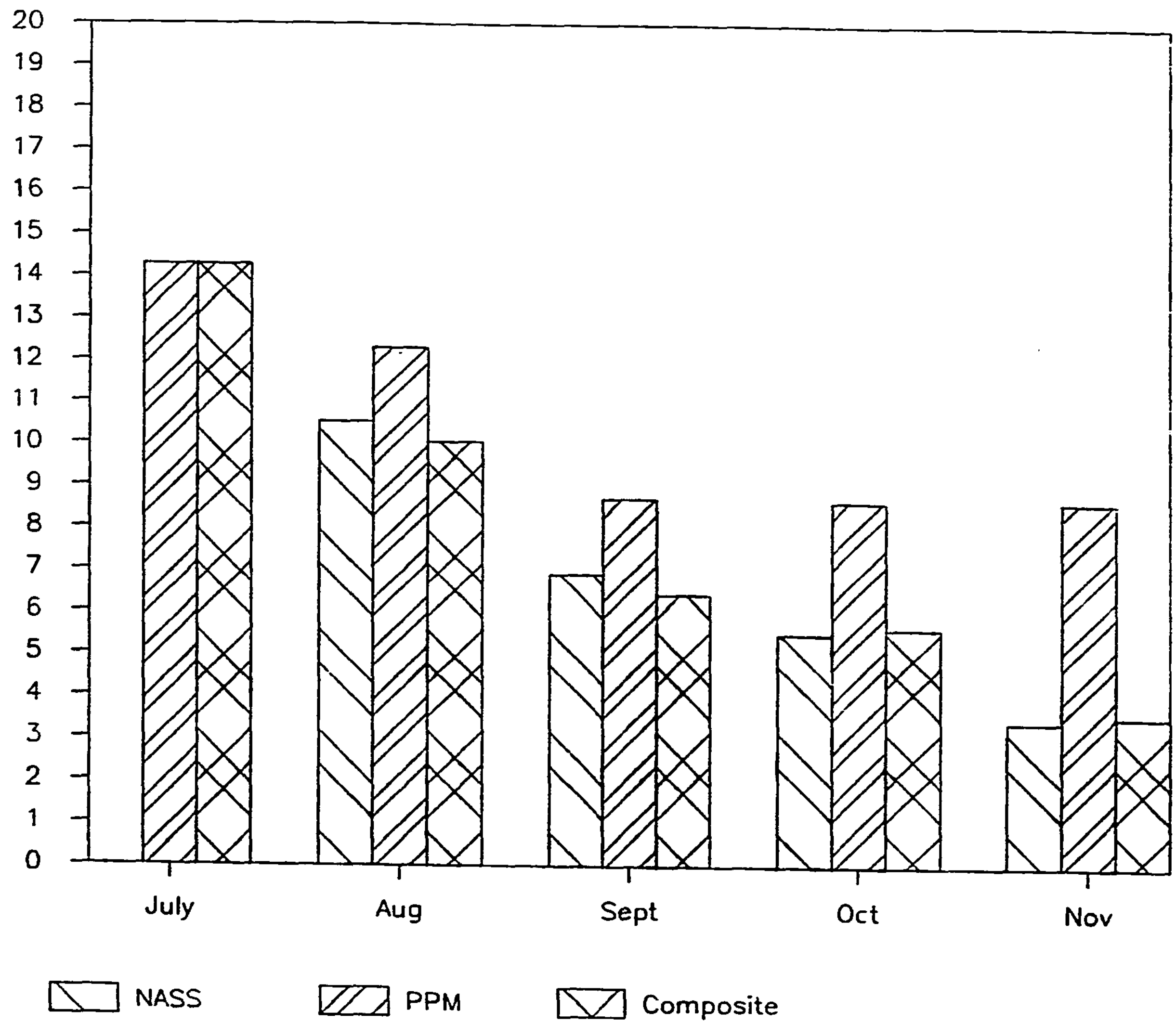


Figure 44. Root mean square error comparisons, Central district

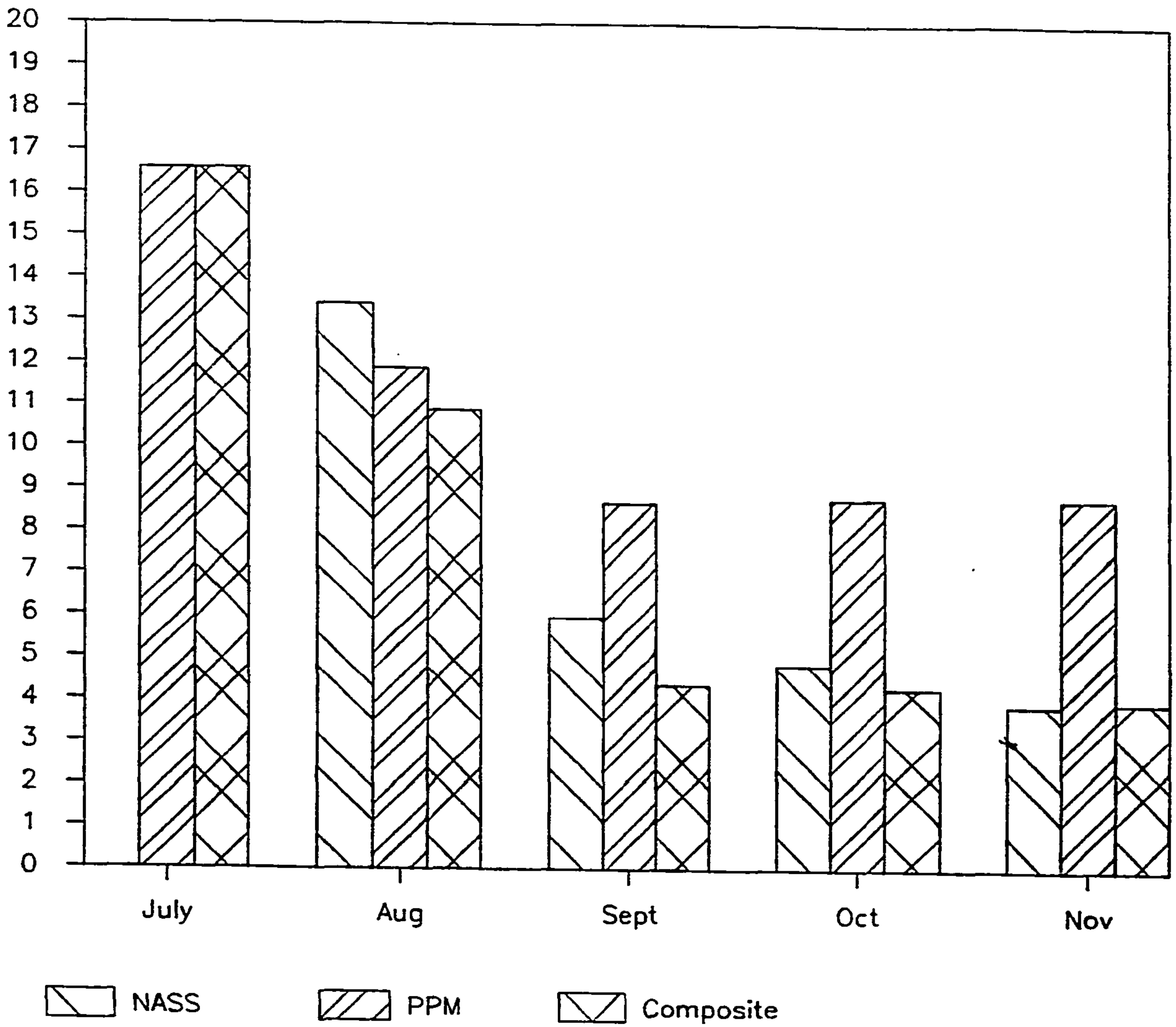


Figure 45. Root mean square error comparisons, East Central district

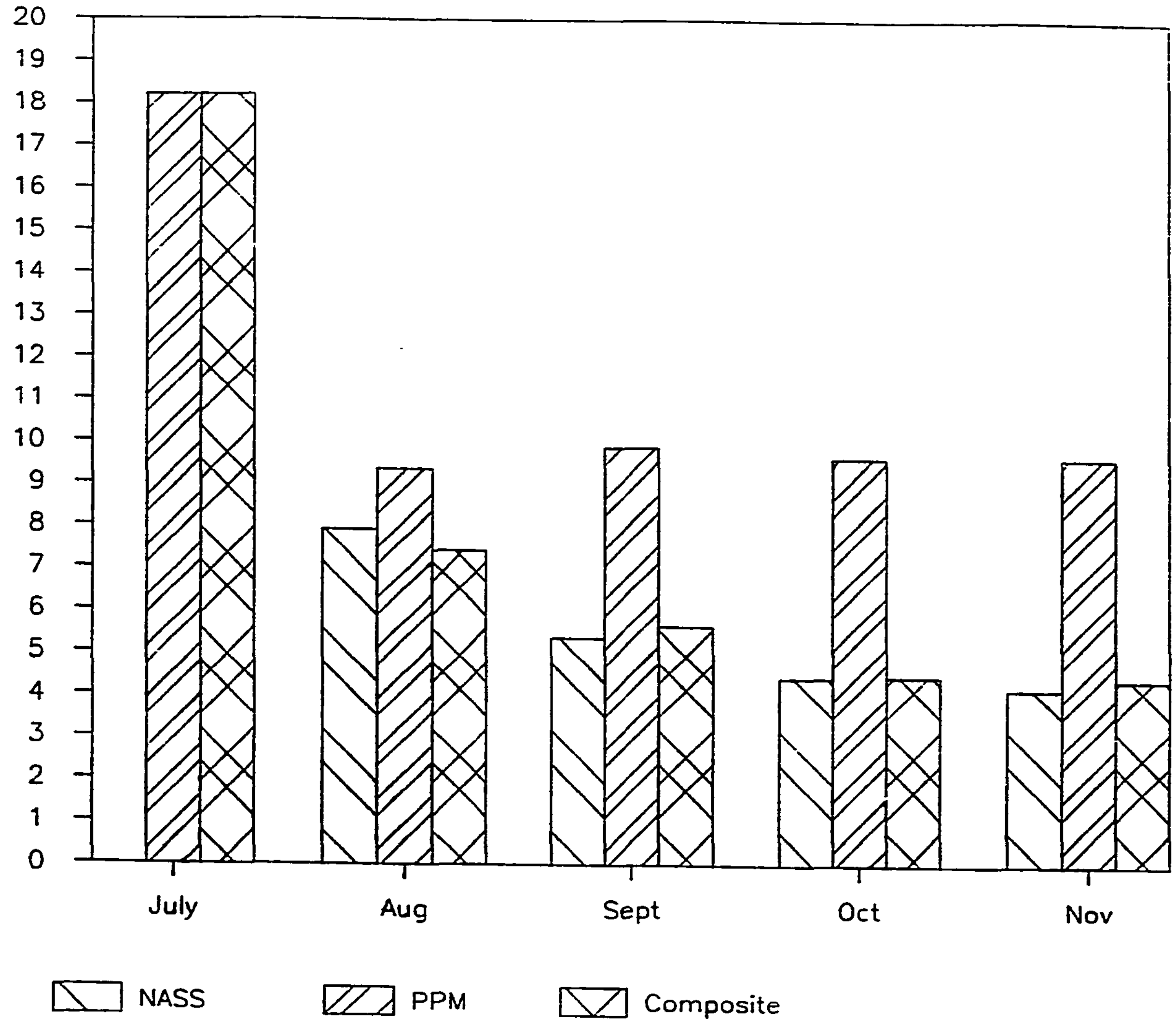


Figure 46. Root mean square error comparisons, Southwest district

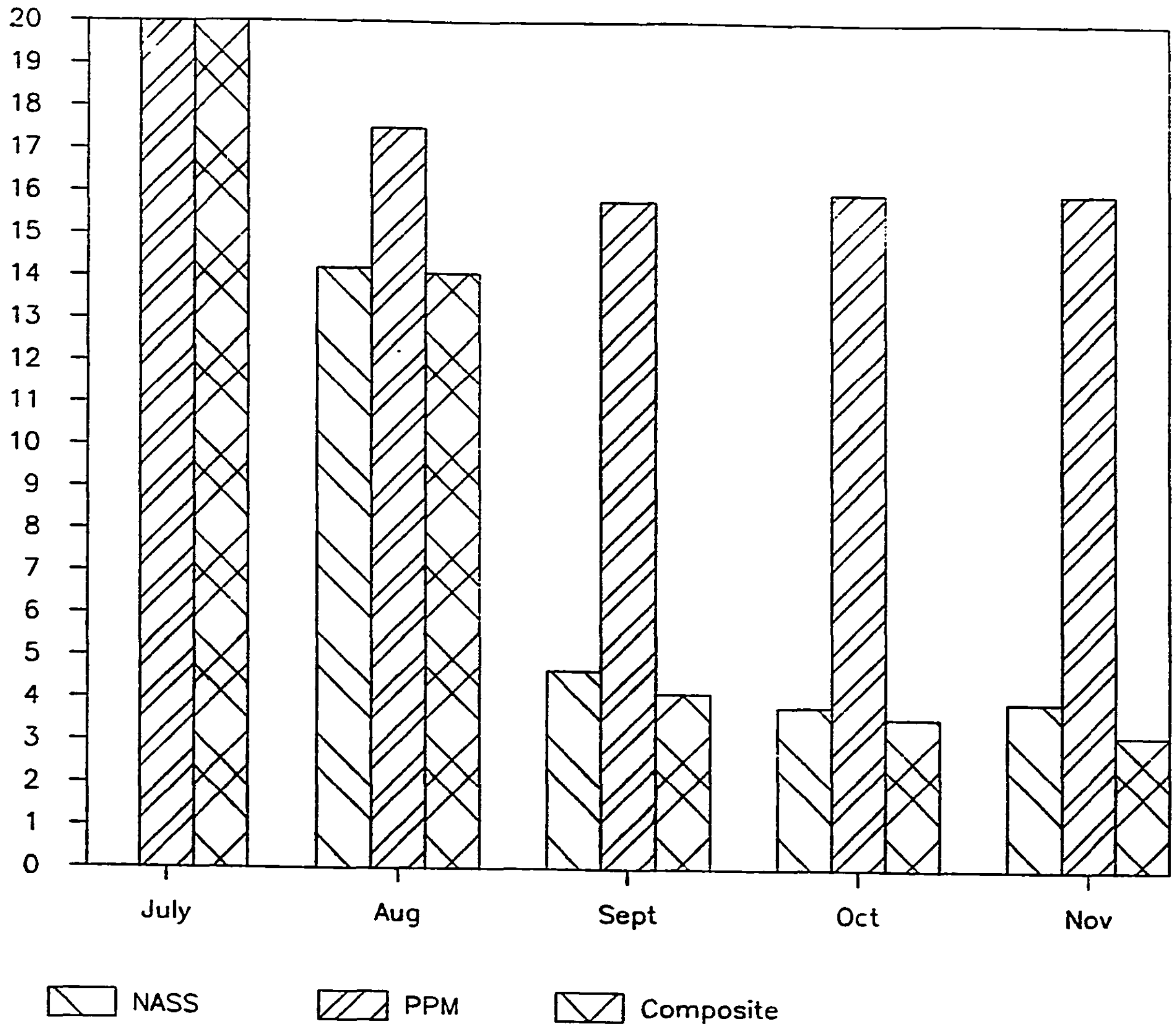


Figure 47. Root mean square error comparisons, South Central district

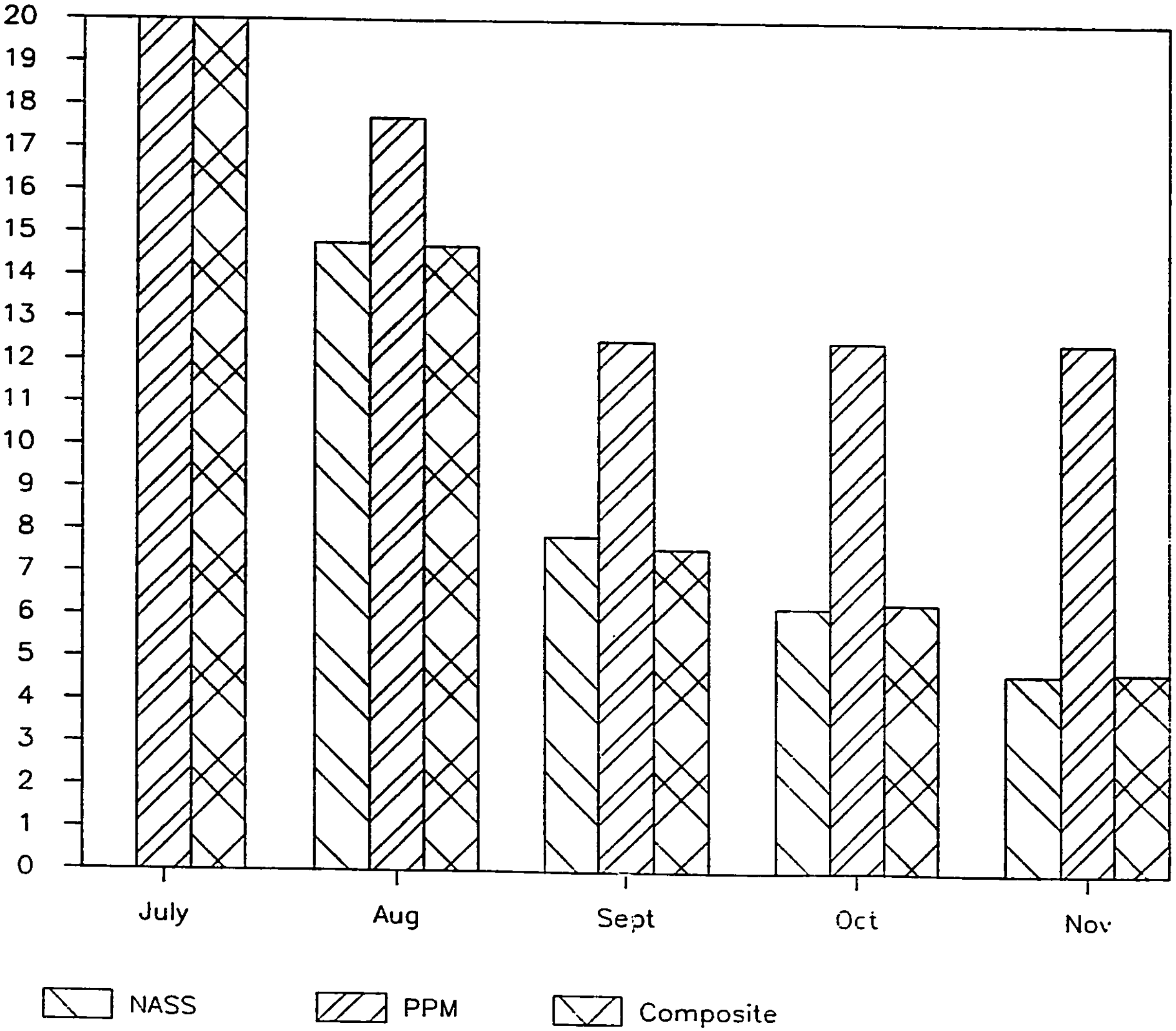


Figure 48. Root mean square error comparisons, Southeast district

the PPM. Top-down composite weights are shown in Table 51. Of course the entire weight of the July forecast was on the PPM forecast since no NASS forecasts were made in July. A significant was, however, also on the August and September PPM forecasts. This indicated a significant contribution from the PPM for the forecast dates in those months.

In order to conserve space, top-down composite forecasts are not shown here. RMSE results are, however, reported. Table 52 shows the RMSE results for the top-down composite forecasts. RMSE values for July were, of course, the same as those for the PPM forecast since no NASS forecasts were made in August. The RMSEs for the top-down state composite forecasts were more reliable than the bottom-up state composite forecasts. This was not surprising since the top-down state forecasts were composites of aggregations and the bottom-up forecasts were aggregations of composites. Aggregation errors were not as large using the former approach.

In general, district forecasts had larger errors using the top-down approach compared to the bottom-up approach. Top-down district forecasts were, however, better than PPM forecasts alone in most districts. For October and November forecasts, RMSEs for the top-down forecasts were large compared to NASS forecasts. The district composites for

Table 51. Top-down composite forecast weights on the PPM and NASS forecasts for five forecast dates

Crop Reporting District	Forecast Dates				
	July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1
Iowa					
PPM	1.00	0.61	0.46	0.11	0.12
NASS	0.00	0.39	0.54	0.89	0.88

Table 52. Root mean square errors for the top-down composite corn yield forecasts for five forecast dates by crop reporting district in Iowa

Crop Reporting District	Forecast Dates				
	July 1	Aug. 1	Sept. 1	Oct. 1	Nov.1
Northwest	18.77	14.82	7.24	7.45	6.99
North Central	15.52	8.53	3.17	5.76	6.44
Northeast	14.46	8.53	6.08	7.86	8.77
West Central	18.13	7.59	6.65	7.96	7.24
Central	14.27	9.84	6.95	7.97	8.64
East Central	16.58	10.19	5.69	6.70	7.35
Southwest	18.20	7.96	8.45	9.07	8.34
South Central	22.10	15.65	13.38	13.98	12.29
Southeast	24.96	15.99	11.05	11.23	10.74
Iowa	14.97	9.68	4.03	3.43	1.88

November had RMSEs ranging from slightly under seven to slightly over twelve.

Results of the top-down composites indicated two conclusions. PPM forecasts combined with NASS forecasts resulted in better state forecasts. The most significant improvement was for the August forecast. In general, the top-down district forecasts were better than PPM district forecasts but not better than NASS district forecasts. In the southern districts, large errors existed even in early forecasts compared with NASS forecasts.

Summary of Forecast Results

In this chapter, results of NASS, PPM, and composite forecasts have been reported and compared. Several observations can be summarized.

- NASS corn yield forecast errors at the district and state level generally decline as the growing season progresses. Errors in the November forecasts are primarily sampling errors.
- NASS forecast errors are significantly higher for August forecasts compared to even the September forecast.
- NASS forecast errors are generally higher in the South Central and Southeast districts, especially early in the season.

- PPM corn yield forecast errors at the district and state level also generally decline as the growing season progresses. Improvements in forecasts, however, are only slight after the September forecast.
- PPM forecasts made in July contain significant error. Calibration results also indicate that July PPM perform poorly.
- In four of the nine districts (North Central, Northeast, West Central, and East Central), the August PPM forecasts outperformed the NASS forecasts based upon RMSE calculations.
- PPM forecasts performed significantly worse than NASS forecasts in October and November.
- PPM forecasts were derived from <u>ex post</u> calibrations whereas NASS forecasts were derived from <u>ex ante</u> calibrations. As a result, PPM forecasts reliability may be biased upward.
- Combining PPM and NASS forecasts using the bottom-up resulted in more reliable district composite forecasts.
- Composite forecast weights were generally high on the PPM forecasts in the August and September forecasts but very low in the October and November forecasts.
- The top-down composite approach resulted in district forecasts that were generally more reliable than PPM

district forecasts but less reliable than bottom-up composite forecasts.

The following conclusions are drawn from the forecast results.

- Based upon historical reliability, it is not likely that NASS would adopt PPM district forecasts as a replacement for district forecasts discontinued in 1987. PPM forecasts were shown to be almost as reliable if not more reliable than NASS forecasts in several districts but only for the early season (August and September) forecasts.
- Use of the PPM as a source of July forecsts is also not likely without further refinements to the PPM.
- Combining forecasts from the PPM and from NASS sample surveys appears to be a potentially useful approach to deriving district forecasts. If the discontinued mail surveys were reinstated and district forecasts were begun again, these could be combined with PPM district forecasts. Another approach would be to combine PPM forecasts with NASS district yield information from the objective yield surveys alone.
- Out-of-sample testing of the PPM corn yield forecasts needs to be pursued.

CHAPTER VI. ECONOMIC VALUATION OF PPM CORN YIELD FORECASTS

The valuation of PPM corn yield forecasts is essentially an economics of information problem. The effect of information is to potentially influence the decisions and actions of market participants. Information, therefore, should be used if the value of the increase in the expected well-being of the users exceeds the cost of obtaining the information. In the context of this study, Does the added information of the PPM forecasts increase the well-being of the users more than it costs to generate the forecasts? The first step in valuing improvements in Iowa's state and district corn yield forecasts is to identify the users of the forecasts.

Users of State and District Corn Yield Forecasts

Five broad categories of users of state and district corn yield and production forecasts are identified. These users include producers, inventory holders, suppliers of transportation, other agricultural input suppliers, and consumers. Within each category, market participants are affected by local corn supply and demand conditions and/or by the interspacial forces of supply and demand within, say, the state. Expectations of future supply and demand conditions at the local level influence the decisions of agents in each category.

The production decisions of corn producers are based partially upon expectations of the future prices they will receive for their crops. Even though producers follow very closely the general level of prices on the futures markets, it is the future local cash price that they must ultimately anticipate. Local cash prices are, among other things, influenced by local supply conditions. Given that producers can adjust production levels and for marketing plans during the growing season, corn yield forecasts for their respective locality may be useful for helping form local price expectations and altering production and marketings.

For two reasons, however, the benefit of local or district yield and production forecasts to producers is likely to be small. First of all, producers are not likely to alter production levels significantly during the course of the growing season. Slight changes could conceivable occur through adjustments in pesticide treatments and so forth, but acreage is the primary production decision variable, and that variable is not likely to be altered significantly after planting. The second reason for limited value to the producer is that in today's environment of government commodity program's, prices received by producers are influenced much more significantly by government program parameters such as support and target prices than by local cash prices.

Inventory holders are another group of potential users of district yield and production forecasts. Inventory holders include farmers, both grain producers and livestock feeders; grain elevators; processors; and others. Inventory holders often protect themselves from large movements in the general price level by hedging their inventories. Storage income can also be earned through skillful hedging. In fact, many grain elevators depend on storage income earned through hedging activities. The essence of hedging is speculation in basis, the difference between local cash price and a specified futures contract price (Hieronymus, 1971). Expectations of basis levels are influenced by expectations of future cash prices which are influenced partially by expectations of local supply conditions. Reliable local production forecasts are needed for forming profitable hedging strategies.

Transporters of grain can use spacial crop production forecasts to plan in advance the allocation and placement of hopper cars in the country-side and barges on the rivers. Pricing of some transportation services could also be tied to expectations of the allocation of grain supplies.

Agricultural input suppliers are also concerned about the spactial distribution of production of corn and other crops. Some seed companies link local cash prices with the payments that are made to seed corn growers. The seed companies typically must hedge their seed crops to minimize the risk of local price flucuations. Since they are hedgers, expectations about basis movements are very important. Suppliers of fuel used for drying corn also need to be aware of where demand is going to be strong and where it will not be strong.

Consumers of corn are also concerned about the spactial distribution of production. This group primarily includes livestock producers and processors. If local areas are expected to run short on corn supplies, for example, alternative areas must be considered. Transportation and other costs may become important factors in the decision processes of these consumers.

The preceeding discussion provides a sketch of the potential users of localized corn production forecasts. There seems to be a potential putting reliable crop reporting district yield and production forecasts to good use. It follows then that increasing the reliability of the information provide by these forecasts would increase their usefulness and value. Two different approaches to accessing the value of information are genrally discussed in the literture. These approaches focus on the market level valuation and the individual valuation. Both approaches are reviewed here.

Market Valuation

At the market level, the social value of information is of interest. Assessing the social value of information has typically been done using a Marshallian framework. In this framework, the area under the market demand curve represents social welfare, and the area under the market supply curve represents social cost. Changes in social welfare and social cost due to new or improved information are generally shown to result from better inventory and/or production decisions. The extent of the improvements in welfare or reductions in cost are related to the elasticities of market supply and demand. Well known applications of this approach include Hayami and Peterson (1972) and Bradford and Kelejian (1977).

Although the market-level approach to valuing information has proven useful in some applications, it does not seem to be the appropriate framework for evaluating improvements in district- and state-level yield and production forecasts. Improvements in state and district yield and production forecasts would need to be generalized to the aggregate market level. Also problems exist with interpreting how market agents use the forecasts (Bradford and Kelejian, 1977). A more appropriate framework for valuing improved state and district corn yield and production forecasts seems to at the individual level.

Individual Valuation

The individual valuation framework is built around the theory of decision under uncertainty. Within this framework, information is viewed as a factor in the decision process which can be used to reduce the level of uncertainty (Johnson and Holt, 1986). Decision-makers are assumed to try to optimize some objective function. Assuming risk neutrality, the decision-maker may be trying to maximize profit or minimize loss. Under risk-aversion a utility function can be maximized (Baquet et al., 1976).

Using the expected utility theorem of von Neumann and Morgenstern (1944) and also Bayes' Theorem of probability, the decision problem can be developed in the following way. Individuals are faced with a set of possible actions a_j ($j=1,...,J$) and a set of possible states of the world θ_i ($i=1,...,I$. Consequences, x_{ij}, of these actions and states are assumed to be known by the individual, and he/she is assumed to have the ability to rank the possible consequences. This is to say that the individual is assumed to have a utility $U(x_{ij})$ associated with each set of possible actions and consequences. The uncertainty in the problem is associated with the probability of realizing the different states of nature. The individual is assumed to have some feeling about the chances of realizing each state. That is, he/she is assumed to have a prior probability distribution $P(\theta_i)$ associated with the possible states. The decision problem is one of choosing the optimal course of action -- one that maximizes expected utility. This can be expressed as:

$$\max E[U(x_j)] = \max \sum_{i=1}^{I} U(x_{ij})\ P(\theta_i) \tag{6.1}$$

where $E[U(x_j)]$ is expected utility. Maximizing equation (6.1) gives the prior optimal action a_j^*.

Assume now that a forecast is available to the individual. The forecast provides more information on the probabilities of the states of the world. The information provided by the forecast is represented by a likelihood function $P(z_k|\theta_i)$ which is a conditional probability of observing the forecast z_k given that the particular state i prevails (Anderson et al., 1980). The forecast then provides a basis for revising the probabilities attached to the states of the world. Using Bayes' Theorem, the prior probabilities and the likelihood function can be combined to form a posterior probability distribution $P(\theta_i|z_k)$. The posterior probability is expressed as:

$$P(\theta_i|z_k) = P(\theta_i)\ P(z_k|\theta_i)/P(z_k) \tag{6.2}$$

where $P(z_k|\theta_i)$ is the joint probability of θ_i and z_k and $p(z_k)$ is the unconditional probability of the occurrence of the forecast z_k (Anderson et al., 1980).

Therefore, with the new information provided by the forecast, the individual pocesses a revised set of probabilities on the states of nature. The decision problem now facing the individual is:

$$\max U(a_j|z_k) = \sum_{i=1}^{I} U(x_{ij} - c)\ P(\theta_i|z_k) \qquad (6.3)$$

where c is the cost of the forecast. Maximizing equation (6.3) gives the posterior optimal action a_{jk}^{**}.

In an ex post sense, the utility or value of the forecast is the difference between the utility of the prior action a_j^* and the utility of the posterior action a_{jk}^{**}. The maximum amount that should be paid for the forecast is clearly equal to an amount that would make a_j^* and a_{jk}^{**} equal.

Using the framework described above, the ex post value of a forecast can theoretically be determined. The information needed includes (1) knowledge of which individuals use the forecasts, (2) consequence functions and utility functions of each user, (3) the prior probability distribution of each user, (4) the likelihood function of the forecast, and (5) the cost of the forecast.

Cost of PPM Operation

Real-time operation of the plant-process corn yield forecasting model is relatively inexpensive. Below are annual cost estimates for operating the model on a real-time basis. These estimates are based upon experience in running the model in this study and on judgements. These estimates do not include development costs for the model. It is assumed that weather data will be retrieved on a weekly basis and that five monthly forecasts will be made during the growing season. The cost estimates are as follows:

Data retrieval and storage:	
Tape mounts - 52 @ $2.00/mount	$ 104.00
Disk space	
Weather data - 1200 tracks for five days	60.00
Programs - 100 track for 365 days	370.00
Misc.	30.00
Phone-line charges - 52 @ $10.00/dial-up	520.00
Computer CPU charges	
Data	1,000.00
Model execution (5 forecasts/year)	1,000.00
Labor - 300 hours/year @ $20.00/hour	6,000.00
Misc. cost	1,000.00
Total cost	$10,084.00

Clearly, the costs of operating the PPM are insignificant compared to the potential value to users of district corn yield forecasts. To put things into proper perspective, a medium-sized local elevator, say with one million bushels of storage capacity, would only have to save $0.01 per bushel in average storage hedges in order to offset the cost of operating the PPM yield forecasting model.

CHAPTER VII. SUMMARY AND IMPLICATIONS FOR IMPLEMENTATION

The purpose of this study was to investigate the potential use of plant-process models (PPM) as a source of corn yield forecasts for Iowa. More specifically, the objective was to develop a plant-process corn yield forecasting model and examine how effective these forecasts might be in improving corn yield forecasts made at the state and crop reporting district in Iowa. This investigation was made in light of recent budget cuts by the National Agricultural Statistics Service (NASS) and the elimination of the reporting of crop reporting district yield forecasts in Iowa. The conjecture was that PPMs utilize a rich source of weather, soil, and other information that may produce reliable yield forecasts at a localized level. Also, PPMs are flexible so that forecasts could be generated at any time during the growing season. Further, combining PPM and NASS forecast information may lead to composite forecasts that are more reliable than either of the two individual forecasts.

Plant-process model corn yield forecasts were generated at the district and state level for the period 1975 through 1984. Forecasts were made for the dates July 1, August 1, September 1, October 1, and November 1. These forecasts were compared and combined with NASS forecasts for the same period. Performance of PPM and composite forecasts relative to NASS forecasts was judged primarily on the root mean squared errors (RMSEs) of the forecasts.

The performance of individual PPM corn yield forecasts varied depending upon the date and the district of the forecast. In general, PPM forecast errors were largest in July and lowest in October and November. Little improvement in forecast reliability was shown, however, after the September forecast. July PPM forecast errors were large in all districts and also for the state. The July forecasts generally performed poorly. The August PPM forecasts, on the other hand, performed relatively well. Compared to NASS forecasts, the PPM forecasts had lower RMSEs in four of nine districts. The August PPM forecasts did not, however, perform particularly well in the southern districts. September PPM forecasts were out-preformed by the NASS forecasts in all but one district. The October and November forecasts for NASS were, however, significantly better than PPM forecasts for those months.

Combining PPM and NASS district forecasts resulted in improved forecasts over the historical period. The most significant improvement was in the months of August and September. Much less improvement was shown for October and November. Improvements were a result of the diversification effect of combining the forecasts. Less of the diversification effect was shown for the southern districts.

Combining PPM and NASS forecasts at the district level (the bottom-up approach) could be done if NASS begins making again the district forecasts that were discontinued in 1987. The alternative would be to combine PPM forecasts with NASS district forecasts that are based only on objective yield survey information. This approach was not done in this study since objective yield information was not available. Combining forecasts at the state level and disaggregating to the district level (the top-down approach) gave results that were only marginally better than the PPM forecasts alone.

Several conclusions can be drawn from the results of this study. On its own and at its present state of development, the CERES-Maize PPM is not likely to be a comparable replacement for the district corn yield forecasts that were discontinued in Iowa in 1987. The PPM did comparatively well in the early season but not later in the growing season. Furthermore, the PPM did not perform well in the southern districts of Iowa. Enhancements and refinements of input data might be a way of improving the performance of the PPM.

As a source of July forecast information, the PPM is limited. The reliability of July PPM forecasts was low. Incorporation of weather forecasting information into the model may prove useful to improving the performance of July, as well as other months', forecasts.

The value of the PPM seems to come from combining PPM forecasts with NASS forecasts, especially for the months of August and September. If NASS district yield forecasts are not started again, the possibility of combining PPM forecasts with objective yield survey information obtained at the district level should be investigated. There are indications, however, that combining the two independent sources of forecast information is a potentially useful approach to improving, at the very least, August corn yield forecasts.

Costs associated with operating the plant-process corn yield forecasting model are low. Most of the data requirements for the model are collected on a routine basis. Most expenses would be in data storage, computer time, and labor. Based upon operation costs in this study, the annual cost of maintaining and operating the model would be less than $10,000 per year. Costs would increase somewhat if the frequency of the forecasts was increased.

Some constaints to implimenting the plant-process forecasting model do exist. The most important factor is the timely collection and processing of weather data. Cooperative station weather data is not currently contained in a real-time data system. Cooperative weather data for Iowa is sent to the National Oceanic and Atmospheric Administration (NOAA) at weekly intervals. Further, the data is not "cleaned" by replacing missing observations or outliers. A data retrieval system would need to be developed that would allow close to real-time access to daily weather observations. Procedures for cleaning the data would need to be implemented also. Given a demand for a real demand for the cooperative weather data, the current problems associated with data availability could likely be overcome.

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APPENDIX: SELECTED DATA AND RESULTS

Table A.1. Harvested corn acres in Iowa by county, 1975-1979

County Name	County No.	1975	1976	1977	1978	1979
			thousand acres			
Northwest District						
Buena Vista	21	163.5	163.5	162.9	167.0	169.0
Cherokee	35	139.5	139.5	141.5	148.0	146.0
Clay	41	142.9	142.9	139.8	142.0	147.0
Dickinson	59	90.5	90.5	87.7	95.0	96.0
Emmet	63	106.2	106.2	102.2	104.0	106.0
Lyon	119	138.7	138.7	149.1	154.0	169.0
O'Brien	141	157.2	157.2	151.8	163.0	155.0
Osceola	143	104.0	104.0	102.5	106.0	110.0
Palo Alto	147	159.6	159.6	151.0	154.0	155.0
Plymouth	149	223.2	223.2	225.3	235.0	244.0
Pocahontas	151	159.6	159.6	152.4	158.0	162.0
Sioux	167	194.1	194.1	217.8	234.0	241.0
Total		1779.0	1779.0	1784.0	1860.0	1900.0
North Central District						
Butler	23	170.7	170.7	164.1	168.0	169.0
Cerro Gordo	33	177.8	177.8	158.8	151.0	151.0
Floyd	67	130.7	130.7	123.0	126.0	128.0
Franklin	69	169.9	169.9	159.9	167.0	171.0
Hancock	81	166.8	166.8	163.7	163.0	162.0
Humboldt	91	122.6	122.6	122.3	127.0	125.0
Kossuth	109	268.1	268.1	254.9	268.0	274.0
Mitchell	131	118.6	118.6	114.3	120.0	119.0
Winnebago	189	117.7	117.7	109.1	108.0	114.0
Worth	195	117.7	117.7	113.7	110.0	110.0
Wright	197	168.4	168.4	164.2	174.0	177.0
Total		1729.0	1729.0	1648.0	1682.0	1700.0
Northeast District						
Allamakee	5	64.9	64.9	69.6	75.0	75.0
Black Hawk	13	141.7	141.7	143.0	146.0	146.0
Bremer	17	114.4	114.4	108.4	109.0	110.0
Buchanan	19	169.1	169.1	164.8	156.0	165.0
Chickasaw	37	113.0	113.0	108.8	115.0	115.0
Clayton	43	131.0	131.0	138.6	147.0	148.0
Delaware	55	152.7	152.7	158.1	162.0	168.0
Dubuque	61	106.6	106.6	112.5	115.0	124.0
Fayette	65	170.3	170.3	171.2	174.0	179.0
Howard	89	92.4	92.4	92.0	99.0	100.0
Winneshiek	191	116.9	116.9	119.0	128.0	130.0
Total		1373.0	1373.0	1386.0	1426.0	1460.0

Table A.1. (continued)

County Name	County No.	1975	1976	1977	1978	1979
				thousand acres		
West Central District						
Audubon	9	115.8	115.8	110.7	122.0	124.0
Calhoun	25	157.3	157.3	152.1	150.0	155.0
Carroll	27	155.7	155.7	139.4	154.0	160.0
Crawford	47	174.9	174.9	167.2	167.0	181.0
Greene	73	164.1	164.1	144.8	153.0	157.0
Guthrie	77	102.3	102.3	104.1	105.0	106.0
Harrison	85	170.6	170.6	166.8	158.0	166.0
Ida	93	125.7	125.7	125.9	131.0	128.0
Monona	133	167.5	167.5	163.4	172.0	162.0
Sac	161	155.0	155.0	160.1	155.0	169.0
Shelby	165	176.5	176.5	168.8	168.0	182.0
Woodbury	193	235.6	235.6	237.7	242.0	260.0
Total		1901.0	1901.0	1841.0	1877.0	1950.0
Central District						
Boone	15	158.1	158.1	153.9	151.0	153.0
Dallas	49	159.6	159.6	154.5	149.0	154.0
Grundy	75	163.0	163.0	151.7	155.0	150.0
Hamilton	79	177.7	177.7	168.5	167.0	165.0
Hardin	83	176.6	176.6	175.3	166.0	162.0
Jasper	99	175.0	175.0	171.4	170.0	170.0
Marshall	127	168.9	168.9	159.7	150.0	156.0
Polk	153	118.0	118.0	119.7	110.0	114.0
Poweshiek	157	127.7	127.7	130.1	130.0	125.0
Story	169	157.2	157.2	155.6	158.0	164.0
Tama	171	178.2	178.2	179.7	177.0	174.0
Webster	187	189.0	189.0	180.9	179.0	183.0
Total		1949.0	1949.0	1901.0	1862.0	1870.0
East Central District						
Benton	11	176.6	176.6	172.1	185.0	173.0
Cedar	31	168.8	168.8	171.7	182.0	177.0
Clinton	45	201.5	201.5	201.0	204.0	210.0
Iowa	95	139.0	139.0	143.9	139.0	142.0
Jackson	97	94.7	94.7	97.0	100.0	104.0
Johnson	103	137.0	137.0	138.5	135.0	144.0
Jones	105	135.2	135.2	136.4	140.0	142.0
Linn	113	159.8	159.8	157.3	147.0	152.0
Muscatine	139	96.9	96.9	92.8	101.0	97.0
Scott	163	129.5	129.5	127.3	135.0	134.0
Total		1439.0	1439.0	1438.0	1468.0	1475.0

Table A.1. (continued)

County Name	County No.	1975	1976	1977	1978	1979
				thousand acres		
Southwest District						
Adair	1	108.8	108.8	109.9	109.0	116.0
Adams	3	68.3	68.3	68.0	67.0	73.0
Cass	29	130.8	130.8	135.1	135.0	144.0
Fremont	71	118.7	118.7	122.0	120.0	120.0
Mills	129	98.6	98.6	94.4	100.0	103.0
Montgomery	137	94.9	94.9	95.5	96.0	105.0
Page	145	108.8	108.8	106.5	107.0	112.0
Pottawattamie	155	221.1	221.1	223.4	220.0	214.0
Taylor	173	67.0	67.0	74.2	71.0	78.0
Total		1017.0	1017.0	1029.0	1025.0	1065.0
South Central District						
Appanoose	7	40.1	40.1	39.4	37.0	37.0
Clarke	39	37.1	37.1	39.5	44.0	44.0
Decatur	53	44.2	44.2	45.0	46.0	45.0
Lucas	117	43.5	43.5	39.8	41.0	43.0
Madison	121	85.2	85.2	81.8	83.0	89.0
Marion	125	89.6	89.6	67.1	79.0	82.0
Monroe	135	43.2	43.2	41.2	40.0	42.0
Ringgold	159	65.1	65.1	62.1	62.0	65.0
Union	175	55.4	55.4	51.8	53.0	57.0
Warren	181	86.4	86.4	76.6	86.0	85.0
Wayne	185	63.2	63.2	65.7	61.0	61.0
Total		653.0	653.0	610.0	632.0	650.0
Southeast District						
Davis	51	62.1	62.1	62.1	58.0	60.0
Des Moines	57	93.6	93.6	91.9	93.0	93.0
Henry	87	105.5	105.5	104.9	99.0	102.0
Jefferson	101	79.8	79.8	82.9	74.0	73.0
Keokuk	107	132.9	132.9	135.0	132.0	126.0
Lee	111	95.2	95.2	89.1	81.0	83.0
Louisa	115	82.9	82.9	84.8	83.0	86.0
Mahaska	123	143.0	143.0	135.8	131.0	135.0
Van Buren	177	59.8	59.8	58.1	55.0	58.0
Wapello	179	64.2	64.2	65.7	62.0	63.0
Washington	183	141.0	141.0	152.7	150.0	151.0
Total		1060.0	1060.0	1063.0	1018.0	1030.0
State Total		12900.0	12900.0	12700.0	12850.0	13100.0

Table A.2. Harvested corn acres in Iowa by county, 1980-1984

County Name	County No.	1980	1981	1982	1983	1984
				thousand acres		
Northwest District						
Buena Vista	21	170.0	175.6	164.6	107.1	157.0
Cherokee	35	143.0	155.6	147.3	86.8	136.7
Clay	41	152.0	158.8	156.8	87.1	131.5
Dickinson	59	94.0	103.0	94.9	56.0	89.3
Emmet	63	110.0	113.0	118.0	76.2	118.7
Lyon	119	164.0	155.7	153.4	111.2	155.2
O'Brien	141	150.0	162.4	157.9	112.4	157.5
Osceola	143	109.0	112.1	106.7	62.7	102.4
Palo Alto	147	160.0	170.6	161.8	100.0	164.3
Plymouth	149	234.0	236.0	233.0	155.4	231.4
Pocahontas	151	169.0	174.8	169.9	97.4	153.4
Sioux	167	236.0	250.0	225.7	142.7	218.4
Total		1891.0	1967.6	1890.0	1195.0	1815.8
North Central District						
Butler	23	169.0	175.7	163.7	104.0	169.7
Cerro Gordo	33	159.0	170.0	168.4	114.8	163.7
Floyd	67	133.0	138.0	134.2	80.3	139.6
Franklin	69	179.0	183.2	180.1	106.8	165.9
Hancock	81	166.0	175.2	171.4	98.6	166.3
Humboldt	91	127.0	131.3	126.7	76.6	120.6
Kossuth	109	276.0	290.3	280.3	180.3	261.3
Mitchell	131	122.0	124.2	126.9	81.6	117.8
Winnebago	189	116.0	129.5	119.1	79.6	119.0
Worth	195	116.0	114.6	111.0	71.1	113.4
Wright	197	179.0	171.9	163.2	102.3	163.6
Total		1742.0	1803.9	1745.0	1096.0	1700.9
Northeast District						
Allamakee	5	76.0	88.7	85.8	51.3	78.6
Black Hawk	13	152.0	152.6	142.4	105.3	161.3
Bremer	17	117.0	127.6	115.5	69.7	116.3
Buchanan	19	166.0	178.0	171.0	129.4	180.4
Chickasaw	37	121.0	135.5	135.5	80.9	135.4
Clayton	43	150.0	163.5	157.7	110.7	167.7
Delaware	55	171.0	178.9	177.8	123.2	175.3
Dubuque	61	127.0	132.0	129.0	93.2	121.0
Fayette	65	188.0	192.4	181.8	117.2	182.0
Howard	89	108.0	116.6	104.1	72.4	113.6
Winneshiek	191	141.0	145.8	137.4	83.7	135.9
Total		1517.0	1611.6	1538.0	1037.0	1567.5

Table A.2. (continued)

County Name	County No.	1980	1981	1982	1983	1984
				thousand acres		
West Central District						
Audubon	9	128.0	127.2	123.9	85.5	117.3
Calhoun	25	158.0	159.5	158.8	104.0	172.5
Carroll	27	160.0	163.9	159.1	103.5	151.8
Crawford	47	180.0	173.3	162.8	114.5	160.9
Greene	73	163.0	155.8	151.5	89.7	132.2
Guthrie	77	111.0	119.2	120.4	73.0	121.1
Harrison	85	170.0	175.3	165.1	96.0	155.9
Ida	93	124.0	129.9	125.7	82.5	132.4
Monona	133	164.0	183.8	174.7	120.5	154.7
Sac	161	169.0	163.4	159.0	111.7	148.2
Shelby	165	182.0	184.8	177.9	109.0	179.2
Woodbury	193	251.0	270.7	239.2	132.1	199.3
Total		1960.0	2006.8	1918.1	1222.0	1825.5
Central District						
Boone	15	154.0	151.5	148.3	87.4	127.1
Dallas	49	160.0	150.3	145.8	92.7	146.5
Grundy	75	152.0	159.5	158.9	101.2	154.2
Hamilton	79	170.0	169.8	159.6	98.7	138.7
Hardin	83	169.0	174.4	171.1	120.1	170.3
Jasper	99	174.0	180.4	169.4	117.7	173.6
Marshall	127	161.0	162.9	154.0	95.5	145.2
Polk	153	110.0	116.7	101.2	66.8	95.0
Poweshiek	157	131.0	140.6	145.6	87.5	123.1
Story	169	170.0	160.8	145.5	96.7	160.7
Tama	171	176.0	190.3	181.4	107.7	179.0
Webster	187	189.0	188.3	175.1	119.0	157.6
Total		1916.0	1945.5	1855.9	1191.0	1771.0
East Central District						
Benton	11	175.0	180.7	181.3	122.1	190.0
Cedar	31	179.0	182.8	184.4	111.1	159.6
Clinton	45	209.0	213.8	215.3	152.0	227.3
Iowa	95	146.0	162.9	154.2	95.1	146.4
Jackson	97	107.0	129.1	122.1	72.5	108.0
Johnson	103	147.0	149.1	149.1	107.3	143.4
Jones	105	143.0	156.9	151.8	105.0	156.5
Linn	113	152.0	162.9	152.7	103.3	152.5
Muscatine	139	102.0	107.7	104.0	75.9	127.6
Scott	163	136.0	143.7	148.0	112.7	141.7
Total		1496.0	1589.6	1562.9	1057.0	1553.0

Table A.2. (continued)

County Name	County No.	1980	1981	1982	1983	1984
				thousand acres		
Southwest District						
Adair	1	116.0	120.1	114.9	73.2	113.5
Adams	3	74.0	79.6	68.3	45.7	60.8
Cass	29	129.0	141.1	136.1	83.9	118.3
Fremont	71	112.0	112.5	100.7	69.2	104.0
Mills	129	103.0	114.1	102.2	61.4	98.2
Montgomery	137	97.0	96.3	85.7	59.8	84.2
Page	145	113.0	103.2	95.3	68.4	93.0
Pottawattamie	155	245.0	241.2	219.5	147.2	246.9
Taylor	173	81.0	83.6	71.4	55.2	75.1
Total		1070.0	1091.7	994.1	664.0	994.0
South Central District						
Appanoose	7	38.0	41.3	34.6	19.5	32.0
Clarke	39	43.0	55.6	49.3	30.6	41.2
Decatur	53	48.0	57.1	51.1	31.9	52.4
Lucas	117	43.0	48.0	40.1	24.6	38.8
Madison	121	88.0	87.3	75.9	55.8	91.7
Marion	125	88.0	89.8	77.0	47.6	74.2
Monroe	135	35.0	38.0	32.8	21.6	38.5
Ringgold	159	62.0	63.6	54.7	32.5	62.4
Union	175	57.0	62.1	49.4	37.8	56.4
Warren	181	87.0	94.9	78.7	55.3	92.2
Wayne	185	64.0	78.0	66.4	37.8	71.5
Total		653.0	715.7	610.0	395.0	651.3
Southeast District						
Davis	51	55.0	63.5	52.7	32.3	50.4
Des Moines	57	93.0	96.5	92.7	66.4	101.9
Henry	87	106.0	112.7	103.9	72.9	95.1
Jefferson	101	76.0	83.4	76.9	48.7	86.6
Keokuk	107	132.0	140.5	127.3	85.5	116.9
Lee	111	86.0	88.3	87.7	54.0	96.9
Louisa	115	97.0	106.1	97.7	66.5	97.1
Mahaska	123	136.0	135.1	127.6	90.6	120.7
Van Buren	177	58.0	64.2	57.5	34.3	57.1
Wapello	179	65.0	67.4	59.3	32.9	50.5
Washington	183	151.0	159.9	152.7	108.9	147.8
Total		1055.0	1117.6	1036.0	693.0	1021.0
State Total		13300.0	13850.0	13150.0	8550.0	12900.0

Table A.3. Uncalibrated PPM corn yield forecasts for five forecast dates and actual corn yields by crop reporting district, 1975

Crop Reporting District	Forecast Date July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	Actual Yield
	bushels per acre					
Northwest	123.9	90.3	90.8	90.8	90.8	88
North Central	128.1	105.1	97.8	97.8	97.8	95
Northeast	124.0	106.6	93.2	92.9	92.9	93
West Central	119.5	97.4	95.4	95.4	95.4	85
Central	134.0	117.0	110.8	110.8	110.8	98
East Central	124.8	122.9	124.9	124.9	124.9	100
Southwest	114.3	72.9	60.0	60.0	60.0	68
South Central	113.2	74.6	62.5	62.5	62.5	74
Southeast	121.1	92.2	87.2	87.2	87.2	93
Iowa						90

[a]Based on revised final estimate.

Table A.4. Uncalibrated PPM corn yield forecasts for five forecast dates and actual corn yields by crop reporting district, 1976

Crop Reporting District	Forecast Date July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	Actual Yield
	bushels per acre					
Northwest	111.3	78.8	64.3	63.3	63.3	73
North Central	114.6	69.4	68.7	68.5	68.5	93
Northeast	123.1	108.0	109.3	109.9	109.9	91
West Central	103.2	75.4	55.7	55.7	55.7	71
Central	126.0	106.8	89.8	89.3	89.3	104
East Central	125.6	113.9	110.3	109.9	109.9	102
Southwest	110.3	89.3	85.1	85.1	85.1	99
South Central	105.1	76.8	79.4	79.4	79.4	95
Southeast	118.2	105.8	109.0	109.0	109.0	107
Iowa						91

[a]Based on revised final estimate.

Table A.5. Uncalibrated PPM corn yield forecasts for five forecast dates and actual corn yields by crop reporting district, 1977

Crop Reporting District	Forecast Date July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	Actual Yield
	bushels per acre					
Northwest	100.5	104.0	108.3	108.3	108.3	103
North Central	95.4	97.8	94.6	94.6	94.6	102
Northeast	97.7	108.9	115.8	115.8	115.8	112
West Central	95.8	92.2	92.0	92.0	92.0	74
Central	80.6	70.7	69.6	69.6	69.6	66
East Central	109.0	111.8	114.4	114.4	114.4	103
Southwest	84.1	71.3	70.5	70.5	70.5	68
South Central	62.6	41.6	40.0	40.0	40.0	40
Southeast	86.4	68.5	68.5	68.5	68.5	76
Iowa						86

[a]Based on revised final estimate.

Table A.6. Uncalibrated PPM corn yield forecasts for five forecast dates and actual corn yields by crop reporting district, 1978

Crop Reporting District	Forecast Date July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	Actual Yield
	bushels per acre					
Northwest	126.3	146.3	146.1	145.7	145.7	119.5
North Central	128.9	133.7	128.2	127.6	127.6	121.0
Northeast	133.8	129.1	124.6	122.9	122.9	118.0
West Central	115.1	133.3	131.7	131.6	131.6	115.0
Central	134.4	137.0	137.4	137.0	137.0	116.1
East Central	130.5	127.8	126.6	126.5	126.5	117.8
Southwest	115.5	128.3	126.8	126.3	126.3	104.7
South Central	118.0	129.6	127.7	127.3	127.3	99.7
Southeast	125.1	127.2	128.2	128.3	128.3	106.6
Iowa						115.0

[a]Based on revised final estimate.

Table A.7. Uncalibrated PPM corn yield forecasts for five forecast dates and actual corn yields by crop reporting district, 1979

Crop Reporting District	Forecast Date					Actual Yield
	July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	
	bushels per acre					
Northwest	117.9	126.4	136.1	135.7	135.7	123.9
North Central	120.9	134.3	137.2	138.2	138.3	130.0
Northeast	129.1	135.9	140.8	143.9	143.9	130.4
West Central	117.5	130.2	126.2	126.1	126.1	119.1
Central	140.1	143.2	146.1	145.2	145.2	135.3
East Central	129.6	134.5	133.8	133.4	133.4	132.3
Southwest	116.7	139.6	135.7	136.1	136.1	120.0
South Central	115.6	123.3	111.4	111.4	111.4	110.5
Southeast	122.8	127.5	128.9	128.9	128.9	133.0
Iowa						127.0

[a]Based on revised final estimate.

Table A.8. Uncalibrated PPM corn yield forecasts for five forecast dates and actual corn yields by crop reporting district, 1980

Crop Reporting District	Forecast Date					Actual Yield
	July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	
	bushels per acre					
Northwest	108.0	81.9	110.7	111.1	111.1	116.8
North Central	122.5	113.6	131.3	131.3	131.3	125.3
Northeast	126.4	119.5	125.4	125.7	125.7	121.4
West Central	104.6	82.7	86.1	86.1	86.1	86.8
Central	128.0	108.6	114.0	114.0	114.0	116.0
East Central	124.8	116.2	112.0	112.0	112.0	117.9
Southwest	99.1	78.3	73.3	73.3	73.3	88.0
South Central	96.6	80.9	76.5	76.5	76.5	88.5
Southeast	117.6	103.2	96.9	96.9	96.9	112.9
Iowa						110.0

[a]Based on revised final estimate.

Table A.9. Uncalibrated PPM corn yield forecasts for five forecast dates and actual corn yields by crop reporting district, 1981

Crop Reporting District	July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	Actual Yield
	Forecast Date					
			bushels per acre			
Northwest	109.5	112.9	128.5	129.1	129.1	125.1
North Central	128.4	130.0	139.0	139.8	139.9	133.5
Northeast	130.3	138.3	145.1	151.8	151.8	129.2
West Central	100.6	120.4	133.4	133.8	133.8	109.7
Central	120.5	118.5	133.3	134.4	134.4	129.5
East Central	128.9	128.9	139.6	140.4	140.4	132.5
Southwest	105.2	123.2	137.1	137.0	137.0	116.7
South Central	111.1	127.9	135.5	135.5	135.5	118.9
Southeast	123.4	118.8	124.1	124.1	124.1	125.7
Iowa						125.0

[a]Based on revised final estimate.

Table A.10. Uncalibrated PPM corn yield forecasts for five forecast dates and actual corn yields by crop reporting district, 1982

Crop Reporting District	July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	Actual Yield
	Forecast Date					
			bushels per acre			
Northwest	112.1	124.7	127.2	127.5	127.5	117.9
North Central	124.5	131.9	137.3	139.3	139.3	127.2
Northeast	126.5	134.1	142.5	142.6	142.6	121.5
West Central	115.1	132.0	140.3	141.7	141.7	115.8
Central	129.3	133.9	133.8	133.8	133.8	128.1
East Central	129.3	131.4	137.2	138.3	138.3	129.3
Southwest	130.5	124.9	148.1	145.3	145.3	102.5
South Central	122.2	126.9	141.8	144.7	144.7	90.9
Southeast	120.4	121.6	122.3	122.3	122.3	122.7
Iowa						120.0

[a]Based on revised final estimate.

Table A.11. Uncalibrated PPM corn yield forecasts for five forecast dates and actual corn yields by crop reporting district, 1983

Crop Reporting District	Forecast Date					Actual Yield
	July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	
	bushels per acre					
Northwest	138.4	128.9	105.3	105.2	105.2	86.5
North Central	132.5	120.9	91.2	91.2	91.2	101.4
Northeast	132.9	127.0	101.9	101.7	101.7	102.4
West Central	128.3	116.4	95.1	95.1	95.1	86.1
Central	135.1	122.8	98.1	98.1	98.1	103.5
East Central	132.3	118.4	91.9	91.9	91.9	85.3
Southwest	122.1	98.0	69.9	69.9	69.9	78.9
South Central	118.4	82.2	62.2	65.2	65.2	47.2
Southeast	120.0	88.9	67.8	67.8	67.8	47.9
Iowa						87.0

[a]Based on revised final estimate.

Table A.12. Uncalibrated PPM corn yield forecasts for five forecast dates and actual corn yields by crop reporting district, 1984

Crop Reporting District	Forecast Date					Actual Yield
	July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	
	bushels per acre					
Northwest	140.2	141.8	129.8	129.3	129.3	107.9
North Central	132.9	132.9	108.5	109.0	109.0	115.0
Northeast	127.7	128.7	111.3	111.1	111.1	114.1
West Central	127.3	134.1	114.5	114.6	114.6	109.3
Central	138.0	149.2	131.1	130.3	130.3	118.2
East Central	129.9	138.6	122.1	121.5	121.5	123.2
Southwest	118.6	114.7	84.3	84.3	84.3	95.8
South Central	111.0	119.8	93.8	93.8	93.8	85.5
Southeast	121.6	142.0	128.0	128.0	128.0	120.7
Iowa						112.0

[a]Based on revised final estimate.

Table A.13. PPM calibration estimation results by crop reporting district for each of five forecast dates

Crop Reporting District	Intercept	Uncalibrated PPM Yield	R-Square	F Value
Northwest				
July 1	138.0 (2.4)	-0.27 (0.57)	0.04	0.32
August 1	67.1 (2.47)	0.34 (1.46)	0.21	2.14
September 1	30.0 (2.2)	0.66 (5.53)	0.79	30.55
October 1	30.2 (2.2)	0.66 (5.67)	0.78	32.16
November 1	30.2 (2.2)	0.66 (5.67)	0.78	32.16
North Central				
July 1	67.2 (1.1)	0.38 (0.83)	0.08	0.68
August 1	49.6 (2.6)	0.55 (3.39)	0.59	11.51
September 1	46.93 (6.5)	0.59 (9.60)	0.92	92.08
October 1	47.8 (6.8)	0.59 (9.71)	0.92	94.2
November 1	47.8 (6.8)	0.59 (9.71)	0.92	94.2

Table A.13. (continued)

Crop Reporting District	Intercept	Uncalibrated PPM Yield	R-Square	F Value
Northeast				
July 1	82.4 (1.4)	0.25 (0.53)	0.03	0.28
August 1	-0.5 (0.0)	0.92 (3.75)	0.64	14.03
September 1	29.5 (1.9)	0.69 (5.55)	0.79	30.77
October 1	36.2 (2.4)	0.63 (5.33)	0.78	28.37
November 1	36.2 (2.4)	0.63 (5.33)	0.78	28.37
West Central				
July 1	28.4 (0.5)	0.61 (1.13)	0.14	1.28
August 1	15.5 (1.11)	0.73 (5.99)	0.82	35.92
September 1	29.0 (2.8)	0.64 (6.81)	0.85	46.34
October 1	29.6 (2.9)	0.63 (6.74)	0.85	45.41
November 1	29.6 (2.9)	0.63 (6.74)	0.85	45.41

Table A.13. (continued)

Crop Reporting District	Intercept	Uncalibrated PPM Yield	R-Square	F Value
Central				
July 1	1.91 (0.1)	0.87 (3.13)	0.55	9.78
August 1	24.2 (1.1)	0.72 (3.99)	0.67	15.92
September 1	24.4 (1.74)	0.75 (6.30)	0.83	39.67
October 1	24.2 (1.73)	0.75 (6.35)	0.83	40.31
November 1	24.2 (1.73)	0.75 (6.35)	0.83	40.31
East Central				
July 1	47.9 (0.5)	0.52 (0.63)	0.05	0.39
August 1	-40.5 (0.8)	1.24 (2.88)	0.51	8.30
September 1	-0.35 (0.1)	0.95 (4.76)	0.74	22.62
October 1	1.90 (0.1)	0.93 (4.69)	0.73	22.00
November 1	1.90 (0.1)	0.93 (4.69)	0.73	22.00

Table A.13. (continued)

Crop Reporting District	Intercept	Uncalibrated PPM Yield	R-Square	F Value
Southwest				
July 1	38.6 (0.7)	0.50 (1.07)	0.12	1.14
August 1	27.9 (2.12)	0.64 (5.16)	0.77	26.65
September 1	47.8 (4.7)	0.47 (4.78)	0.74	22.88
October 1	46.9 (4.7)	0.48 (4.96)	0.75	24.61
November 1	46.9 (4.7)	0.48 (4.96)	0.75	24.61
South Central				
July 1	132.9 (1.2)	-0.38 (0.38)	0.02	0.14
August 1	35.6 (1.13)	0.52 (2.1)	0.39	4.40
September 1	42.3 (2.2)	0.48 (2.64)	0.50	6.96
October 1	43.6 (2.3)	0.47 (2.56)	0.48	6.55
November 1	43.6 (2.3)	0.47 (2.56)	0.48	6.55

Table A.13. (continued)

Crop Reporting District	Intercept	Uncalibrated PPM Yield	R-Square	F Value
Southeast				
July 1	-11.5	0.99	0.18	1.77
	(0.1)	(1.33)		
August 1	6.1	0.90	0.59	11.42
	(0.2)	(3.38)		
September 1	4.2	0.95	0.80	31.07
	(0.2)	(5.57)		
October 1	4.2	0.95	0.79	30.96
	(0.2)	(5.56)		
November 1	4.2	0.95	0.79	30.96
	(0.2)	(5.56)		

Table A.14. Composite forecast OLS estimation results by crop reporting district for each of four forecast dates

Crop Reporting District	PPM	NASS	R-square	Durbin-Watson D
Northwest				
August 1	0.34 (1.61)	0.68 (3.07)	0.61	1.12
September 1	0.57 (2.02)	0.43 (1.51)	0.83	1.18
October 1	0.27 (1.10)	0.73 (2.93)	0.90	1.23
November 1	-0.04 (0.29)	1.04 (7.92)	0.98	2.03
North Central				
August 1	0.82 (2.17)	0.18 (0.47)	0.60	1.12
September 1	0.60 (3.61)	0.40 (2.44)	0.95	1.99
October 1	0.43 (1.98)	0.57 (2.63)	0.96	1.93
November 1	0.10 (0.62)	0.90 (5.43)	0.98	2.34
Northeast				
August 1	0.89 (3.19)	0.11 (0.41)	0.64	1.44
September 1	0.55 (3.82)	0.45 (3.18)	0.90	1.25
October 1	0.52 (3.68)	0.48 (3.42)	0.90	1.03
November 1	0.26 (1.31)	0.74 (3.78)	0.91	0.97

Table A.14. (continued)

Crop Reporting District	PPM	NASS	R-square	Durbin-Watson D
West Central				
August 1	0.87 (2.86)	0.13 (0.40)	0.82	1.32
September 1	0.32 (0.95)	0.68 (2.05)	0.90	2.27
October 1	0.16 (0.47)	0.84 (2.41)	0.91	2.24
November 1	0.05 (0.27)	0.95 (5.31)	0.96	2.25
Central				
August 1	0.45 (1.41)	0.55 (1.73)	0.75	1.14
September 1	0.40 (1.60)	0.60 (2.39)	0.90	2.17
October 1	0.18 (0.68)	0.82 (3.13)	0.92	2.38
November 1	-0.07 (0.39)	1.07 (6.17)	0.97	1.90
East Central				
August 1	0.77 (2.49)	0.23 (0.75)	0.54	1.16
September 1	0.40 (3.12)	0.60 (4.77)	0.93	1.10
October 1	0.28 (1.93)	0.72 (4.96)	0.93	1.37
November 1	0.12 (0.76)	0.88 (5.51)	0.94	1.79

Table A.14. (continued)

Crop Reporting District	PPM	NASS	R-square	Durbin-Watson D
Southwest				
August 1	0.45 (1.55)	0.55 (1.93)	0.84	1.75
September 1	-0.05 (0.17)	1.05 (3.96)	0.91	2.04
October 1	-0.20 (0.89)	1.20 (5.32)	0.94	2.10
November 1	-0.01 (0.06)	1.01 (5.43)	0.94	1.78
South Central				
August 1	0.43 (1.29)	0.57 (1.68)	0.64	1.54
September 1	0.17 (1.93)	0.83 (9.67)	0.97	1.40
October 1	0.14 (1.83)	0.86 (11.54)	0.98	1.65
November 1	0.17 (2.74)	0.83 (13.06)	0.99	2.54
Southeast				
August 1	0.28 (0.63)	0.72 (1.61)	0.68	1.45
September 1	0.27 (1.32)	0.73 (3.55)	0.91	2.19
October 1	0.15 (0.81)	0.85 (4.71)	0.94	2.43
November 1	0.11 (0.84)	0.89 (6.82)	0.97	2.55

Table A.15. Composite forecast ridge regression estimation results by crop reporting district for each of four forecast dates

Crop Reporting District	PPM	NASS	R-square	Durbin-Watson D
Northwest				
August 1	0.37 (2.01)	0.63 (3.46)	0.61	N.A.
September 1	0.54 (3.24)	0.46 (2.73)	0.83	N.A.
October 1	0.38 (2.81)	0.62 (4.63)	0.90	N.A.
November 1	0.22 (2.84)	0.78 (9.81)	0.96	N.A.
North Central				
August 1	0.68 (3.21)	0.32 (1.80)	0.59	N.A.
September 1	0.53 (7.34)	0.47 (6.41)	0.95	N.A.
October 1	0.47 (7.45)	0.53 (8.36)	0.96	N.A.
November 1	0.41 (9.44)	0.59 (13.77)	0.97	N.A.
Northeast				
August 1	0.74 (4.18)	0.26 (1.64)	0.63	N.A.
September 1	0.51 (5.60)	0.49 (5.31)	0.90	N.A.
October 1	0.50 (5.51)	0.50 (5.47)	0.90	N.A.
November 1	0.37 (4.11)	0.63 (7.06)	0.91	N.A.

Table A.15. (continued)

Crop Reporting District	PPM	NASS	R-square	Durbin-Watson D
West Central				
August 1	0.73 (3.78)	0.27 (1.69)	0.81	N.A.
September 1	0.42 (2.84)	0.58 (3.95)	0.90	N.A.
October 1	0.37 (2.61)	0.63 (4.52)	0.91	N.A.
November 1	0.27 (2.86)	0.73 (7.68)	0.96	N.A.
Central				
August 1	0.47 (2.22)	0.53 (2.54)	0.75	N.A.
September 1	0.44 (3.10)	0.56 (3.94)	0.90	N.A.
October 1	0.35 (2.71)	0.65 (5.10)	0.92	N.A.
November 1	0.23 (1.90)	0.77 (6.80)	0.96	N.A.
East Central				
August 1	0.69 (3.17)	0.31 (1.74)	0.53	N.A.
September 1	0.42 (4.76)	0.58 (4.43)	0.93	N.A.
October 1	0.34 (3.89)	0.66 (6.99)	0.93	N.A.
November 1	0.29 (3.21)	0.71 (7.74)	0.93	N.A.

Table A.15. (continued)

Crop Reporting District	PPM	NASS	R-square	Durbin-Watson D
Southwest				
August 1	0.46	0.54	0.84	N.A.
	(2.52)	(2.92)		
September 1	0.20	0.80	0.90	N.A.
	(1.30)	(5.23)		
October 1	0.14	0.86	0.93	N.A.
	(1.06)	(6.63)		
November 1	0.18	0.82	0.94	N.A.
	(1.57)	(6.96)		
South Central				
August 1	0.54	0.46	0.64	N.A.
	(1.72)	(1.48)		
September 1	0.21	0.79	0.97	N.A.
	(2.79)	(10.50)		
October 1	0.18	0.82	0.98	N.A.
	(2.84)	(12.84)		
November 1	0.21	0.79	0.99	N.A.
	(3.88)	(14.58)		
Southeast				
August 1	0.33	0.67	0.68	N.A.
	(1.07)	(2.18)		
September 1	0.33	0.67	0.91	N.A.
	(2.13)	(4.35)		
October 1	0.24	0.76	0.94	N.A.
	(1.96)	(5.67)		
November 1	0.21	0.79	0.96	N.A.
	(2.12)	(7.91)		