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Production variability for major Arizona field crops

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PRODUCTION VARIABILITY FOR MAJOR ARIZONA FIELD CROPS

by

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ABSTRACT

Previous variability studies in both U.S. and worldwide agriculture have indicated that crop production has been accompanied by increasing variation. In this research, four different variability indexes were estimated in order to evaluate the production variability associated with the major Arizona field crops. Results show that major Arizona field crops, which are all irrigated, did not have a uniform production variability over the last 24 years and the variability of these crops did not generally increase between the periods of 1967-1978 and 1979-1990. Although biological factors (e.g. pests, weather) influenced variability, the variation of crop production measures over time also was related to market factors (e.g. prices), government farm programs, producers' crop management experience, and the geographical area selected for the analysis. Crops covered by government farm programs usually varied more in harvested acreage and fluctuated less in yield per acre than vegetable crops.

1. INTRODUCTION

Arizona is in the southwestern United States. Its arid weather determines its crop farming pattern: a combination of cotton, alfalfa hay, wheat, citrus, lettuce, and other minor crops. Arizona crop production is a small player in the United States agricultural sector, but some crops such as cotton, lettuce, and citrus play an important role in national and international markets. Arizona's cotton production of Arizona ranked fourth in the nation in 1989 (AAS, 1989). Its unique American-Pima cotton is especially well-known for its extra long-staple fiber and quality. Arizona also ranked second in the United States in lettuce, cauliflower, and lemon production.

Since 1960, the aggregate growth in agriculture in Arizona has been significant. Pima cotton production has increased 5 fold between 1960 and 1990 (AAS, 1990). Upland cotton production has increased by 19 percent in 1990, as compared to 1960. During the same time, alfalfa and lettuce production have increased by 20 and 38 percent respectively. The increase in agricultural production has been attributed to increasing crop productivity since total acreage has declined. But, reviewing agricultural statistics, one can see that the growth of major Arizona field crop production is accompanied by significant fluctuations in planted and harvested acreage, per acre yield, prices, etc. Are these variations in crop production important to crop growers and society? How should we measure and explain these fluctuations in field crop production? This study concentrates on the fluctuations of major Arizona field crops over past three decades and attempts to provide policy makers and crop producers with new and practical information concerning crop production variability.

The Importance of Variability

Farming is a symbiotic relationship between man and his environment. Because of this biological and social feature, agricultural operations are greatly influenced by the vagaries of weather, markets, politics, and world economies. Each year Arizona farmers must decide what crops they will plant and how much acreage they will plant given their individual land, labor, capital, and other resource constraints. Similarly, long-run investment decisions are made to expand the farm, construct new storage facilities, and purchase a new equipment. The success and survival of the business is determined by the producers' ability to make the correct decisions and to cope with the uncertainty in their operations.

Since crop growers operate in an uncertain environment, crop production varies with environmental conditions such as weather and infestations of pests and disease. The fluctuation of crop production can be expressed by a statistical term - variability. Based on the magnitude of variability, one can see how largely the crop production fluctuates. A high yield variability for a crop, for example, simply implies that the yield of the crop is high in good years or low in bad years.

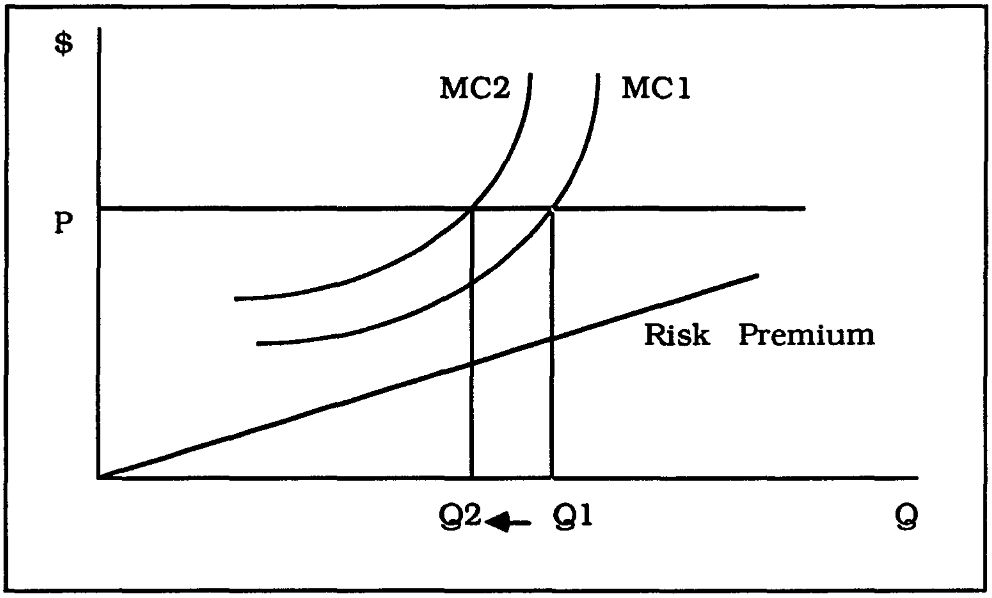
Variability originates from the relative frequency of an event in a large sample. It is the random variation not explained by the predictable trend. In the economic literature, variability is often an alternative terminology for objective risk (Young, 1982). It reflects the relatively long-term unpredictable fluctuation. The replications of experiments are often substituted by historical time series data such as annual statistics, crop budgets, economic reports, etc. In this case, objective risk is fixed because past information is certain. However, the magnitude of variability is greatly affected by the researchers' detrending technique for historical data. In contrast to variability (i.e. objective risk), economists often use subjective risk to describe a decision maker's personal judgement concerning uncertain events in his or her future.

Variability in crop production is one of the most important factors to be considered in crop growers' decision making. High variability in crop production often implies that producers may have more difficulty to in making optimal decisions, thereby leading to some negative consequences such as lower level economies of scale, credit shortage in crop operation, etc.

First, high variabilities in production may lead farmers to pursue sub-optimal production in the short-run. A grower's production decision under certain output price is, for example, different from that under uncertain output price (Robison and Barry, 1987). Based on production economics theory, profit maximization criteria requires that marginal revenue must be equal to marginal cost *ceteris paribus*.

A farm's marginal cost with a certain output price (MC1) is lower than that with an uncertain output price (MC2) under the assumption of risk aversion (Figure 1-1). This is because MC2 includes not only MC1 but also a marginal risk premium at the same production level. "Risk aversion" does not mean that producers are afraid of risk but recognize the trade-off between risk and returns. The farm with

Figure 1-1, Marginal Costs under Fixed and Variable Output Prices



Source: Robison and Barry. The Competitive Firm's Response to Risk. 1987, pp. 92.

variable output prices lowers its output level (Q1-Q2) to ensure that its marginal costs equal its marginal revenue for optimal production. In other words, MC2 curve shifts to MC1 curve by cutting off output (Q1-Q2), so that risk can be adjusted. Consequently, farmers sacrifice by reducing their profits and consumers lose by realizing fewer goods and services than could be produced from the limited resources generally employed in agriculture and the economy.

Second, high variabilities often generate some difficulties in crop growers' long term decision making. Some farmers may be so worried about the uncertain market, policy environment and future that they will hesitate to make their long-term investment decisions. They may spend their capital on short-term assets and exploit natural resources.

Third, high variabilities in farming may increase the possibility of bankruptcy for crop producers. In a good year, farmers may have a bumper harvest and consumers may get more goods to consume at a lower price. In a bad year, farmers may be driven out of business if they can not cover their costs, and consumers have to pay relatively higher prices for their agricultural goods. If government subsidizes agriculture, the loss in some years may be transferred from crop producers to taxpayers.

Finally, the further impact of higher yield variability may hinder farmers' adoption for new varieties or technologies, thereby limiting growth in national food and fiber supply. It is important to recognize and provide variability information in crop production to farmers and governmental policy makers to assist in their decision making.

Factors Related to the Variability in Crop Production

There are many factors which have an impact on crop production variability, and many of these factors are different from that of most industries. This divergence between agriculture and other industries is determined by the special climatic and biological dimension of agricultural production. To farmers, some of these factors are manageable while others are beyond their control.

Weather. Weather is one of the most important and uncontrollable factors for farmers. Weather variability continues to be a major cause of fluctuations in crop yield. Past experience tells us that several years of good weather may result in large harvests in agriculture and turn a major agricultural importer into an exporter. Conversely, several years of bad weather may convert a major agricultural exporter to an importer. For example, a study on U.S. maize production shows that the drought occurring in 1934, 1936, 1980, and 1983, resulted in sharp reductions in the U.S. maize production (Duvick, 1989). Also excessive rain and cold weather in 1947 delayed farmers planting date and led to a large decrease in maize production.

Evapotranspiration has a specific meaning for farmers in the desert. Studies show that growing crops contain large quantities of water which accounts for about 50 to 90 percent of the plants (Metcalfe and Elkins, 1980). The quantity of water in those growing plants is only a very small proportion of the water that must pass through these plants during growing season and most of the water is evaporated from these plants and soil surfaces. Evapotranspiration experiments on alfalfa show that one ton of alfalfa production needs 750 tons of water in dry weather. Therefore, the rate of water used by crops is largely influenced by temperature, solar radiation and varieties of plants. High water consumption by crops results in increased production costs in irrigated agriculture.

Market. Agriculture is the process of purchasing inputs, producing and selling products. The history of agricultural development shows that the more advanced the agriculture is the more market oriented the agricultural sector will be. Since U.S. agriculture is more commercialized than most countries in the world, the stability of agricultural production is more related to market conditions. Market uncertainty influences crop production through prices in the both input and output markets. A higher market price for a product often attracts more farmers to plant the crop. Conversely, a lower price for product often leads farmers to reduce their production for the crop. Recent U.S. agricultural history provides evidence that U.S. crop production has varied considerably with an uncertain world market. For example, the total agricultural production in the 1970's increased dramatically due to the increased demand by foreign countries.

Pests and diseases. Pests and diseases are the unique biological phenomena which make agriculture different from other sectors of a nation's economy. Pests and diseases are positively correlated to the variability of agricultural production. Without pests and diseases, farmers would have higher yields and less variability in crop production. Pests and diseases in agriculture can lead to disastrous declines in crop yields, particularly, if the pests and diseases are not controlled at an early stage. Even if farmers have the ability to control pests and diseases in agriculture, their efforts increase production costs, and profitability levels decline.

Entomologists estimate that about 10,000 species of insects are "public enemies" (Metcalfe and Elkins, 1980). Annual crop losses in the U.S. due to pests range from 5 to 10 percent of total crop production with an economic value of approximately $4 billion. In addition, pest control incurs costs of another $1 billion annually. Plant diseases also have a heavy impact on the variation of agricultural production. It has been estimated that the losses from plant diseases are about $3 billion annually. The costs of controlling crop diseases are more than $115 million every year.

Policies. Domestic policies and programs greatly influence the variability in crop production, particularly acreage planted. The U.S. government has intervened in agricultural sector for over 50 years. The types of governmental intervention include price supports (i.e. target price), commodity loans, acreage allotments, etc. An example of intervention is the Cotton and Wheat Act of 1964. In the early 1960's, the U.S cotton carryover reached 17 million bales, which exceeded total yearly use by 4.5 million bales (Stults et al, 1990). Meanwhile, cotton production was increasing steadily. To cope with the tremendous surplus in cotton, the U.S. government issued the

Cotton and Wheat Act of 1964 to reduce cotton carryover and production. The main components in this Act were demand enhancement and voluntary acreage reduction. Demand enhancement simply increased governmental payments to domestic handlers or textile mills in order to bring the price of cotton consumed in the United States down to the export price. The voluntary acreage reduction program offered producers who planted within the domestic allotment higher support through a direct price support program. This legislation was significant in reducing cotton carryover and production. The production and carryover fell to about 7.5 million bales annually. U.S. cotton acreage planted trended sharply downward.

The agricultural policy of other nations has also an impact on the variations in U.S. agriculture. For example, the sharp increase of Chinese cotton exports in the early 1980's produced a decline in world cotton prices and a reduction in U.S. cotton exports, although China's impact was only temporary. During this period, the Chinese government reduced its control over agriculture and Chinese farmers responded to the new market situation by sharply expanding their cotton production (Ayer, 1986).

Technology. There is no doubt that modern agriculture has benefited from new and improved technologies. However, there is a long debate about whether modern technology stabilizes agriculture production. For example, biological technology creates more varieties for producers. One of the advantages of hybrids and new cultivars is the potentially higher yields with favorable weather. Yet some researchers believe that higher-yielding varieties may lead to greater variability in production. This was true in the U.S. maize production in the 1970's, when U.S. maize production decreased disastrously because of genetic uniformity (Duvick, 1989). At that time, 80 percent of U.S. maize was based on T cytoplasm and especially susceptible to the T race of southern corn leaf blight. A counter argument is that although higher-yielding varieties lead to higher yield variances, the coefficient of variation is not necessarily larger due to the increase in mean yields relative to the change in variation.

Second, mechanical, chemical and management technologies greatly enhance farmers' ability to manage inputs such as fertilizer, pesticide, water, and the timeliness and efficiency of harvesting the crop. For example, laser leveling techniques can help crop growers use water more efficiently, enhance land productivity, and stabilize crop production. The influence of most mechanical technologies on variability in agriculture depends on the petroleum supply.

In addition, information technology also plays a more important role in crop production. Information and variability are negatively correlated in the sense of farmers' decision making. If producers have more information about their production, they can better cope with the variability in their production. Satellite and computer information techniques are the most common information technologies applied to agriculture. Satellite techniques help us to provide producers with more information about weather, pest forecasts, and markets. Producers can know world market information in a short time, and thus make adjustments in their operations. In recent years, computer software programs have assisted some crop growers with budgeting, cost-benefit analysis, and decision making although computers are not popular at farm level (Putler and Zilberman, 1988).

Objectives

This study focuses on the production variability of major field crops in Arizona. It attempts to measure and describe the variations in crop production during the past three decades, test the hypothesis that the variability has increased in recent years, and investigate the causes related to the fluctuations of crop production. In order to achieve these goals, three specific steps will be taken:

First, a database with information concerning planted and harvested acreage, yields, total production, price and production values, is developed for major field crops at both the state and county levels for the past three decades (1960-1990).

Second, variability indexes of different crops, areas (state and counties), and time periods (1967-1990, 1967-1978, 1979-1990) are estimated using four detrending techniques. A statistical test is used to see if the change of variance across time periods is significant.

Finally, an analysis of the probable environmental, economic and social forces which explain these variations in these major crops is conducted. Particular attention is given to inter-county differences in variability.

The remainder of this study will proceed as follows. Chapter 2 reviews previous literature of both domestic and international research about variability in crop production. Chapter 3 describes data sources and discusses the analytical techniques used to measure variability. Chapter 4 statistically and graphically presents the results at the state level, and explores probable causes responsible for the variations in Arizona field crop production. Chapter 5 describes the variability situation at county levels and discusses how major Arizona field crop production varies with regional environmental conditions. A comparison of variability between the state and county levels and its further analysis is conducted. Chapter 6 summarizes analytical results, proposes some general policy implications, and explores some issues which need further study.

2. LITERATURE REVIEW

There is an extensive literature which analyzes variability in U.S. and international crop production. Although risk has been an important topic in economics since Knight (1921), variability studies in agriculture have only a history of four decades. In the 1950s, Heady (1954) first studied economic instability and decisions involving income and risk for Iowa crops. In the 1960's, variability studies became more popular at the state level. Since then, economists, policy makers, and crop producers have realized the importance of risk and uncertainty in the agricultural sector. These past studies in variability have enriched the theory of risk and uncertainty in agriculture and provided practical and useful information to crop growers and decision makers.

Concepts of Risk, Uncertainty and Variability

Risk, uncertainty and variability often are used interchangeably in the economics literature, yet many researchers argue that these three terms are different conceptually. Risk and uncertainty refer to two different situations while variability is one type of risk.

In 1921, Knight first distinguished risk from uncertainty (Knight, 1921). Knight indicated that risk refers to a situation where the probability distribution of the outcome of an event is known. Therefore, the parameters of the outcome can be estimated empirically and quantitatively. Uncertainty can not be estimated quantitatively, because the probability distribution of outcome is unknown. From Knight's point of view, rain, hail, crop pests, and diseases should be classified into the risk category for crop producers since the probability distribution of their occurrence and damage can be estimated, and crop producers can also buy crop insurance. However, some government interventions present an uncertain event for farmers because the outcome or timing of government interventions are difficult to predict.

In 1954, Heady and others studied the instability of Iowa agriculture. Heady viewed risk as the variabilities of yield, price and other outcomes in agriculture. Variability could be estimated by means, standard deviations, skewness, etc. in an empirical manner. The authors argued that uncertainty is a unique purely subjective phenomenon to each individual producer and characterized by the degree of confidence for future events. From this point of view, risk and uncertainty are different while there is no difference between risk and variability.

When Carter and Dean (1960) studied the variability of crops in California, they advocated Knight's definitions of risk and uncertainty and gave a more explicit explanation. They viewed risk as a situation where the parameters of the probability distribution of outcomes might be predicted so as to be insurable. They referred to uncertainty as the situation where various possibilities of the event are known but their probabilities are not known. Carter and Dean indicated that empirical estimates of the possibilities are the objective measures of past variability in crop production and are not exactly equal to the conventional definitions of risk and uncertainty. Empirical estimates of variability provide a more reasonable basis for crop growers' decision making since future variability of particular crops is closely related past variability.

Young (1982) classified risk into subjective and objective risk. He referred to objective risk as variability. Objective risk is estimated from time series data such as agricultural statistics, economic reports, crop budgets, etc. Subjective risk is related to personal judgement. Young defined variability as the second moment about the mean of decision makers' subjective probability distribution of an event. He later argued that the concept of risk varies with different conditions (Young, 1984). As a matter of fact, one may see that risk is fundamentally different under different assumptions. He discussed risk with different decision rules. If the decision rules do not require probability information, risk may be interpreted as the action with the largest possible loss. With a safety-first decision rule, risk may be interpreted as the chance of loss. In the expected utility model, risk is represented by the moments of a probability distribution, i.e. mean, variance, skewness, kurtosis, etc.

Robison and Barry (1987) viewed risk and uncertainty differently from past researchers in that they regarded risk as a subset of an uncertain event. An uncertain event simply means that its outcome is unknown with certainty. If the outcome of an uncertain event changes the decision maker's well-being, then the uncertain event is risk.

That is, a risky event influences decision makers' benefits while an uncertain event is not necessarily interesting to decision makers.

In this study, variability is treated as objective risk using Young's definition due to the fact that past variability is objective and past information is certain.

Measures of Variability

There are many ways to estimate variability which is defined as the deviation of the actual value from the decision maker's expected value. Since past actual value is certain, the magnitude of variability is often determined by the detrending methods for the expected value.

The most popular technique for the estimation of variability has been the coefficient of variation. Coefficient of variation is the ratio between standard deviation and expected value (i.e. long term mean). The long term mean is the variability base. The deviation of actual values from long-term mean captures the variability. A coefficient of variation serves as an indicator of the amount of risk relative to the amount of expected return.

The coefficient of variation assumes that producers have no knowledge of the long term trend since it uses the long term mean as its variability base. Many researchers have questioned the reliability of this technique (Carter and Dean, 1960, Wildermuth and Gum, 1968). These authors suggested that farmers, in fact, do have some knowledge about long-term trends in technological advances, inflation, price movements, etc. Carter and Dean proposed five alternatives to derive the current level (i.e. the variability base). They indicated that the current level may be represented by a regression fitted trend line. Variability is the residuals of the fitted regression line in absolute value. Second, the current level may be represented by the previous year value. Variability is the first difference of the data. Third, the current level may be represented by a moving average. Variability is the difference between the actual value and the moving average. Fourth, the current level may be represented by a "real" time series value. And finally, the current level may be represented by the trend derived by the variate difference method. Carter and Dean regarded the variate difference method as the best technique to obtain the current level because they believed that farmers have some knowledge about long-term trends in critical variables.

A yield probability function is another measure of variability in crop production. In 1963, Boskwick developed yield probability functions in order to estimate the stability of Montana wheat production based on Gumbel and Chow's extreme value statistical distribution technique. The extreme value statistical distribution function had been extensively applied to problems in river flooding, materials, experimental crops yields and many other areas. This distribution function approach assumed that each datum must be an extreme observation from each of several independent, unlimited and exponentially distributed series of observations.

Young (1982) suggested that variability be measured as an appropriately weighted mean square forecast error from a series of one-step ahead forecasts. Similar to Carter and Dean, Young's computation of variability depends on the decision maker's expectation. In addition to the six detrending methods discussed above, Young selected several alternative methods to estimate the current level. Furthermore, he examined the variability measures used in past studies and developed seven evaluation criteria to be used in variability studies. The essence of the seven criteria is: first, the concept of variability should reflect one's personal risk perception and *ex post* disappointments due to the deviation of actual values from expected outcomes; second, the method used for variability computation should be simple; third, information used for variability assessment should be limited to a valid time period, often updated and revised, and weighted differently according to the research objective.

By examining those detrending techniques, Young found that the equally weighted moving average and constantly adjusted weighted moving average (CAWMA) models were better models with respect to the other detrending techniques. Both models met the seven criteria and empirical studies for processed green peas and lentil prices showed very reasonable results. The CAWMA model appeared more theoretical than the equally weighted moving average model, but the results produced by the equally weighted moving average model were extremely similar to that of the CAWMA model. In consideration of computation simplicity, the simple moving average model was superior to the CAWMA model.

The variance decomposition model was developed by Hazell

(1985) and has been used by many researchers (Hazell, Stone and Zhong, Walker, et al, 1989). A good example of the application of this method is to estimate how per acre yield, total acreage and their interaction effects influence the variability of crop production. The decomposition of the variance in crop production yields ten components. They are the change in mean yields, change in mean areas, change in yield variances and covariances, changes in area variances and covariances, change in area-yield covariances, interaction between changes in mean yields and mean areas, interaction between changes in mean areas and yield variances, interaction between changes in mean yields and area variances, interaction between changes in mean areas and yields and changes in area-yield covariances, and the change in residuals. Among the ten components, the first five are pure effect and the second four components are interactive effects.

Variability Studies in the U.S. Crop Production

A comprehensive national level variability study in crop production for the U.S. has not been completed. However, many variability studies have been done at the farm and more aggregate levels over the past four decades. These studies have enhanced our understanding of variability in agriculture. A select number of these studies are reviewed below.

California. Carter and Dean (1960) studied the variability in California's cropping system. Using the variate difference method, they estimated the degree of variability in crop prices, yields, gross income, and investigated the relationship of the stability in farm income between cropping systems. Their findings are summarized in Table 2.1. The divergence of variability indexes in the three categories of crops are obvious with the exception of price variability between field crops and vegetable crops.

Table 2.1, Variability Comparison in California Crops (1918 - 1957)

Crop	Yield	Price	Gross Income
Field Crops (9 crops)	Low (Variability Range: 3%-10%)	High (Variability Range: 4-43%)	Low (Variability Range: 7%-35%)
Vegetable (30 crops)	Middle (Variability Range: 2%-16%)	Middle (Variability Range: 5%-42%)	Middle (Variability Range: 7%-44%)
Fruits & Nuts (19 crops)	High (Variability Range: 3%-31%)	Low (Variability Range: 11%-31%)	High (Variability Range: 5%-50%)

Note: Variability coefficient is different from coefficient variation because the standard deviation refers to the variance of "random" portion of a time series as computed by the variate difference method. The mean is computed as the mean of the last five years.

Carter and Dean argued that the largest swing in fruit crop yield variability was due to the alternate bearing tendency (e.g. large harvests every other year) of most fruit and nut crops (e.g. olives avocados, apricots, etc.). At the other extreme, grapefruit yield was stable because California grapefruit was grown in the desert area where weather was uniform and predictable. Price variability appeared unusual because of the swing of variability indexes between field crops and vegetable crops in their study. However, the most variable crop in prices was early potatoes (potatoes are often classified into the vegetable crop category). The largest price variability was attributed to farmers' "over-response" to the previous year's potato prices. The overall price variability of vegetable crops were much higher than that of field crops. Gross income variability of fruits and nuts was higher than those of vegetable and field crops. The reason for this was that the effect of yield variability on gross income overrode the impact of price variability on gross income.

Montana. As noted previously, Bostwick (1963) used yield probability functions to estimate the variability of wheat production in Montana. Bostwick selected four sample counties for the period of 1921-1956 and analyzed the variations of Montana dry land wheat production. He found that a farmer on a small farm with a history of poor yields could resist risks better than a farmer on a large farm with a history of poor yields. Bostwick, however, failed to give further explanations for his finding.

Boskwick studied how farm size affected wheat yield variability in dry land agriculture. He tested the hypothesis that the yield variability of a farm would decline as the farm size (acreage) expanded. He found that the variability of yield decreased as acreage increased in a certain range of acreage. Yet these results were statistically different across farm sizes. When the farm went beyond a certain limitation, the variability of wheat production did increase. However, Boskwick found that mean yield increased as a function of acreage. Boskwick also analyzed how wheat yield variability was correlated with farm dispersion. He found that wheat yield variability and field dispersion were inversely correlated due to different environmental factors such as thundershowers, hail activity, and growth stages of wheat crop. He concluded that field dispersion was a good way to reduce yield variability.

Arizona. Wildermuth and Gum (September-October and November-December 1968) analyzed variability faced by Arizona crop growers and provided an objective basis for evaluation of the risk over a wide range of Arizona field crops. Drawing on the earlier work of Carter and Dean, Wildermuth and Gum used the variate difference method to estimate the variability coefficients of cotton and some other 23 field crops in price, yield and gross income. They found that Pima cotton was only slightly riskier than upland cotton in terms of their price variability indexes. The variability coefficient of price was 9.7 percent for Pima cotton and 9.5 percent for upland cotton. Secondly, the yield variability for cotton production varied considerably from county to county. Pinal County had, for instance, the lowest yield (per acre) variability for both upland and Pima cotton. Cochise County had the highest yield variability in extra long staple cotton and Maricopa County had the highest yield variability in upland cotton. The impact of environmental factors on yield variability of both upland and extra long staple cotton changed with different regions. Thirdly, gross income variability appeared in the same pattern as yield variability. This is because yield variability had greater influence on gross income variability than price variability for both cottons.

Wildermuth and Gum also found that truck crops were riskier in both price and yield than standard field crops. For example, onions, potatoes, early spring lettuce, and early spring cantaloup were risky crops in terms of price variability (variability coefficient ranged from 22.2% to 36.6%). Data for barley, oats, corn, wheat and hay demonstrated relatively lower measures of price variability (variability coefficient ranged from 3.3% to 6.3%). Winter cauliflower, honeydew melons, early spring cantaloup had higher yield variability (variability coefficient ranged from 26.4% to 27.4%). Alfalfa hay, barley, grain hay and upland cotton had lower yield variation (variability coefficient ranged from 3.7% to 5.6%). Yield variability was generally lower than price variability. This relatively lower yield variability in crops might be due to Arizona's relatively stable weather and the use of irrigation. The gross income variability pattern was similar to the price variability pattern. Truck crops were much risker than standard field crops in terms of gross income variability indexes. Crops with large price variability also had large gross income variability. This was contradictory to Carter and Dean's finding for California. In the Arizona case, the impact of price variability on gross income crowds out the yield variability effect.

Texas. How does farm policy influence the risk environment of farms? Richardson and Knutson (1987) attempted to answer this question for rice and cotton farmers in Texas. The authors used the FLIPSIM model to estimate the effect of farm programs on the farm's level risk environment. They isolated the impact of policy changes in the 1960's and 1970's (e.g. the Rice Production Act of 1975) on the variability of rice production from that of other variables. Richarson and Knutson found that the chance of firm survival fell for all farms (i.e. full owner vs. part owner vs. tenant) and the policy change made rice farmers' good times better and bad times worse.

Richardson and Knutson also analyzed the impact of alternative farm programs on cotton production for southern Texas high plains cotton producers. They found that the impacts of farm programs on farms varied with the size of farm in term of the changes of the probability of survival, success, and net present value. The chance of survival for a moderate size farm was reduced by both the reduction in target prices and the imposition of an effective payment limit. The impact of farm programs on large size farms was less than on middle size farms. Large farms were able to achieve economies of size and had more financial ability to survive. Finally, policy changes had little impact on small size farms because these operations had relatively high off-farm income and did not rely upon farm programs for their economic survival.

National level. An example of a national variability study is the recently reported research of Duvik (1989). Duvik noted that the long-term trend line of maize yields had continuously risen since 1930. His analysis indicated that the coefficient of variation was 6 percent in the period of 1950 to 1966, and 10.5 percent for U.S. maize production in the 1967 to 1985 period. In Duvik's study, four factors were discussed which might explain maize variability. First, the increased variation was correlated to vagarious weather and diseases. Weather such as drought, excessive rain and temperature were found to be the overriding causes which led to the variation in total maize production. Disease, such as 1970's southern corn leaf blight, reduced maize yields disastrously. A second factor was the change in maize cultural practices. Changes in cultural practices included an increased use of synthetic nitrogen fertilizer, higher-density planting, improved weed control techniques, better precision and timeliness of planting, and improved harvesting machinery. These changes amplified or lessened the effect of weather and exaggerated the fluctuation of maize production. For instance, higher-density planting with high levels of nitrogen fertilizer greatly increased the possibility for extremely high yields if weather was favorable, and vice versa.

A third factor discussed by Duvik was the increased uniformity of the genetic base for hybrids. The narrow genetic base of these hybrids generated the possibility of sharp rise or fall in maize production. Since their yields were high, these varieties were widely adopted over a short period. Yet these new varieties were susceptible to some particular pests and diseases at the early stage of development. Pest and disease outbreaks also had a sizable negative impact on farm-level and aggregate yields. A related final factor was that the yield variation of modern hybrids was greater than that of unimproved varieties.

International Variability Studies in Crop Production

Variability studies in international crop production have been popular in recent years. Concerns about long-term food supplies and impact of modern technologies on crop production have stimulated these activities. Two types of research have been conducted: a single country or crop analysis, or aggregate analyses for a region or the world.

China. China is one of the world's largest cereal producers. By using conventional methods (coefficient of variation) and the variance decomposition technique, Stone and Zhong (1989) found that the variability of China's cereal production in area declined during the period of 1952 to 1983 since planted acreage was under an increasingly administrative planning and control by the government. However, the variability in yield and production increased slightly due to weather, varieties, and more risk-prone areas used for crops induced by grain policy. Particularly, the variability in yield and production were extremely high during the two periods, 1952-1957 and 1979-1983, and no long term trends existed for the coefficient of variations in yield and production. Stone and Zhong argued that the lack of trend for coefficient of variation in production and yield was predominantly due to the increased yield correlations among provinces. Their results provided the evidence that a 91 percent of increased feedgrain production variance could be explained by the increase in interprovincial covariances.

Great Britain. Arnold and Austin (1989) studied the impact of plant breeding on yield variability for wheat. Using Hazell's variance decomposition framework and winter wheat data in the Great Britain, the authors decomposed the variability of wheat yield into: the variations of varieties (genotypes), location, year, and the interactions of location and yields, varieties and location, varieties and years. The interaction of varieties and locations was explored. They found that modern varieties with higher yields and greater disease resistance generated only slightly more yield variability than traditional unimproved varieties. However, modern varieties would lead to a larger variation in yields than unimproved varieties if a disease had a adverse impact on crop yields over a large proportion of the region. Arnold and Austin also found that the effect of a new variety on variability was very sensitive to climatic conditions. These findings imply that breeders should understand the relationship between genotype and environmental conditions to obtain more stable producing varieties.

World cereal production. Hazell (1985) indicated that world cereal production had been relatively more unstable in the past three decades. While world cereal production grew at an average yearly rate of 2.7 percent, it was accompanied by a more than proportional increase (3.4%) in the standard deviation of production between 1960/1961 - 1982/1983. Using his variance decomposition technique, Hazell found three important components which affected cereal production variance. First, the variances of world cereal yields had increased. The increased variances of cereal yield resulted from wide adoption of improved modern technologies. These new technologies required more modern inputs. The increased yield variances were also attributed to the more unstable world cereal and oil markets. Second, the yield correlation between regions for the same and different crops had increased. This increase in yield correlation might be due to use of fewer varieties (a narrowing genetic base) and the increased use of more modern inputs. A final component was that the area-yield correlation had declined. This occurred especially between crop yields in one region with sown areas of the same or different crops in other regions. The reason given by Hazell for the declining area-yield correlation was that all farmers allocated their acreage based on expected relative prices. So crop growers allocated more land and modern inputs to favored crops.

Lessons Learned

Risk, uncertainty and variability are different concepts although they are often treated synonymously in the economic literature. Risk is distinguished from uncertainty if the probability distribution of outcome of an event is known. Risk may also be defined as the sub-event of uncertainty which may alter decision maker's well-being. Risk can be classified into subjective risk and objective risk. Objective risk is variability and measures the unexplainable random deviation from a decision maker's expectation based on a historical time series.

There are many ways to estimate variability in crop production. Each detrending technique has its advantages and disadvantages. For instance, the coefficient of variation takes the overall mean as the base to compute relative deviations. The current level of overall mean represents a "no knowledge" case for farmers. Many applied studies have used this technique because the coefficient of variation is extremely simple to calculate and can be easily understood by the public. Some studies have also used the constantly adjusted weighted moving average (CAWMA) to derive the current level for variability estimation. The CAWMA model is much more theoretical and accurate, but much more difficult to compute than the overall mean.

A lesson learned from past researches is that the selection of detrending techniques in variability estimation must be based on the research objectives and available data. If the research requires highly accurate estimation, a more theoretical model (e.g. CAWMA) is recommended. Second, it is always a good idea to use more than one model to estimate variability indexes, so that the results can be confirmed.

Based on the variability studies reviewed above, one can see that vegetable crops have a higher variability than standard field crops (i.e. grain and cotton) in yield per acre in both California and Arizona although there is a divergence in climate and soil between the two states. Second, variability in crop production varies with the farm's crop diversification. The farm with more crop diversification tends to have low variation in crop production. Third, government programs had an influence on the variations of crop production, yet this impact varies greatly with countries. Finally, variability in crop production is related to modern technologies in agriculture, but there is no a priori reason to believe that modern technologies lead to an increase in variability for crop production.

Reviewing the past variability studies in crop production, one has noted that most of the past research focused on yield and price variabilities. There are few studies that select the variability of acreage planted or harvested as an independent topic. As a matter of fact, harvested or planted variability should be one of the most important components for the variability of crop production. Acreage variability directly reflects how crop producers respond to the change in governmental programs and environmental conditions.

Since Wildermuth and Gum's variability studies in 1960's, there has been no empirical study done for Arizona crops. This research attempts to fill the gap of variability estimation and analysis for major Arizona field crops in the past three decades.

3. DATA SOURCES AND ANALYTICAL TECHNIQUES

Data Sources

The data used in this research are from Arizona Agricultural Statistics (1965, 1980, 1989, and 1990). These four volumes have continuous historical information for field crop production for nearly one century. The original objective of the database work was to graphically analyze Arizona agricultural production levels for use in an extension program. Information gathered included planted and harvested acreage, yield per harvested acre, total production, and prices received by farmers at the both county (15 counties) and state levels for all crops. Some data such as cotton and wheat was first collected in the 1890's and 1920's respectively.

Some of these data were selected for use in this research. Harvested acreage, yield per harvested acre and commodity prices were treated as the three most important indicators for the variability study. The reasons for this selection are first, that the variability of total production of one crop is based on its harvested acreage and the productivity of the harvested land (i.e. yield per acre). The production value of a crop (some researchers call it gross income) is the multiplication of total production and price. Secondly, these measures are more easily understood by crop growers. The data used in this study is only a small portion of the whole database for Arizona.

Statistical inconsistencies in these historical data are inevitable for crops due to a long time period. There are, for instance, three statistical criteria for lettuce production for the periods of pre-1965, 1966-1978, and 1979-1990. Before 1965, lettuce was reported in terms of winter, early spring, and fall lettuces. At the period of 1966-1980, lettuce was categorized into other, Yuma, and all lettuce. Since 1979, lettuce has been classified into western lettuce and other lettuce. Furthermore, the calendar year was used before 1965, but crop year for the period after 1966. The crop year used at the state level is not consistent with the crop year at the county level for other lettuce after 1979. The crop year used for Yuma lettuce is not the same as crop year for other lettuce. For example, the statistics of Yuma lettuce in 1980 were reported by the crop year of 1980/1981 while the statistics of other lettuce in 1981 were also reported by the crop year of 1980/1981. A second example is that the alfalfa hay price has been discontinued since 1970.

The inconsistency and discontinuance of data have been adjusted. The statistics of crops reported by crop year were converted into calender year's. Lettuce per acre yield was a weighted average of all different lettuce yield. A simple seasonal average price was used as the substitute for alfalfa hay.

Sample Chosen

Seven crops were selected as major field crops from about 20 field crops in Arizona: all wheat, alfalfa hay, upland cotton, Pima cotton, all lettuce, cauliflower and potatoes. In an economic sense, these crops are the most important to Arizona based on their economic value. Their production value averages about 95 percent of the total crop production value (excluding fruit crops) in the state for 1987, 1988 and 1989. Although cauliflower and potatoes are not grown across the whole state, as are cotton and wheat, their production values rank fifth and sixth in importance.

In order to gain an insight into the aggregation issue, county level data are used in addition to state data for this research. Seven counties (out of 15) were selected for the analysis: Cochise, Graham, La Paz, Maricopa, Pima, Pinal, and Yuma. These counties are located in the southern Arizona (Figure 3-1) and represent the most important areas for field crop production in this state. The cash receipts of the seven counties in field crops (excluding fruit crops) accounts for an average of 98 percent of the total state cash receipts from agricultural marketings in 1987, 1988, and 1989. The average (1987-1989) of the seven counties is above $150 million while each of the other counties produce cash receipts below $3 million. The ranking of sample counties is Maricopa, Yuma, Pinal, La Paz, Cochise, Graham and Pima in terms of crop cash receipts (AAS, 1989).

Yuma County[1] was divided into Yuma and La Paz counties in 1983. This change created some difficulty for our analysis because there was no data available for La Paz County before 1983. Since both Yuma and La Paz are important counties in field crop production, Yuma and La Paz were aggregated together for the convenience of analysis. The data of Yuma County before 1983 are the same as that of Yuma

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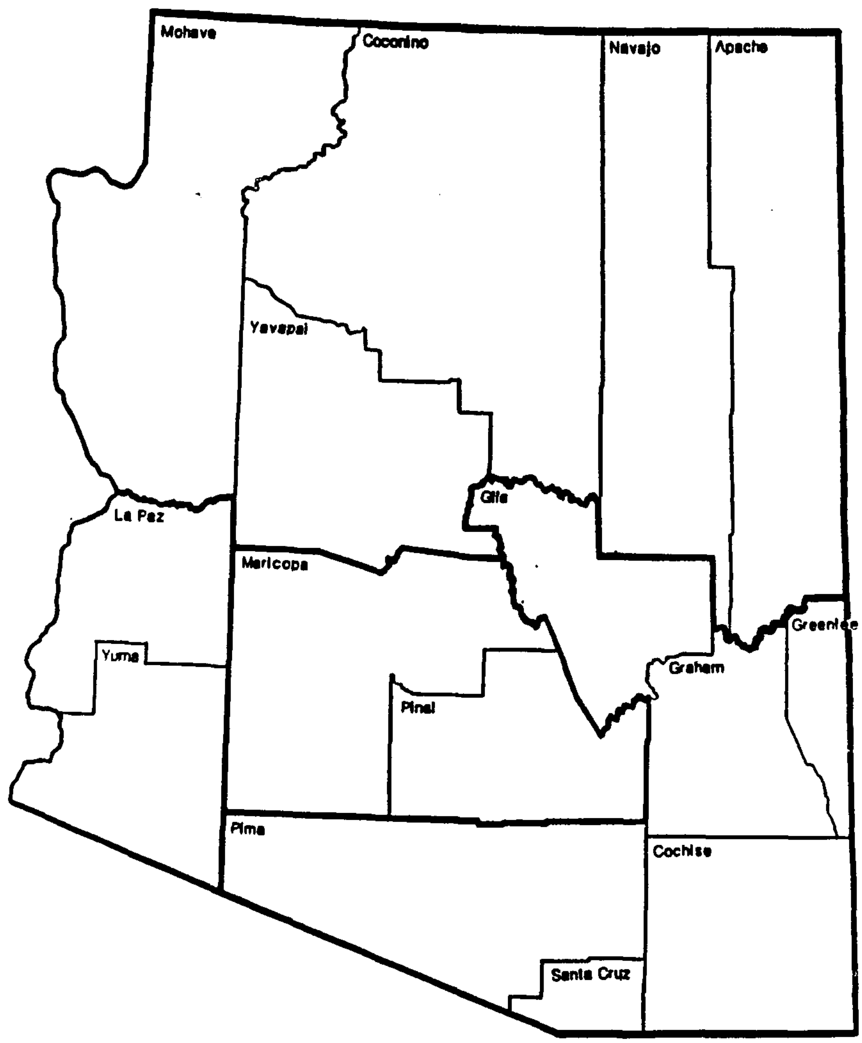
[1] Yuma County includes both Yuma and La Paz counties

Figure 3-1, Arizona Map



Source: Arizona Agricultural Statistics, 1989

County in annual Arizona Agricultural Statistics. The data after 1983 in Yuma County are a weighted average of Yuma and La Paz counties.

Although some crop data can go back one century, 24 years are the maximum time period for variability estimation across counties for Arizona field crops in this study. There were no data available at the county level before 1965 for all field crops except for cotton. Also, it is not worth considering the data before 1960 due to biological and chemical technological change which have occurred after 1960. As a matter of fact, producers are likely to consider the information from distant periods obsolete after a certain time point in their decision making.

In order to test how variability changes for major Arizona field crop production, the 24-year period was divided into two equal subperiods: 1967-1978 and 1979-1990. Upon visual inspection of the data from the past three decades in field crop production, it appears that the end of the 1970s was an important turning point for crop production due to technological improvement. Although it seems that there were more fluctuation in acreage planted in the mid-1970's for some crops, the data constrain us from making more than two divisions or justifying unequal divisions. It is recognized that the comparison of variability between the two selected periods is sensitive to the division process.

Analytical Techniques

The selection of an appropriate analytical technique is important in the measurement of variability for major Arizona field crops. Based on the literature reviewed in Chapter 2, it is clear that there are many ways to compute variability (more than ten techniques reported in the literature). The magnitude of the variability is related to the chosen method. Based on Young's evaluation for different detrending techniques, a non-detrending technique (i.e coefficient of variation) is naive for variability estimation. But, this method has still been used by many researchers due to its simplicity. In this study, four methods are used to estimate the variability of major Arizona field crops: a non-detrending technique, a linear time trend, an equally weighted moving average, and a running median. Every technique has its own advantages and disadvantages. The objective in using different methods is to compare and confirm the results of variability estimation, and therefore to increase the confidence of the analysis. Relatively speaking, the four techniques in question are easily understood by the public and have been commonly used by researchers.

Non-detrending method. The non-detrending method is the technique used to estimate the coefficient of variation. This technique has been extensively used in variability studies (Hazell, Stone and Bruce, 1989). The coefficient of variation is defined as the ratio of standard deviation and expected value (Barry et al, 1988). The expected value is defined as:

(3.1) $$E(Y) = P_1 Y_1 + P_2 Y_2 + \cdots\cdots + P_i Y_i$$

where E(Y) denotes the expected value of Y. Y is a random variable such as harvested acreage, yield per acre, and commodity prices. P is the probability of each of Y occurring (the sum of P is equal to one); i is the number observations for Y. The expected value of the random variable, Y, is called its mean (Kelejian and Oates, 1989). Statisticians often use sample mean, $\bar{Y}$, to infer population.

Standard deviation measures the amount of dispersion or variation of the predicted outcome from actual value of Y. It can be written as:

(3.2) $$S_y = \sqrt{\frac{\sum_{i=1}^{t}(Y_i - \bar{Y})^2}{t-1}}$$

where S_y represents standard deviation. t is the total number of observations. Therefore, the coefficient of variation (CV) is defined mathematically as:

(3.3) $$CV = \frac{S_y}{\bar{Y}}$$

The coefficient of variation provides a relative measure of degree of objective risk. It serves as an indicator of variability related to the amount of expected return. For instance, a crop with a coefficient of variation of 10 percent in yield per acre means that a 100 pound increase in yield per acre produces a 10 pound increase in risk or variability. The larger the value of CV, the higher the variability associated with the crop.

Linear time trend. A linear time trend is estimated from time series of data using linear regression (Johns, 1969; Smith, 1972). The time trend estimated from the OLS regression is more accurate than overall sample mean as was used in the non-detrending approach.

$$Y_i = a_0 + a_1 T_i + \varepsilon_i \tag{3.4}$$

where T is a numerical value for time period measured from the origin of the time series. The selection of the origin for the series is rather arbitrary (in this study, the origin begins from the year 1967). a_1 represents the slope of the linear trend line. ε_i is the random error of this model. The detrending procedure is:

$$\hat{Y}_i = \hat{a}_0 + \hat{a}_1 T_i \tag{3.5}$$

$$\hat{\varepsilon}_i = Y_i - \hat{Y}_i \tag{3.6}$$

Where $\hat{Y}_i$ denotes the predicted value for observation of year i. $\hat{\varepsilon}_i$ takes into account all unpredictable and unknown factors that are not explained by the time trend. Since the data are a time series, autocorrelation of $\hat{\varepsilon}_i$ is inevitable. The Cochrane-Orcutt technique was used to correct for the serial correlation in the regression.

Since $\hat{\varepsilon}_i$ may be a positive or negative value, the following adjustment is necessary:

$$S_{y1} = \sqrt{\frac{\Sigma(\hat{\varepsilon}_i)^2}{t-1}} \tag{3.7}$$

A new "coefficient of variation" can be obtained as:

$$VC_1 = \frac{S_{y1}}{\bar{Y}} \tag{3.8}$$

The new "coefficient of variation", VC_1, is referred to as the "Variability Coefficient 1." Similar to the coefficient of variation, variability coefficient 1 is often expressed in terms of a percentage. It represents the percentage change of random error in the OLS model as decision makers' expectation change. The larger the value of VC_1, the higher the level of variability for the crop.

Equally weighted moving average. The equally weighted moving average is a simple moving average detrending technique. A simple moving average of the values in a time series can be obtained by averaging several consecutive values in the series and letting the computed value be the predicted value (Brink et al, 1978; Young, 1982). The relative variability base in this study is represented by three previous years moving average as the following:

$$\hat{Y}_i = \frac{Y_{i-1} + Y_{i-2} + Y_{i-3}}{3} \tag{3.10}$$

$$\hat{\varepsilon}_i = Y_i - \hat{Y}_i \tag{3.11}$$

where $\hat{Y}_i$ is the three previous years average, $\hat{\varepsilon}_i$ is the deviation of the actual value from predicted value, and

$$S_{y2} = \sqrt{\frac{\Sigma(\hat{\varepsilon}_i)^2}{t-1}} \tag{3.12}$$

A second variability index can be estimated:

(3.13) $$VC_2 = \frac{S_{y2}}{\bar{Y}}$$

where VC_2 represents the "variability coefficient 2".

Running median. The relative variability base may also be obtained by the technique of a moving median (Hammida and Ediman, 1991). A theoretical argument for this method is that producers' behavior is risk averse. According to these authors, producers often selects the median of the three values in their decision making.

Assume that there are observations for three years, Y_{j-1}, Y_j and Y_{j+1}. If the values of all three observation are not equal, then

(3.14) $$\hat{Y}_j = \text{Median of } Y_{j-1},\ Y_j \text{ and } Y_{j+1}$$

If $Y_{j-1} = Y_j = Y_{j+1}$, then

(3.15) $$\hat{Y}_j = Y_{j+1} \text{ or } Y_j \text{ or } Y_{j-1}$$

If any two of the three observations are equal, then one of the two equal value observations will be the median. We can compute the deviation of Y_j from $\hat{Y}_j$, the standard deviation and the variability in the same manner used in the two previous methods:

(3.16) $$\hat{\varepsilon}_i = Y_i - \hat{Y}_i$$

(3.17) $$S_{y3} = \sqrt{\frac{\Sigma(\hat{\varepsilon}_j)^2}{t-1}}$$

(3.18) $$VC_3 = \frac{S_{y3}}{\bar{Y}}$$

where VC_3 represents "variability coefficient 3".

Since moving median method uses three years observations in this study, the observations for the first and last year are lost. Each of two subperiods has 10 years (1968-1977, 1979-1989) and the whole period has 22 years (1968-1989) for the moving median technique.

Estimation of variability in this study involves four models, three periods, seven major crops, seven counties, and the state aggregated data. A TSP program was designed to do these calculations (Appendix A). One of the strongest advantages of this computer program is that all results can be replicated and it is easy to make an adjustment and correction for the computation.

4. ANALYTICAL RESULTS - STATE LEVEL

The literature reviewed in Chapter 2 shows that crop production, both domestic and worldwide, has been accompanied by larger variations, in the past four decades. Specifically, Wildermuth and Gum found that Arizona crop producers operated in a risky and uncertain environment in the 1960's. Three decades have already gone by since Wildermuth's and Gum's studies of variability in crop production, but certain questions remain, such as: what is the uncertain environment for Arizona crop producers? Has the production variability of major Arizona field crops increased or decreased or remained unchanged since the 1960's? What are the forces that drive these fluctuations? This chapter attempts to answer these questions by using statistical, graphic, and expert analysis techniques[1].

Model Selection

Four types of variability indexes, a standard coefficient of variation, deviations around a linear time trend, equally weighted moving average (previous three years), and running median (three years), were estimated for acreage harvested, yield per harvested acre,

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[1]Expert analysis is the technique that researchers extensively ask experts' opinions according to the questions in the research, then find the most reasonable explanations. The experts interviewed are Dr. Harry Ayer, Dr. Neil Conklin (Agricultural Economics), Dr. Robert Dennis (Plant Sciences), Lew Daugherty, Dr. Jimmye Hillman (Agricultural Economics), Dr. Norman Oebker, Dr. Brooks Taylor (Plant Sciences), and Dr. James Wade (Agricultural Economics).

nominal price, and real price for major Arizona field crops. Although the magnitude of variability indexes generated by the four models are different, similar qualitative results are reached for most of the selected crops independent of the selected models (Appendix B). This similarity of conclusions produced by four different models greatly increases the degree of confidence in the analysis.

This analysis is based on the results from Model 3 (the equally weighted moving average). Other results estimated from the non-detrending, linear time trend, and running median models are reported in detail in Appendix C. Past research provides the evidence that the moving average model is an acceptable technique for detrending data. In 1980, Young evaluated 8 detrending techniques, and used price data of processed green pea and lentils to test each method empirically. He found that moving average procedures (i.e equally moving weighted average and the constantly adjusted weighted moving average) were superior to the other detrending techniques. The results of this study demonstrate that the moving average model generated less conflicting conclusions in the change direction of variability than the other models (Appendix B). Also, the analysis based on one index can make the discussion simpler, explicit, and readily understood.

Structure of Analysis

The analysis of this chapter is organized by crops at the state level. County level variability will be discussed in Chapter 5.

Variability first will be evaluated for the entire time period: 1967-1990. Then, the change of variability between the first period (1967-1978) and the second period (1979-1990) will be discussed.

Under each crop, the variability of acreage harvested, yield per harvested acre, and prices (both nominal and real prices) will be discussed separately. Acreage harvested is one of the most important indexes to measure field crop production. Harvested acreage usually is smaller than planted acreage if farmers do not harvest all their crops due to low expected profits. Whenever one talks about gross income in crop production, acreage harvested is one of the key factors. The variability of acreage harvested also indicates how farmers allocate their land in response to the adjustments of government programs, relative commodity prices, input prices, productivity, etc. Acreage harvested and acreage planted are approximately equal in irrigated agriculture. Yield per harvested acre reflects the productivity per unit of land for a crop. Based on the magnitude of yield variability, one can see how land productivity is influenced by weather, new varieties, modern inputs, new technologies, and management. Price variability exerts an important influence on farmers' planting decisions because prices are important in determining an agricultural producer's income.

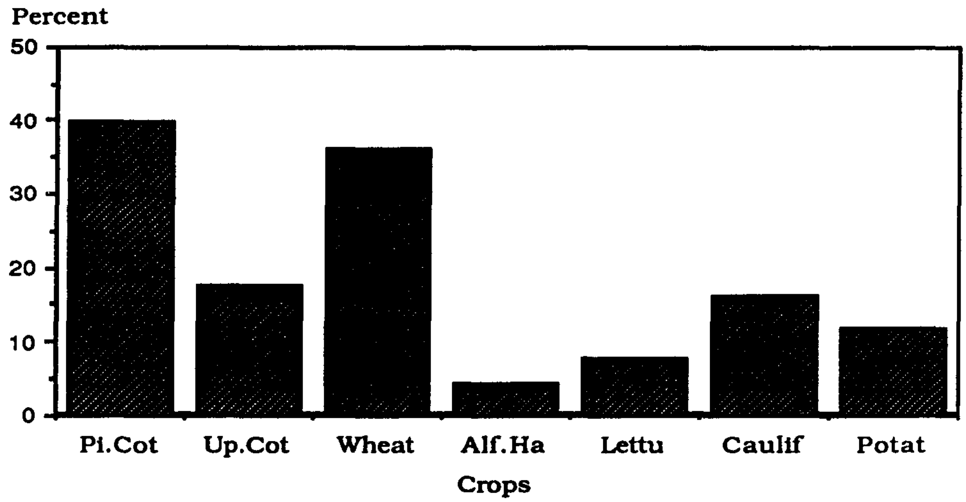
Pima Cotton

Harvested acreage variability. Pima cotton [i.e. Amerian-Pima cotton, or Pima long staple cotton, or Extra Long Staple (ELS) cotton] has become one of the most important crops in Arizona in recent years. The planted acreage of Pima cotton has greatly increased due to incentives created by relatively higher prices and improved yields. Based on variability estimation, Pima cotton was the most variable in harvested acreage among the 7 selected crops for the past 24 years (1967-1990) (Figure 4-1, Panel A). The variability coefficient of Pima cotton in acreage harvested reached 39.6% (Table 4.1). The variance of Pima cotton in harvested acreage has increased significantly between the two periods (1967-1978 and 1979-1990). The variability coefficient of Pima cotton increased by a factor of 2.4 between the two study periods (Figure 4-2, Panel A).

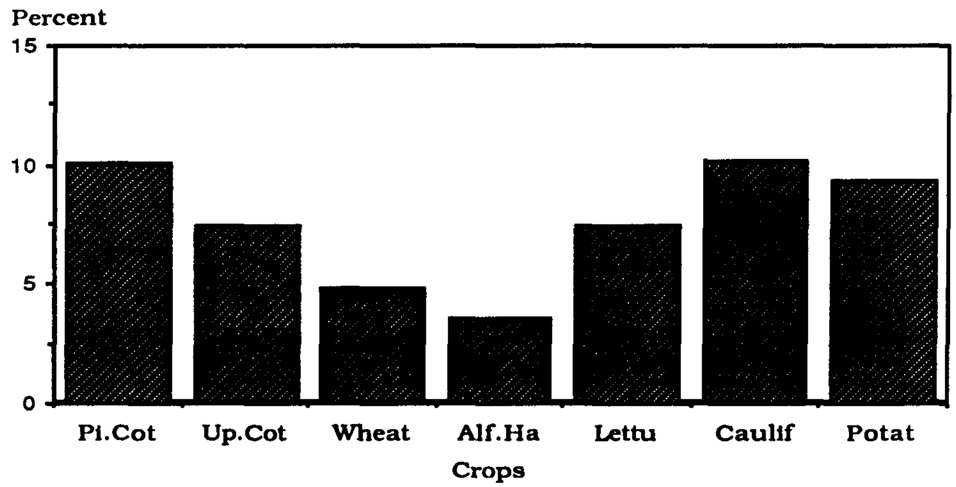
The highest variability of Pima cotton in acreage harvested was attributable to large fluctuations in planted acres in recent years. Pima cotton acreage was stable before 1983 (Figure 4-3, Panel A) with only about 30,000 acres harvested. The amount of land planted to Pima cotton was only one tenth of the acreage planted to upland cotton. However, Pima cotton acreage has been increasing sharply since 1984, peaking in 1989, and falling dramatically in 1990. The sharp rise in acreage harvested was related to the rising Pima cotton price relative to upland cotton, the introduction of new Pima varieties, and a more efficient Pima cotton seed distribution system. Favorable Pima cotton prices attracted more farmers to produce Pima cotton, more efficient seed distribution provided cotton growers with more timely information concerning varieties, and the introduction of new Pima varieties created an opportunity of higher profits for cotton producers

Figure 4-1, Variability of Major Arizona Field Crops at State Level (1967-1990)[1]

Panel A, Acreage Harvested

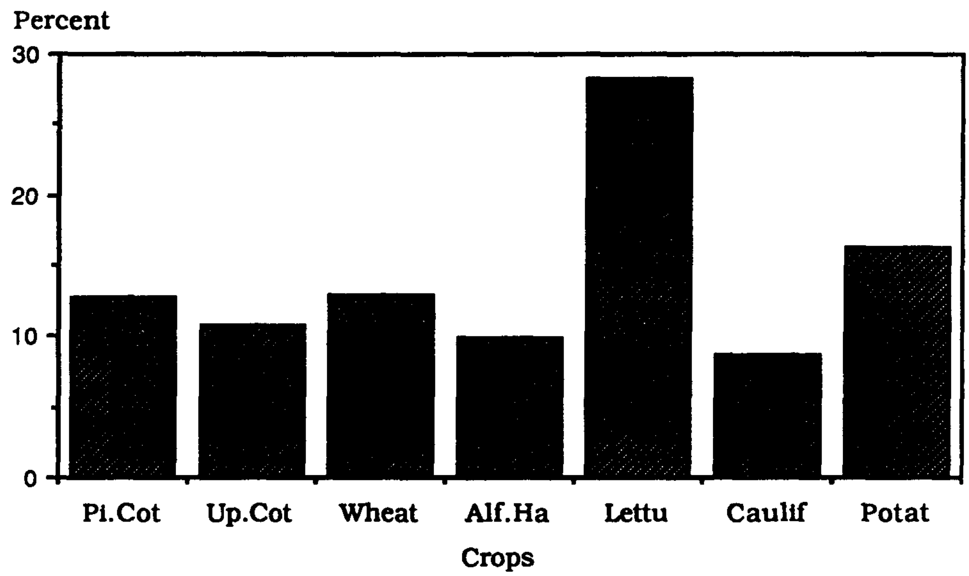


Panel B, Yield per Harvested Acre



(1) Pi.cot, up.cot, wheat, alf.ha, lettu, caulif, and potat denote Pima cotton, upland cotton, all wheat, alfalfa hay, all lettuce, cauliflower and potatoes respectively.

Panel C, Nominal Prices



Panel D, Real Prices

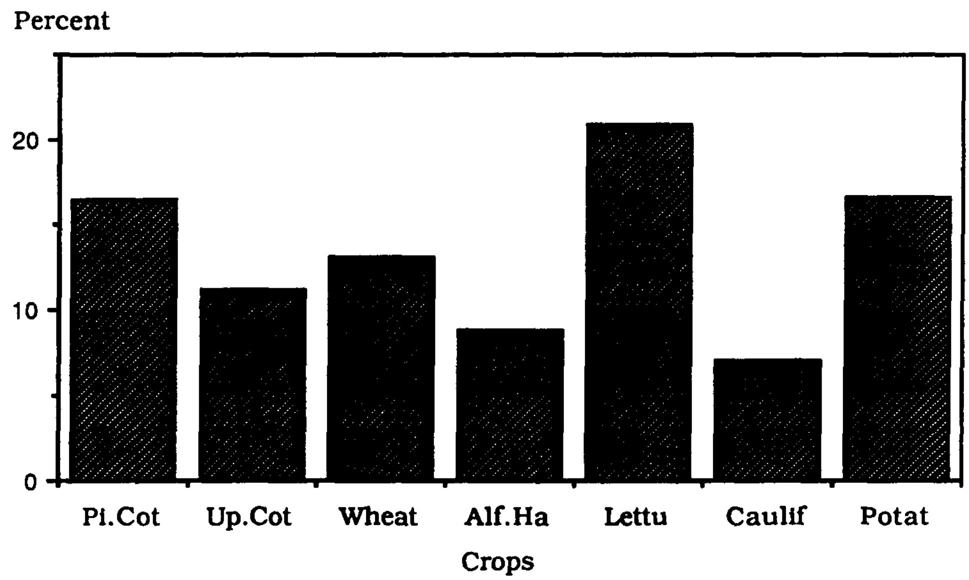


Table 4.1, Variability of Major Arizona Field Crops at State Level

Items	Unit	Ranking (1=Lowest)	Mean				Standard Deviation
			Overall	1st Period	2nd Period	Change (%)	Overall
Harvested Acreage							
Alfalfa Hay	Thou. Acres	1	174.75	194.50	155.00	-20.31	23.86
All Lettuce	Thou. Acres	2	42.70	43.84	41.57	-5.18	5.55
Potatoes	Thou. Acres	3	7.19	8.93	5.45	-38.97	2.41
Cauliflower	Thou. Acres	4	2.67	0.96	4.39	357.29	2.22
Upland Cotton	Thou. Acres	5	357.67	320.33	395.00	23.31	121.34
All Wheat	Thou. Acres	6	150.92	168.50	133.33	-20.87	82.12
Pima Cotton	Thou. Acres	7	57.13	34.46	79.80	131.57	48.68
Yield per Acre							
Alfalfa Hay	Tons/Acre	1	6.73	6.11	7.34	20.13	0.77
All Wheat	Lbs./Acre	2	4605.55	3934.72	5276.39	34.10	789.52
All Lettuce	Cwt./Acre	3	233.70	191.35	276.05	44.26	49.33
Upland Cotton	Lbs./Acre	4	1332.90	1045.28	1220.51	16.76	134.40
Potatoes	Cwt./Acre	5	260.63	254.17	267.08	5.08	29.98
Pima Cotton	Lbs./Acre	6	742.67	626.00	859.33	37.27	167.59
Cauliflower	Cwt./Acre	7	87.75	62.08	113.42	82.70	28.08

Note: Ranking is based on variability coefficient 2 (overall Level). The first and second periods represent 1967-1978 and 1979-1990 respectively.

Table 4.1 (Continued). Variability of Major Arizona Field Crops at State Level

Items	Standard Deviation		F-ratio	Variability (%)			
	1st Period	2nd Period		Overall	1st Period	2nd Period	Change
Harvested Acreage							
Alfalfa Hay	8.79	6.39	1.90	4.23	4.52	4.12	-8.85
All Lettuce	2.99	3.56	1.42	7.53	6.82	8.57	25.66
Potatoes	1.11	0.53	4.36*	11.86	12.45	9.77	-21.53
Cauliflower	0.14	0.61	20.03**	16.13	14.16	13.86	-2.12
Upland Cotton	58.24	68.81	1.40	17.43	18.18	17.42	-4.18
All Wheat	70.37	36.51	3.72*	36.32	41.76	27.38	-34.43
Pima Cotton	4.19	32.41	59.91**	39.56	12.15	40.61	234.24
Yield per Acre							
Alfalfa Hay	0.27	0.22	1.49	3.56	4.37	2.98	-31.81
All Wheat	261.66	182.56	2.05	4.79	6.65	3.46	-47.97
All Lettuce	7.44	23.77	10.20**	7.37	3.89	8.61	121.34
Upland Cotton	96.69	73.23	1.74	7.40	9.25	6.00	-35.14
Potatoes	21.86	27.62	1.60	9.35	8.60	10.34	20.23
Pima Cotton	81.57	70.21	1.35	10.02	13.03	8.17	-37.30
Cauliflower	5.91	11.47	3.76*	10.17	9.52	10.11	6.20

Note: The first and second periods represent 1967-1978 and 1979-1990 respectively. **, * denotes that the variance in the second period is significantly different from that of the first period at 1 and 5 percent confidence levels, respectively (two tail test).

Table 4.1 (Continued), Variability of Major Arizona Field Crops at State Level

Items	Unit	Ranking (1=Lowest)	Mean				Standard Deviation
			Overall	1st Period	2nd Period	Change (%)	Overall
Nominal Price							
Cauliflower	Dollars/Cwt.	1	26.14	20.08	32.19	60.31	8.00
Alfalfa Hay	Dollars/Ton	2	64.62	44.93	84.30	87.63	23.86
Upland Cotton	Cents/Lb.	3	51.53	39.64	63.43	60.02	16.68
Pima Cotton	Cents/Lb.	4	82.13	64.76	99.51	53.66	25.38
All Wheat	Dollars/Ton	5	101.43	76.42	126.45	65.47	34.07
Potatoes	Dollars/Cwt.	6	6.01	4.32	7.70	78.24	2.41
All Lettuce	Dollars/Cwt.	7	9.65	7.15	12.16	70.07	4.14
Real Price							
Cauliflower	Dollars/Cwt.	1	34.98	39.07	30.88	-20.96	7.23
Alfalfa Hay	Dollars/Ton	2	82.81	86.18	79.44	-7.82	12.68
Upland Cotton	Cents/Lb.	3	68.14	75.74	60.54	-20.07	15.96
All Wheat	Dollars/Ton	4	133.74	146.77	120.72	-17.75	32.04
Pima Cotton	Cents/Lb.	5	109.67	124.72	94.16	-24.50	28.61
Potatoes	Dollars/Cwt.	6	7.70	8.28	7.11	-14.13	1.49
All Lettuce	Dollars/Cwt.	7	12.80	14.19	11.41	-19.59	3.39

Note: Ranking is based on variability coefficient 2 (overall Level). The first and second periods represent 1967-1978 and 1979-1990 respectively.

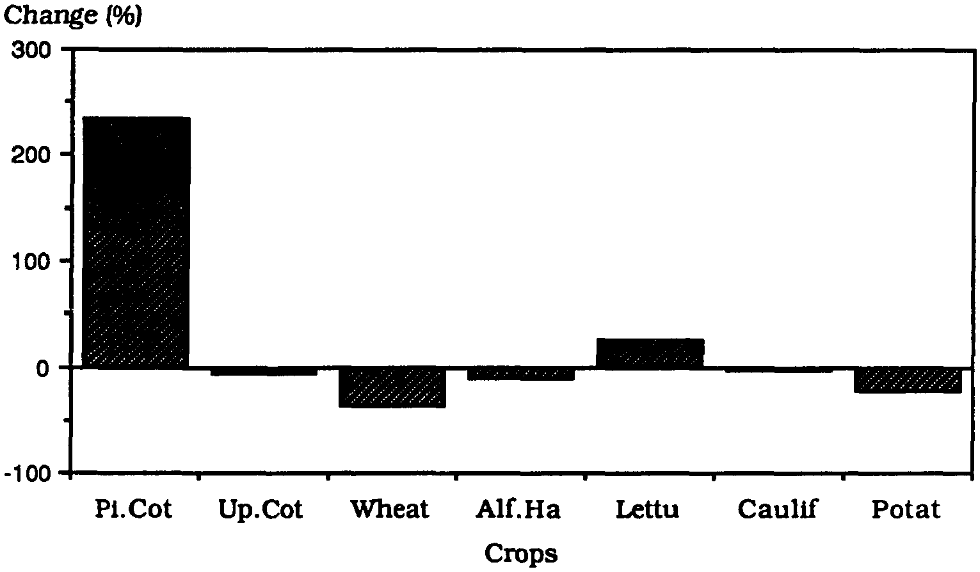
Table 4.1 (Continued), Variability of Major Arizona Field Crops at State Level

Items	Standard Deviation		F-ratio	Variability (%)			
	1st Period	2nd Period		Overall	1st Period	2nd Period	Change
Nominal Price							
Cauliflower	1.94	2.67	1.88	8.73	9.68	8.29	-14.36
Alfalfa Hay	5.54	7.36	1.77	9.86	12.32	8.73	-29.14
Upland Cotton	5.32	6.00	1.27	10.75	13.41	9.46	-29.46
Pima Cotton	12.87	7.85	2.69	12.70	19.88	7.89	-60.31
All Wheat	12.68	14.01	1.22	12.89	16.59	11.08	-33.21
Potatoes	0.86	1.13	1.70	16.32	19.97	14.62	-26.79
All Lettuce	1.07	3.80	12.59**	28.27	14.97	31.23	108.62
Real Price							
Cauliflower	2.20	2.82	1.64	7.07	5.63	9.12	61.99
Alfalfa Hay	8.35	6.47	1.66	8.83	9.69	8.15	-15.89
Upland Cotton	8.45	6.99	1.46	11.13	11.16	11.55	3.49
All Wheat	21.58	13.17	2.68	13.07	14.70	10.91	-25.78
Pima Cotton	24.68	8.79	7.88**	16.53	19.79	9.34	-52.80
Potatoes	1.38	1.24	1.23	16.69	16.67	17.47	4.80
All Lettuce	1.91	3.36	3.10*	20.85	13.44	29.41	118.82

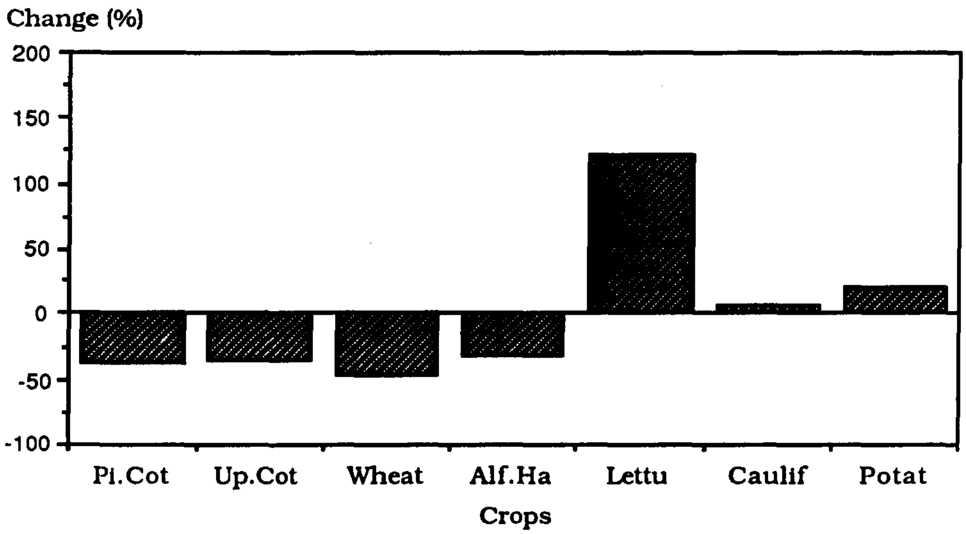
Note: The first and second periods represent 1967-1978 and 1979-1990 respectively. **, * denotes that the variance in the second period is significantly different from that of the first period at 1 and 5 percent confidence levels, respectively (two tail test).

Figure 4-2, Change of Variability for Major Arizona Major Field Crops at State Level (1967-1978 and 1979-1990)[1]

Panel A, Acreage Harvested



Panel B, Yield per Harvested Acre



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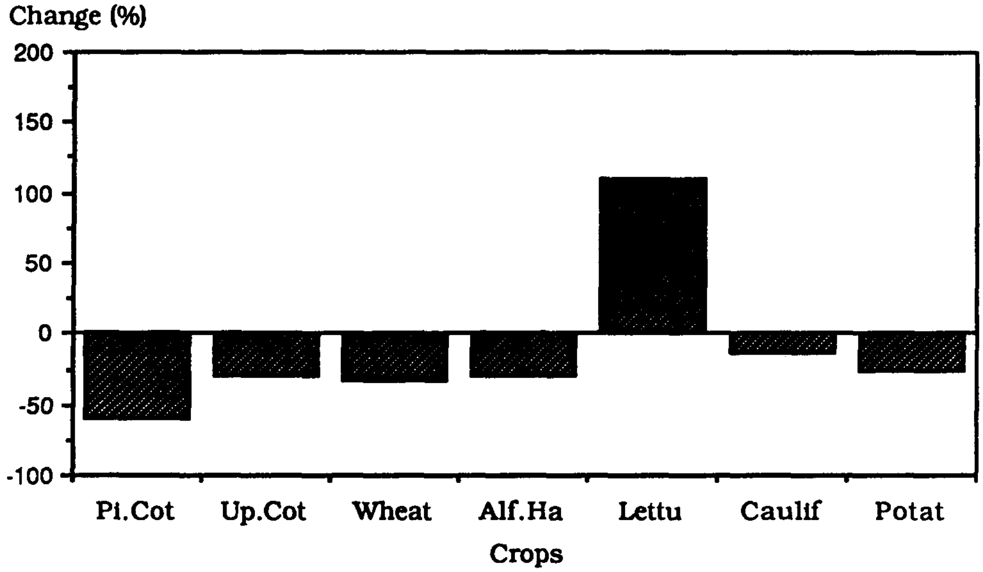
(1) Pi.cot, up.cot, wheat, alf.ha, lettu, caulif, and potat denote Pima cotton, upland cotton, all wheat, alfalfa hay, all lettuce, cauliflower and potatoes respectively.

Panel C, Nominal Price



Panel D, Real Price

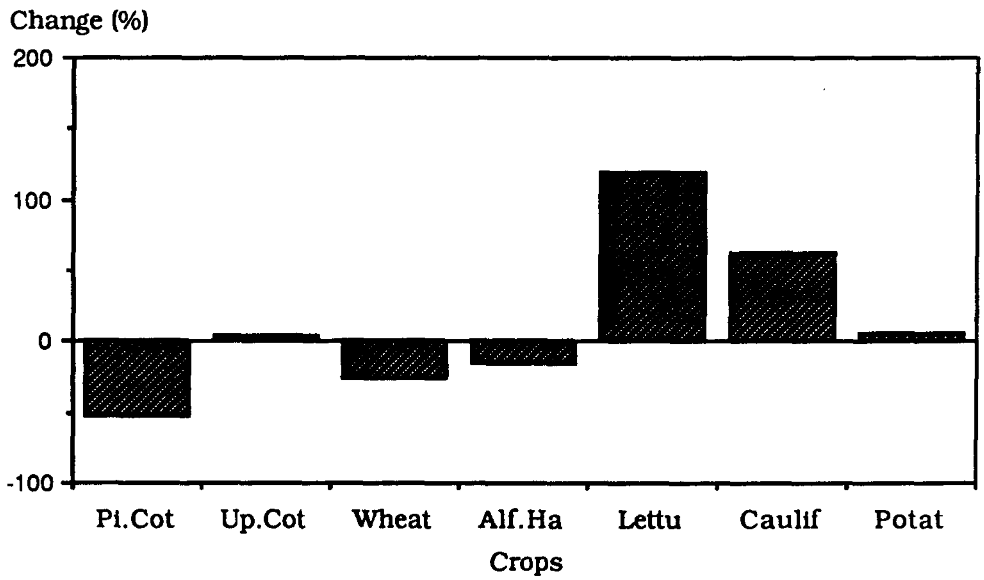
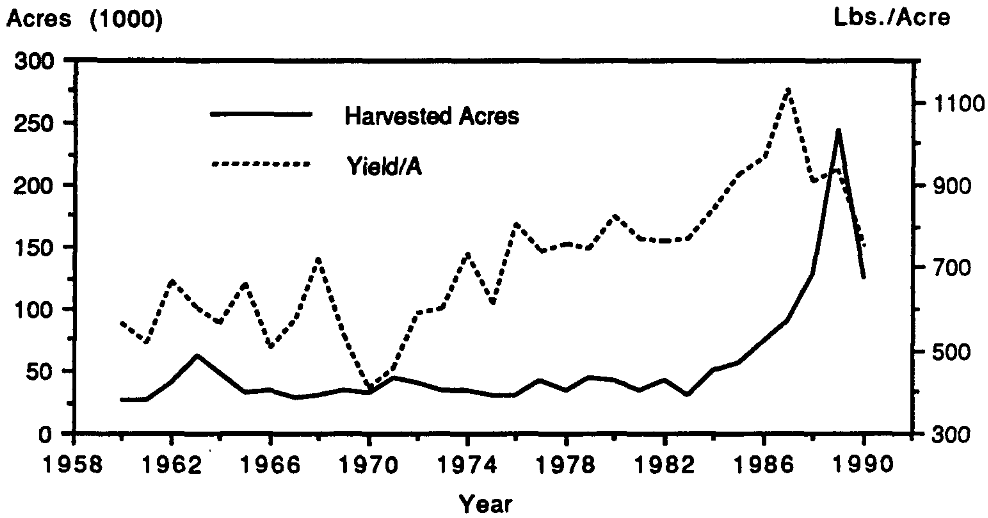
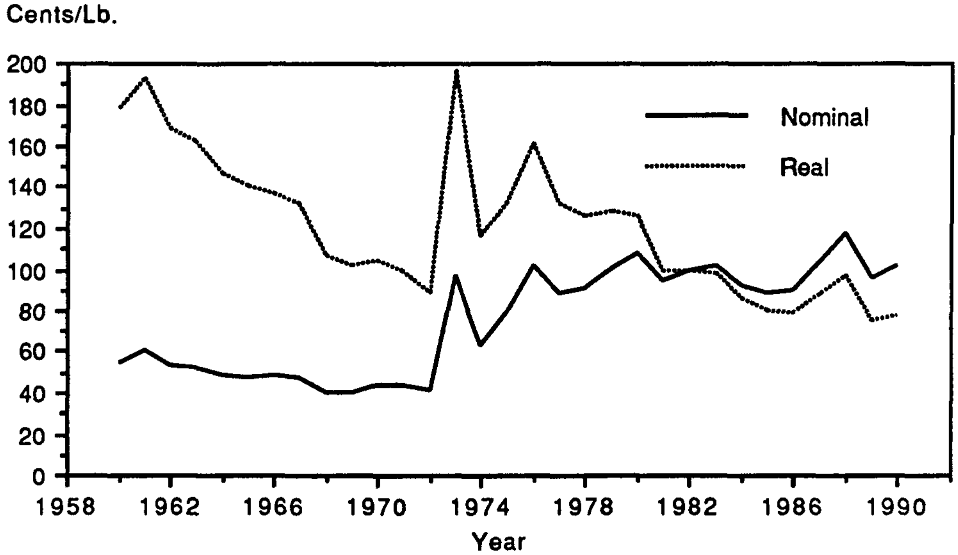


Figure 4-3, Pima Cotton (1960-1990)

Panel A, Harvested Acreage and Per Harvested Acre Yield



Panel B, Nominal and Real Prices (1982=100)



through higher yields. The sharp fall in harvested acreage in 1990 was due to the decline of Pima cotton prices and poor yields in 1989. In contrast to upland cotton, U.S. agricultural programs had less impact on Pima cotton than upland cotton. So when demand for upland cotton declined, cotton producers switched some of their land to Pima cotton.

Yield variability. The Pima cotton per acre yield has increased by about 37 percent between the two study periods due to new technologies, especially new, higher yielding varieties. The yield variability of Pima cotton ranked second (10%) among the seven crops (Figure 4-1 and Table 4-1). This high variability in yield is due to the fact that Pima cotton is relatively more sensitive to pests and weather, and requires more intensive management. Pima cotton yield fell to its lowest point in 1970 (Figure 4-3, Panel A). This sharp fall resulted from the infestations of pink bollworm and sweet potato whitefly. Also, 1970 was the year that DDT was forbidden for use in agriculture. Yield per acre increased steadily since 1971 and peaked in 1987. This steady upward trend in Pima cotton yield was attributed to the introduction of new Pima cotton varieties (e.g. Pima S-6, and S-7), improved farming technologies (e.g. laser leveling), and better farm management. These factors are also the reasons why the yield variability of Pima declined by 37 percent between the two study periods. Pima cotton yields have fallen sharply since 1989 because of bad weather and pink bollworm infestations. The large fall in 1970 and sharp rise in 1987 generated a large yield variability for Pima cotton.

Price variability. The nominal price of Pima cotton has steadily increased due to inflation while the real price level has declined in the past 24 years because of the rise of farm productivity. Pima cotton price variability ranked fourth and third in nominal and real terms respectively among the seven selected crops. This large variability index was related to the the large fluctuations in 1973, 1976, and from 1984 to 1990. The first sharp rise in 1973 (Figure 4-3, Panel B) in Pima cotton price was attributable to the worldwide energy crisis. The second sharp rise in price in 1976 was due to crop shortages, the devaluation of the dollar, and generally favorable economic growth worldwide. The third rise after 1986 was possibly attributed to the Pima cotton promotion program. In this program, cotton industry promoters traveled to European countries to advertise Pima cotton. They showed cotton processors how to produce a high quality cotton lint in their mills. This effort made Pima cotton better known both nationwide and worldwide. The demand of Pima cotton increased dramatically after this cotton promotion program.

Little governmental intervention in the Pima cotton market may be another reason for this large variation. The price variability of Pima cotton has declined in both nominal and real prices between the two periods.

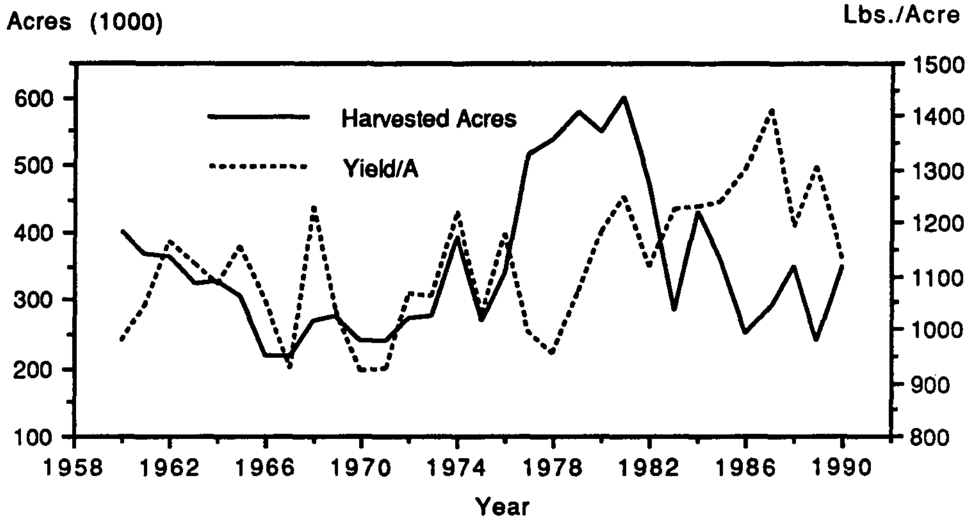
Upland Cotton

Harvested acreage variability. Over the years, upland cotton has been the most important crop in Arizona agriculture. Compared with the acreage harvested in the 1960's, the acreage harvested in the late 1980's has declined slightly. Upland cotton ranked third in harvested acreage variability among the seven selected crops (Table 4.1). Upland cotton was less variable in harvested acreage than Pima cotton (17.4% vs. 39.6%). The reason for this lower variability is probably due to the fact that upland cotton acreage has been influenced to a greater extent by governmental programs.

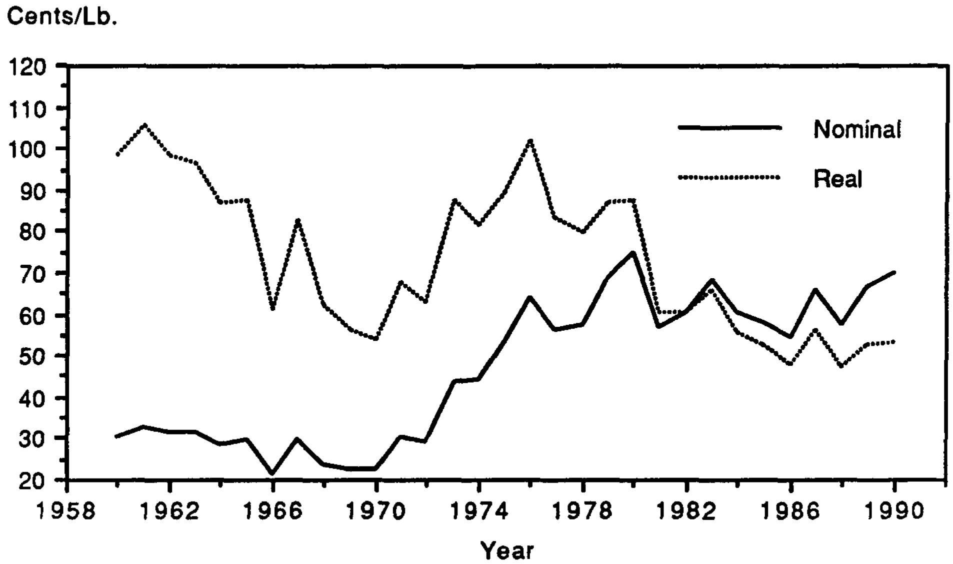
Although the variance of upland cotton acreage increased, its variability measure declined by 4 percent between periods. This suggests that upland cotton varied less in period two than period one. The reduced variability was due to the fact that the largest fluctuation of upland cotton occurred in the 1970's (Figure 4-4, Panel A). Before 1967, there was a downward trend in acreage harvested for upland cotton due to the cotton acreage reduction program (i.e. the Agricultural Act of 1956 to reduce cotton carryover). The relative stability in acreage harvested during the period of 1967 and 1972 was attributed to the voluntary reduction program. After 1973, the acreage of upland cotton began to increase due to the worldwide demand for American cotton. However, a significant drop in acreage occurred because of a strongly cost-price squeeze in 1975. During the period of 1976 and 1982, upland cotton climbed to a plateau in acreage harvested due to heavy foreign demand for upland cotton,

Figure 4-4, Upland Cotton (1960-1990)

Panel A, Harvested Acreage and Per Harvested Acre Yield



Panel B, Nominal and Real Prices (1982=100)



decreased foreign for wheat, and government interventions. The Food and Agricultural Act of 1977 set target prices on the basis of cost of production, which encouraged the movement of acreage to more efficient producers and to the regions where cotton production enjoyed a comparative advantage. After 1982, a worldwide recession reduced both domestic and foreign demand. Cotton supplies largely exceeded demand in a short time due to record high yield levels and lower inflation rates. The payment-in-kind program, issued in 1983, induced the reduction of acreage planted still further.

Yield variability. Because of new technologies, the per acre yield of upland cotton has increased steadily since 1978. Upland cotton yield was less variable than Pima cotton and had a variability coefficient of 7.4 percent (ranked fourth). The relatively low yield variability of upland cotton was probably due to the fact that upland cotton grows in more diverse regions and has larger aggregated data. Similar to Pima cotton, 1970 was a bad year for upland cotton because the use of DDT was forbidden in agriculture and pest infestations were disastrous. The yield of upland cotton was extremely low (less than 1000 lbs. per acre) in 1978 due to bad weather and pest infestations. The sharp rise in upland cotton per acre yield after 1979 was mainly attributed to the introduction of new varieties such as DPL 90. The highest historical per unit yield of upland cotton in 1987 was due to favorable weather and higher yielding varieties. However, bad weather and pest infestations (i.e. pink bollworm and potato white fly) resulted in the decline of upland cotton yields in recent years.

As compared to period one (1967-1978), the yield variability of upland cotton has declined about 35 percent in period two (1979-1990). The declining yield variation probably can be attributed to improved technologies such as new varieties and improved water management.

Price variability. As compared with the Pima cotton prices, upland cotton prices varied less (Figure 4-1, Panel C), but fluctuated for a longer time period (Figure 4-4, Panel B). The variability of upland cotton declined in nominal prices and increased in real prices slightly between the two study periods. The reason for the price fluctuation of upland cotton was due to government interventions and uncertainty in the world cotton market. First, government programs greatly influenced upland cotton prices. For example, in the 1960's, farm programs reduced high cotton stocks and brought the price of cotton used in the United States down through direct payment to domestic cotton users and voluntary acreage reduction programs. Second, the real price level of upland cotton trended upward steadily during the period of 1970-1980. This upward trend was mainly attributed to increased foreign demand and more market-oriented government programs. For example, the government considerably reduced its direct payments to cotton producers during the period of 1974 and 1981. Third, the price variations in upland cotton from 1980 to 1986 were probably affected by the sharp increase of cotton exports from mainland China (Ayer, 1986). China used to be a large cotton importer, but it has quickly become one of the largest cotton exporters due to its new more market-focused farm policies during this period.

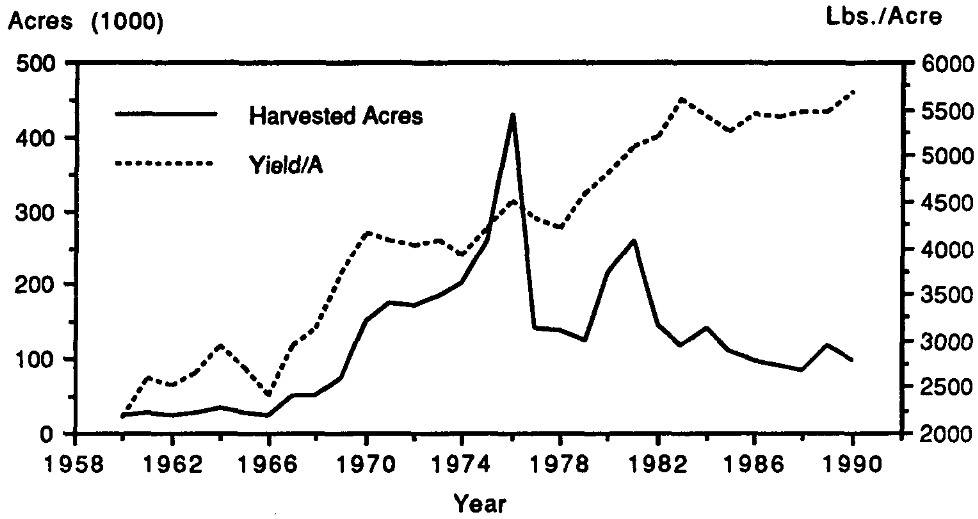
Wheat

Harvested acreage variability. Wheat is the third most important crop in Arizona crop production in terms of acreage harvested. Based on the variability estimation, wheat acreage was the second most variable with a variability coefficient of 36.3% (Figure 4-1, Panel A). This higher variation for wheat may be due to the fact that wheat has been an important export commodity and an eligible crop in government's commodity program. So, wheat production is tied closely to world markets and governmental policies.

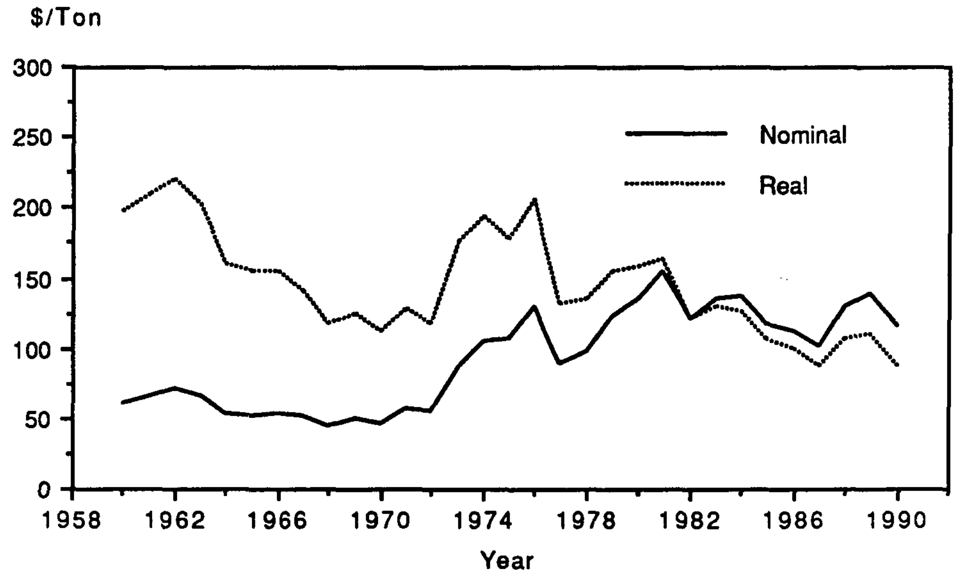
Both the variance and the variability index have declined in harvested acreage for all wheat between the two periods. The decreased variability in acreage harvested resulted from the declining variation after 1982. Wheat harvests increased very slowly overall, but varied greatly from 1970 to 1982 (Figure 4-5, Panel A). This largest fluctuation (1974-1977) was related to the instability of the world grain market. The acreage harvested of all wheat (especially durum wheat) peaked at 431,000 acres due to economic incentives caused by heavy foreign demand (AAS, 1976). During this period, the Soviet Union greatly increased grain imports; so did several developing countries since their economies were expanding. A second explanation for this large fluctuation of wheat was that the introduction of durum wheat in 1976 made Arizona wheat farming

Figure 4-5, All Wheat (1960-1990)

Panel A, Harvested Acreage and Per Harvested Acre Yield



Panel B, Nominal and Real Prices (1982=100)



more profitable, thereby attracting more farmers to this enterprise. The world wheat market has been, however, relatively stable since 1982. Accordingly, the acreage harvested in Arizona has not fluctuated as before.

Yield variability. Wheat yield per acre was the second most stable (4.8%) over the past 24 years (Table 4.1). The lower variation in wheat per unit yield was due to the fact that wheat can resist pests better than cotton and grow better in Arizona's dry weather conditions. The variability of wheat yield per acre has declined by 47 percent between the two periods. This decrease of yield variations was related to new varieties and improved farming techniques. Wheat yield has been upward trending since the 1960's with improvements in varieties and fertilization. Specifically, there were two periods with rapid yield increase: 1966-1970 and 1978-1983 (Figure 4-5, Panel A). The sharp rise in the first period was due to the introduction of new varieties such as Sonora 66 and 67. The more moderate rise in the second period was attributed to the introduction of new varieties such as semi-dwarf, stiff-strawed, and high-yield wheat.

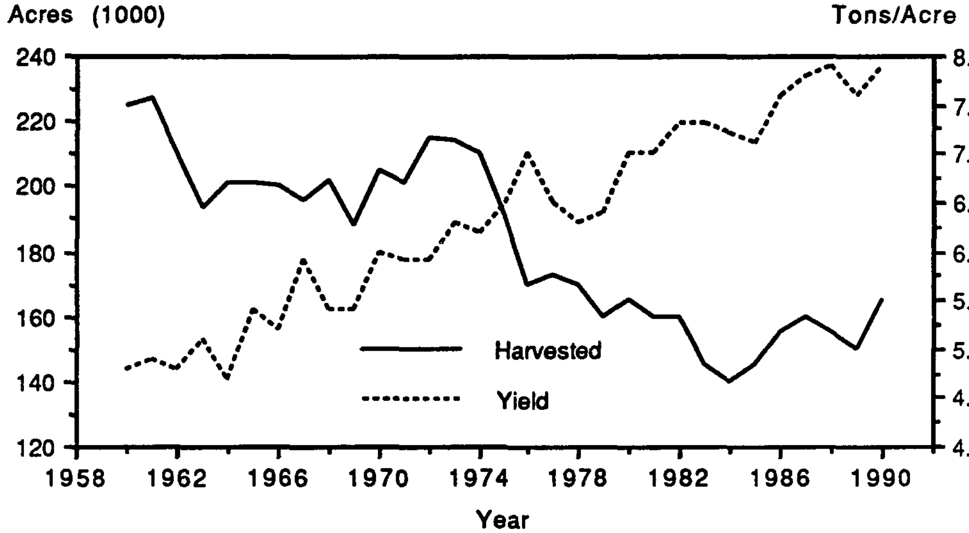
Price variability. Wheat was the third variable crop in terms of nominal price variability and ranked fourth in real price variability (Figure 4-1, Panel D). The large variability in wheat prices was mainly caused by variable foreign demand. The real wheat prices have been trending downward overall since 1960. However, the trend in real wheat prices was interrupted by shocks to the world wheat market in the mid-1970s (Figure 4-5, Panel B). The major factor during this period was the large amount of wheat imported by the USSR. Since the large fluctuation of wheat prices occurred in the middle of the 1970's and the dividing point of the analysis is 1978-1979, the variabilities of both nominal and real prices have declined between the two periods.

Alfalfa Hay

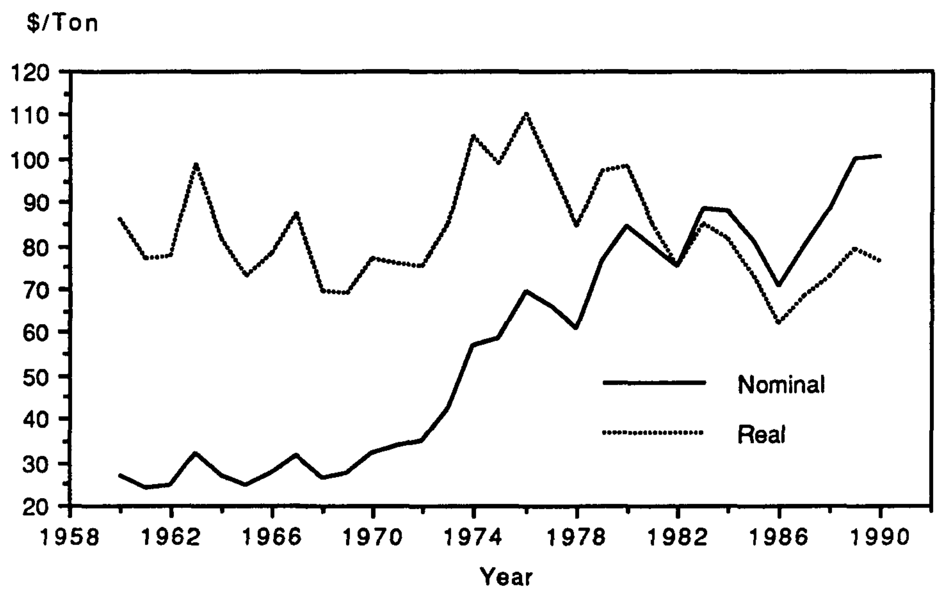
Harvested acreage variability. Alfalfa hay was the least variable crop (4.2%) in acreage harvested (Figure 4-1, Panel A). Its variability decreased by about 8 percent between the two periods (Figure 4-2, Panel A). The harvested acreage of alfalfa hay has been trending downward and the yield per acre has been rising since 1960 (Figure 4-6, Panel A). The relative stability of alfalfa hay is due to its stable market needs. Alfalfa hay is primarily used for livestock such as dairy cows and horse feed. Because it is a low value crop and costly to transport, the production of alfalfa hay is mostly for Arizona use, although some alfalfa cubes are exported to Japan and an increasing trade is developing between Arizona and California. Reduced harvested acreage has been offset by increased land productivity so total production has remained relatively stable. Furthermore, because of its rapid growth, length of growing season, and large amount of green matter produced each season, alfalfa has a high water requirement compared with most crops. Increased water costs in Arizona might further constrain alfalfa growers from planting more alfalfa.

Figure 4-6, Alfalfa Hay (1960-1990)

Panel A, Harvested Acreage and Per Harvested Acre Yield



Panel B, Nominal and Real Prices (1982=100)



Yield variability. Since 1960, alfalfa yield per acre has been trending upward steadily due to new varieties and improved water management. Compared to the other selected six field crops, alfalfa hay demonstrated the least variation in yield per acre (Figure 4-1, Panel B). The per acre yield stability of alfalfa hay is largely determined by its biological character. Alfalfa usually has a stable yield with irrigation and a favorable climate. The variation in alfalfa hay yields also declined about 32 percent between the two study periods. This declining variation of per acre alfalfa yield was probably attributed to the regional shift of alfalfa production. In recent years, alfalfa hay production has shifted from the regions with relatively high water costs (e.g. Cochise and Pinal Counties) to the region with inexpensive water (i.e. Yuma County).

Price variability. Nominal and real prices of alfalfa hay were the second least variable (9.9% and 8.8% respectively) (Table 4-1). This lower variability probably resulted from the stability of alfalfa hay production and demand in Arizona. Visual inspection of alfalfa hay prices (Figure 4-6, Panel B) illustrates that the stable real price trend was only interrupted in the mid-1970s. This large fluctuation was related to the variations of other crops such as cotton and wheat in the 1970's. In other words, the shock from the world cotton and wheat market had an indirect impact on the Arizona alfalfa market. The declining variation of alfalfa hay prices between the two periods was related to the choice of study periods since most of the price fluctuations occurred before 1978.

Lettuce

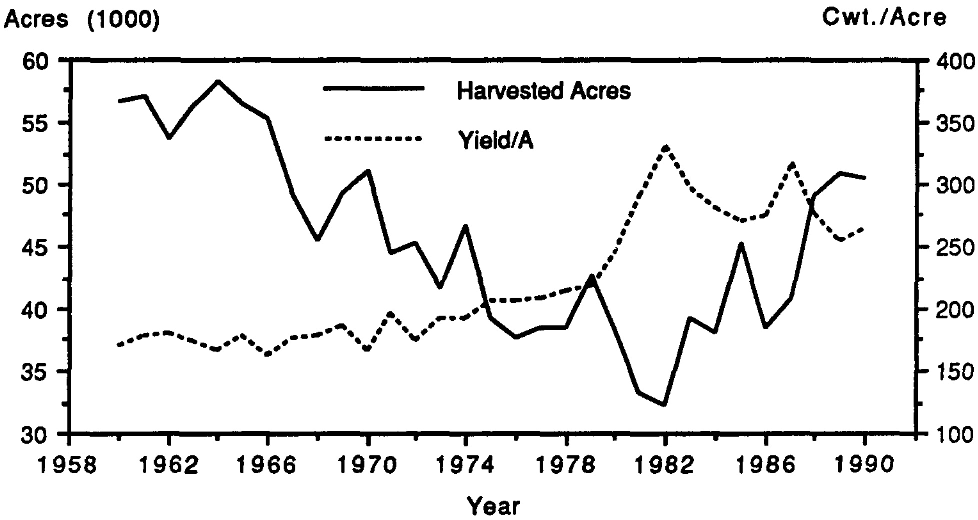
Harvested acreage variability. Lettuce is the most important vegetable crop in Arizona in both acreage planted and production value. Based on variability estimates, lettuce was the second least variable crop in harvested acreage among the seven selected crops (Figure 4-1, Panel A) with a variability coefficient of 7.5 percent (Table 4.1). Surprisingly, this relatively low variation in acreage harvested may be due to the fact that lettuce is not a government program crop.

The lettuce variability index increased by 25.7 percent between the two study periods. This change in harvested acreage variation lettuce was caused by the following events: first, all lettuce acreage trended downward from 1960 to 1981 (Figure 4-7, Panel A) due to the increasing urbanization of Maricopa County (i.e. Phoenix) and the loss of California lettuce growers producing in Arizona. In the 1970s California lettuce producers left Arizona due to sharply increasing water cost related to the energy crisis. But since 1982, harvested lettuce acreage has been increasing gradually because the American diet has been changing in recent years due to health conscious consumers eating more food with a higher fiber content. In the 1980s, California lettuce growers returned to Arizona as chemical use regulations became more restrictive in California. As a matter of fact, most lettuce growers in Yuma County were from California.

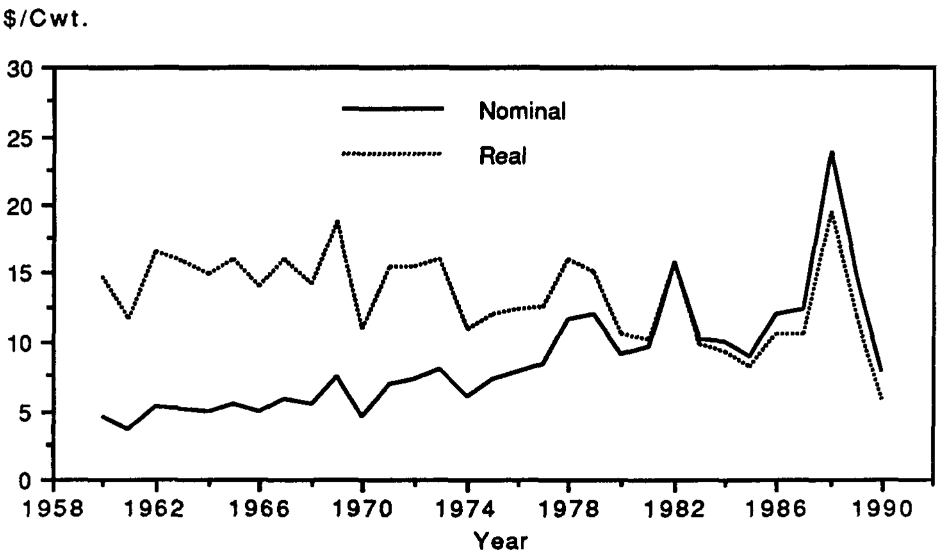
Yield variability. Per acre lettuce yield was relatively stable for the past 24 years. Lettuce was the third least variable crop in per acre

Figure 4-7, All Lettuce (1960-1990)

Panel A, Harvested Acreage and Per Harvested Acre Yield



Panel B, Nominal and Real Prices (1982=100)



yield with a variability coefficient of 7.4 percent. However, lettuce yield varied more in period two than period one. The variance of lettuce yield increased significantly between the two periods at the 1 percent level of significance. The variability index of lettuce yield rose by about 120 percent between the two study periods. The increasing fluctuation was caused by more serious pest problems in recent years. Based on Figure 4-8, Panel A, one can see that the yield of lettuce was extremely stable before 1979. From 1979 to 1982, there was a sharp rise in lettuce yield. This rise might have resulted from the decline in marginal acreage and heavy demand in lettuce market. Lettuce has a high "potential yield". When market prices for lettuce are high, farmers may manage their lettuce harvests better and also harvest more low quality lettuce. If lettuce prices are too low, sometimes lettuce growers do not even harvest their lettuce due to low expected profits. For example, lettuce yield was extremely high (329 cwt./acre) and the lettuce price was also high ($15.74/cwt.) in 1982. In 1988, lettuce was affected by whitefly, and theoretically per unit lettuce yield should have been low. However, lettuce yield (per acre) was still high (276 cwt.) because lettuce prices reached $23.73/cwt. (overall prices) that year. The potential yield is often very large when other neighboring states, such as California and New Mexico, have more serious pest or disease problems in lettuce production than Arizona.

Price variability. Lettuce prices (both nominal and real) were the most variable of the seven selected field crops (Figure 4-1, Panel C and D). The variability coefficient reached 28 percent and 20.9

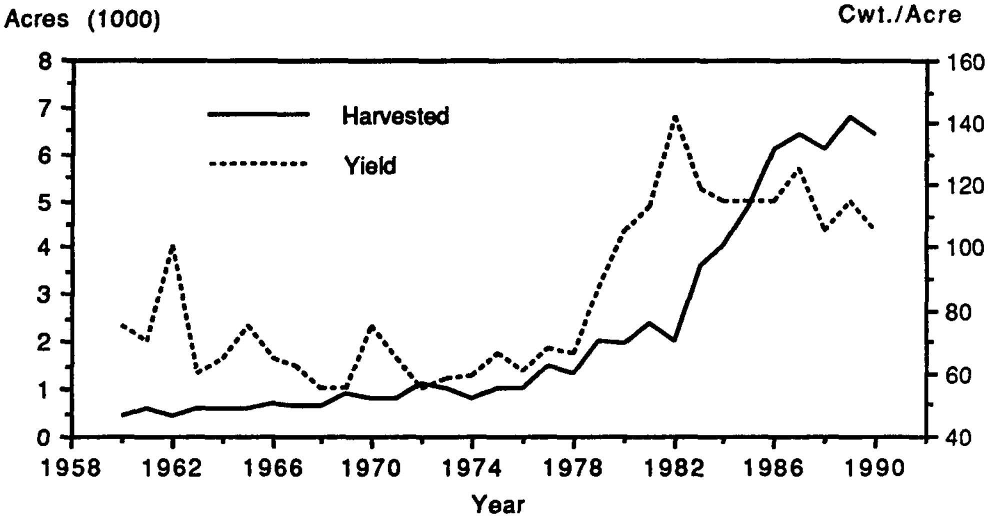
percent in nominal and real prices respectively (Table 4.1). The change in variance was statistically significant at a 99 percent confident level for all lettuce. The nominal price variability of all lettuce in the first period doubled in the second period. The increased variability of all lettuce prices largely resulted from whitefly infestations and poor planting conditions in the western Arizona in 1988. Western lettuce prices peaked in November 1988, with an average price of $51.20 per hundredweight, but only $15 per hundredweight in November 1989 (AAS, 1989). Pest infestations and unfavorable weather resulted in the decrease of lettuce supply, changing consumers' market expectation, and driving lettuce prices up.

Cauliflower

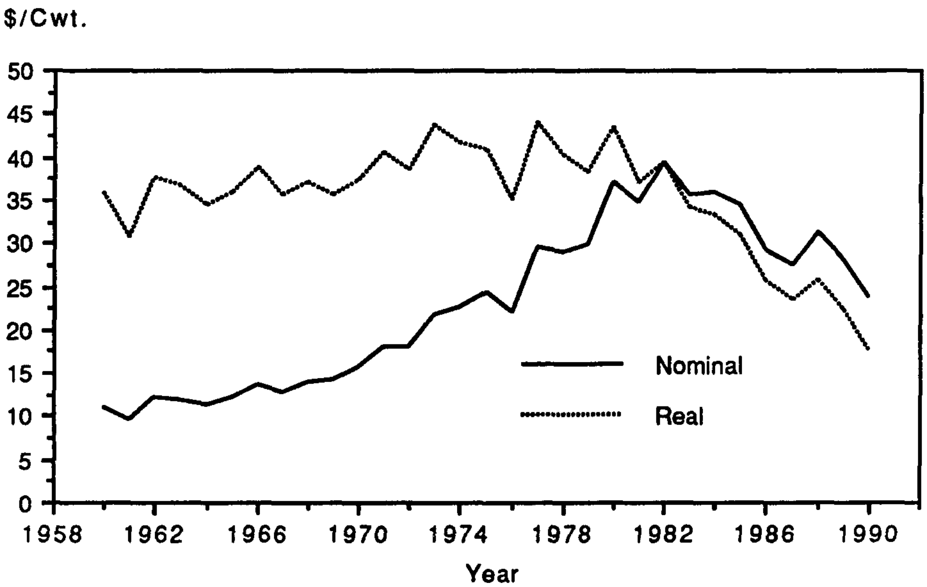
Harvested acreage variability. Cauliflower is mainly grown in Yuma and Maricopa counties. In the past 24 years, the acreage harvested of cauliflower has increased steadily. Cauliflower ranked fourth in harvested acreage variability due to a relatively stable cauliflower market. Although the variance of cauliflower in acreage harvested increased significantly between the two periods, the variability index declined slightly. This implies that the increase in harvested acreage has been accompanied by reduced fluctuations. Cauliflower acreage harvested exhibited a slightly upward trend prior to 1981 (Figure 4-8, Panel A). Since 1982, the acreage harvested of cauliflower has increased sharply due to the change in people's diet

Figure 4-8, Cauliflower (1960-1990)

Panel A, Harvested Acreage and Per Harvested Acre Yield



Panel B, Nominal and Real Prices (1982=100)



(i.e consume more food with more fiber content). Most of the cauliflower is produced in Yuma County because of relatively inexpensive water.

Yield variability. Cauliflower yields per acre were the most variable among the seven selected crops (Figure 4-1, Panel A). The variability index reached 10.2 percent (Table 4-1). This high variability could be attributed to its small acreage (less than 3,000 acres on average for the last 24 years) and some farmers' lack of experience with this crop. The yield variance of cauliflower increased significantly, at the 5 percent significant level, between the two study periods. Its variability coefficient also increased by 6.2 percent. Cauliflower yields experienced a decrease (1960 to 1972), an increase (1978 to 1982) and a decline (after 1982) (Figure 4-8, Panel A). As noted above, before 1978 there were a limited number cauliflower growers in Arizona (annual harvested acreage was about 1500 acres) and the yield per acre was sensitive to yield fluctuations on portion of these acres. After 1978, the sharp rise in cauliflower yield was due to its high "potential yield" like lettuce due to pest infestations. The yield has been declining since 1982 due to unfavorable prices.

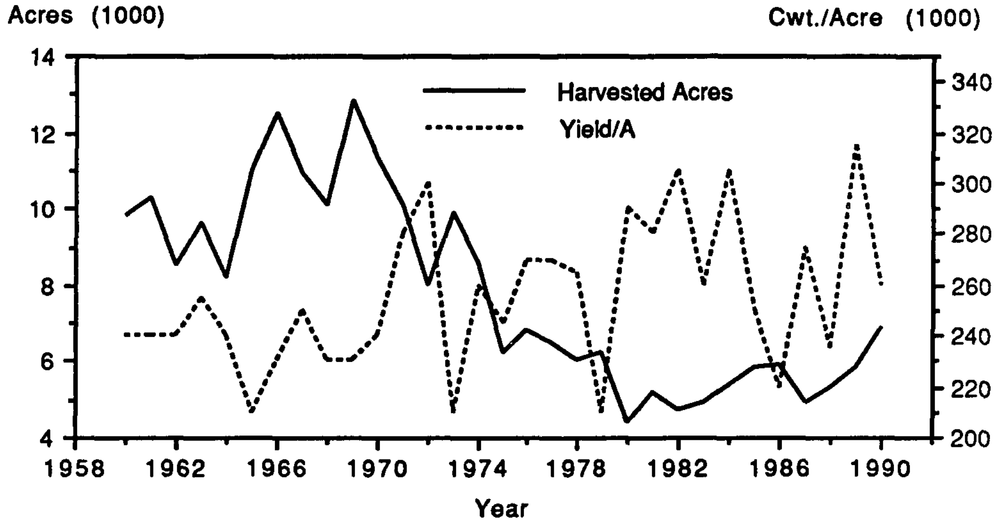
Price variability. Nominal and real prices for cauliflower demonstrated the lowest variability among the seven selected crops (Figure 4-1, Panel C and D). This low price variability of cauliflower is related to the relative stable cauliflower market. Although cauliflower prices have experienced years of increase (before 1982) and decline (after 1982), the deviations along the price trend are extremely small over the last 24 years. The nominal price variability declined by 14 percent, but real price variability increased by 62 percent (Table 4.1). Visual inspection of cauliflower prices shows that the upward trend in nominal prices was much sharper than the real price trend before 1982 and the downward real price trend was much steeper than the nominal price trend due to inflation. The price pattern for cauliflower is unique: the real price level steadily increased for about 20 years (1960-1980) and nominal price has been declining for about 8 years (since 1982). An explanation for the 20-year real price rise is that cauliflower production was always profitable for a limited number of producers supplying an increasing demand. Also, cauliflower could only grow in certain geographical areas during most of the year. The decline in nominal prices for the last 8 years reflects the supply response to earlier profitability levels.

Potatoes

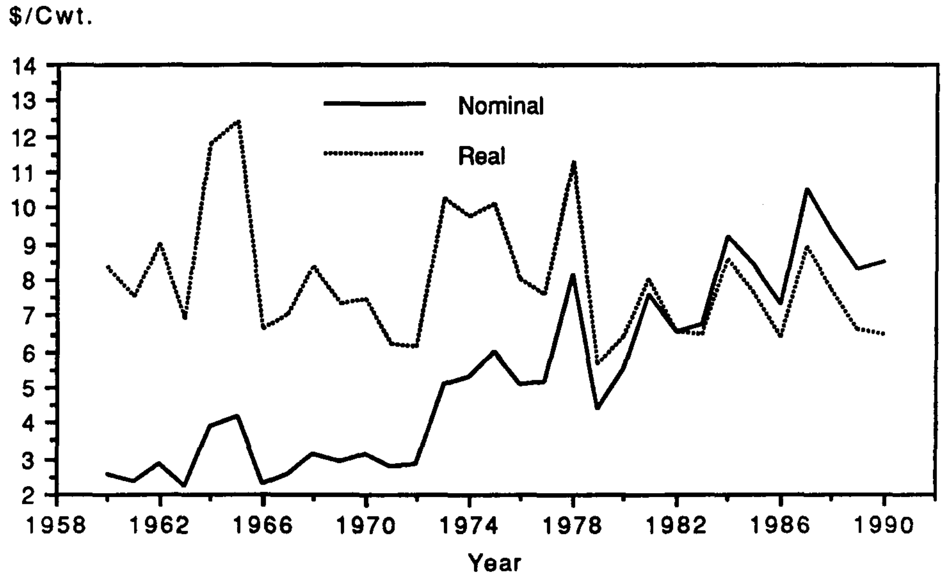
Harvested acreage variability. Potatoes are mostly grown in Maricopa County, but represent one of the major field crops in Arizona in terms of production value. Potatoes were relative stable (11.9%) in harvested acreage. The variance of potatoes decreased significantly at the 1 percent level of significance between the two study periods (Table 4-1). The variability of potatoes, as measured by the variability coefficient, declined by about 22 percent between these periods. This declining variability can be mainly attributed to the large acreage fluctuations before 1975 (Figure 4-9, Panel A). Arizona potatoes used

Figure 4-9, Potatoes (1960-1990)

Panel A, Harvested Acreage and Per Harvested Acre Yield



Panel B, Nominal and Real Prices (1982=100)



to have a good national and regional market, because Arizona potatoes are harvested two months earlier than potatoes grown in other states. But, storage techniques for potatoes have become more economic and practical since 1970, thereby reducing the demand for Arizona potatoes. Since the mid-1970s, the acreage harvested of potatoes ranged from 5,000 to 7,000 acres.

Yield variability. Potato yields were the third variable over the past 24 years. These large yield fluctuations were probably related to its relatively small acreage base like cauliflower. Potato yield (per acre) fluctuated more in the second period than the first period due to increasing pest infestations in recent years.

Price variability. Potato prices varied greatly over the past 24 years. Its price variability, both nominal and real, ranked second among major field crops in Arizona. The large variation in potato prices resulted from the uncertain potato market before 1980. There were two big price jumps for potatoes in the past three decades. The first price jump took place during the period of 1963 and 1966. This price change was probably related to the low yield of potatoes (due to unfavorable weather). The second price jump in the 1970's was indirectly caused by the increasing wheat and cotton exports. The rise in wheat and cotton prices pushed potato prices up automatically. Since 1980, potato prices have tended to be less variable due to improved contracting procedures and stable markets.

As a result of the preceding analysis, some general conclusions can be produced for major Arizona field crop production over the past three decades. First, harvested acreage varied more than prices and yield per acre for major Arizona field crops. Cotton and wheat fluctuated more than alfalfa and vegetable crops in acreage harvested since government farm programs and uncertain international market have a large impact on cotton and wheat production. Vegetable crops had relatively high yield and price variability due to the fact that vegetable crops are more sensitive to pests and weather. Pima cotton is an exception in terms of yield variability in the category of standard field crops and ranked second due to the serious pink bollworm infestations in recent years.

The change of production variability between two study periods varied with crops and indexes selected for major Arizona field crops. Harvested variability changed slightly for all crops except for Pima cotton. The variability of harvested acreage for Pima cotton increased by two fold in the second period than the first period due to the incentive created by higher Pima cotton prices in recent years. Yield variability increased for all vegetable crops but declined for standard field crops. Nominal prices varied less in the second period than the first period for all crops except for lettuce. The large price fluctuation of lettuce was attributable to the whitefly infestations in 1988. The variability in real prices declined for all vegetable crops while it increased for all the standard field crops between the two study periods.

5. ANALYTICAL RESULTS - COUNTY LEVELS

The analysis discussed in Chapter 4 gives us a clear picture about variability in major Arizona field crops at the state level during the past three decades. But, crop production is related to the environment where crops grow such as climate, elevation, and soil. Arizona does not have a uniform weather pattern across the whole state (Table 5.1). How different is the variability of these crops between the six selected major agricultural counties? What is the force that leads major Arizona field crops to fluctuate from region to region? Is there any difference in terms of the magnitude of variability between the state and county levels in general? Why? This chapter attempts to answer these questions.

The analytical techniques and structure adopted in this chapter are the same as those used in Chapter 4. The discussion, however, focuses on the highest and lowest variations of some specific crops and regions. The crops in question are Pima cotton, upland cotton, all wheat, alfalfa hay, and lettuce. Cauliflower and potatoes are excluded because these two crops are mostly grown in two counties. The six counties selected are Cochise, Graham, Maricopa, Pima, Pinal, and Yuma[1].

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[1]Yuma is not the reported "Yuma" in the current Arizona Agricultural Statistics. It is a weighted average of Yuma and La Paz Counties since Yuma County was divided into Yuma County and La Paz County in 1983.

Table 5.1, Climatic Differences in the Six Selected Counties

Counties	Mean monthly temperature (Fahrenheit)	Total Precipitation (Inches)	Last Freeze Day in Spring	First Freeze Day in Fall	Elevations (Feet)
Cochise (Wilcox)	59.3	11.52	May 9	Oct. 27	3000-4000
Graham (Safford)	62.5	8.60	Apr. 3	Oct. 28	above 3000
Maricopa (Phoenix)	71.2	7.11	Feb. 5	Dec. 25	1000-2000
Pima (Tucson)	68.0	11.14	Mar. 13	Nov. 15	2000-4000
Pinal (Casa Grande)	70.1	8.58	Mar. 12	Nov. 14	1000-2000
Yuma (Yuma)	73.9	2.65	Jan. 18	Dec. 26	0-2000

Note: temperature and precipitation are long-term average; Freeze days are the dates occurred at the period of 1985-1989. Elevation is the height above the sea level for the city in each individual county.

Pima Cotton

Harvested acreage variability. Variability in harvested acreage for Pima cotton was the highest in Yuma (57.01%)[1] County, and lowest in Graham County (16.40%) (Table 5-1). The instability of Pima cotton in acreage harvested at Yuma County was caused by Yuma's specific environmental conditions. Yuma County's farmers had more alternative crops to select due to a year around growing season and inexpensive water. The stability of Pima cotton in harvested acreage at Graham County was mainly attributed to the local growers' longer cultivation history with this crop due to its adaptation to Graham County's climate.

Better Pima cotton farming management in Graham explains why the variance in acreage harvested increased significantly for all counties except Graham County. The increased variability of Pima cotton in acreage harvested was extremely large (by 3.5 times) in Pinal County between the two periods. Pinal County growers shifted upland cotton acreage into Pima cotton during this period. When Pima cotton prices were low, Pinal County cotton growers kept their Pima cotton land at around 10,000 acre annually. But, Pinal cotton producers expanded their Pima cotton land to 114,000 acres in 1989 when Pima cotton prices were higher in 1987 and 1988. (Appendix D, Figure 1, Panel E).

Yield variability. Pima cotton was the most variable (20.06%) in yield per acre in Cochise County (Table 5-2). This highest variation in

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[1] Variability Coefficient 2 (estimated by moving average detrending technique).

Table 5.2. Variability in Harvested Acreage by County and Crop

Items	Ranking (1=Lowest)	Mean: Overall	Mean: 1st Period	Mean: 2nd Period	Mean: Change (%)	St. Dev.: Overall	St. Dev.: 1st Period
Pima Cotton							
Graham	1	9.92	8.30	11.54	39.04	3.36	1.42
Pima	2	2.98	2.82	3.15	11.70	1.46	0.51
Cochise	3	2.54	2.51	2.58	2.79	1.68	0.93
Maricopa	4	14.54	9.29	19.78	112.92	12.23	1.59
Pinal	5	20.68	8.03	33.32	314.94	26.09	0.79
Yuma	6	6.39	3.51	9.26	163.82	6.17	0.76
Upland Cotton							
Pinal	1	109.96	107.94	111.97	3.73	26.45	12.23
Maricopa	2	145.51	126.19	164.10	30.04	53.25	24.57
Pima	3	13.99	15.22	12.76	-16.16	4.41	2.95
Graham	4	8.50	6.64	10.37	56.29	3.45	2.07
Cochise	5	18.61	17.34	19.88	14.65	7.92	5.13
Yuma	6	57.24	44.60	69.88	56.68	29.94	14.33
All Wheat							
Yuma	1	42.10	43.54	40.67	-6.59	20.28	20.76
Pinal	2	36.46	40.32	32.60	-19.15	22.62	15.12
Maricopa	3	48.81	50.82	46.80	-7.91	29.14	19.04
Pima	4	4.25	5.30	3.19	-39.81	3.32	2.64
Graham	5	2.57	2.25	2.88	28.00	2.20	1.65
Cochise	6	12.82	23.94	1.69	-92.94	16.07	12.73

Note: Ranking is based on variability coefficient 2 (overall level). The first and second periods represent 1967-1978 and 1979-1990 respectively.

Table 5.2 (Continued), Variability in Harvested Acreage by County and Crop

Items	St. Dev.	F-ratio	Variability (%)			
	2nd Period		Overall	1st Period	2nd Period	Change
Pima Cotton						
Graham	1.88	1.75	16.40	17.08	16.27	-4.74
Pima	1.31	6.47**	32.50	18.20	41.44	127.69
Cochise	1.33	2.03	44.21	37.24	51.61	38.59
Maricopa	9.31	34.38**	44.95	17.10	47.09	175.38
Pinal	14.88	355.55**	49.85	9.83	44.67	354.43
Yuma	5.21	46.62**	57.01	21.73	56.24	158.81
Upland Cotton						
Pinal	18.56	2.30	13.98	11.33	16.58	46.34
Maricopa	28.59	1.35	17.96	19.47	17.42	-10.53
Pima	2.69	1.20	19.73	19.38	21.08	8.77
Graham	2.01	1.06	23.44	31.15	19.36	-37.85
Cochise	4.06	1.59	24.30	29.56	20.42	-30.92
Yuma	15.51	1.17	25.51	32.13	22.20	-30.91
All Wheat						
Yuma	5.34	15.14*	35.22	47.69	13.12	-72.49
Pinal	11.78	1.65	36.35	37.49	36.14	-3.60
Maricopa	22.67	1.42	41.95	37.46	48.45	29.34
Pima	1.11	5.67**	46.60	49.76	34.71	-30.25
Graham	1.03	2.56	52.56	73.45	35.88	-51.15
Cochise	0.45	814.57**	68.72	53.17	26.39	-50.37

Note: The first and second periods represent 1967-1978 and 1979-1990 respectively. **, * denotes that the variance in the second period is significantly different from that of the first period at 1 and 5 percent confidence levels, respectively (two tail test).

Table 5.2 (Continued), Variability in Harvested Acreage by County and Crop

Items	Ranking (1=Lowest)	Mean Overall	Mean 1st Period	Mean 2nd Period	Mean Change (%)	St. Dev. Overall	St. Dev. 1st Period
Alfalfa Hay							
Yuma	1	60.37	57.12	63.61	11.36	7.06	3.24
Maricopa	2	67.31	86.58	48.03	-44.53	22.26	6.05
Pinal	3	14.26	16.38	12.15	-25.82	3.03	1.45
Cochise	4	8.53	8.94	8.13	-9.06	1.20	0.40
Graham	5	5.87	6.56	5.18	-21.04	1.19	0.55
Pima	6	1.90	2.03	1.78	-12.32	0.42	0.22
All Lettuce							
Yuma	1	27.33	21.00	33.66	60.29	8.82	2.72
Maricopa	2	7.61	11.38	3.84	-66.26	5.43	2.29
Pima	3	1.78	2.70	0.86	-67.99	1.10	0.45
Pinal	4	3.91	6.71	1.12	-83.31	3.46	1.62
Cochise	5	1.99	1.83	2.16	18.03	0.77	0.78
Cauliflower							
Maricopa	1	0.63	0.67	0.60	-9.88	0.13	0.13
Yuma	2	1.99	0.31	3.67	1071.40	2.10	0.07
Potatoes							
Maricopa	1	7.01	8.84	0.52	-94.12	2.42	1.09

Note: Ranking is based on variability coefficient 2 (overall level). The first and second periods represent 1967-1978 and 1979-1990 respectively.

Table 5.2 (Continued). Variability in Harvested Acreage by County and Crop

Items	St. Dev. 2nd Period	F-ratio	Variability (%) Overall	1st Period	2nd Period	Change
Alfalfa Hay						
Yuma	3.64	1.26	5.59	5.68	5.72	0.70
Maricopa	3.35	3.27*	7.11	6.99	6.97	-0.29
Pinal	0.56	6.64**	7.54	8.85	4.63	-47.68
Cochise	0.87	4.62**	7.73	4.50	10.64	136.44
Graham	0.62	1.29	9.78	8.35	12.03	44.07
Pima	0.44	4.17**	17.90	10.68	24.88	132.96
All Lettuce						
Yuma	3.62	1.77	11.44	12.93	10.74	-16.94
Maricopa	0.71	10.41**	21.77	20.10	18.46	-8.16
Pima	0.42	1.16	23.82	16.64	48.34	190.50
Pinal	0.66	6.03**	30.90	24.14	58.90	143.99
Cochise	0.50	2.41	32.04	42.47	23.18	-45.42
Cauliflower						
Maricopa	0.07	3.04*	15.83	18.86	12.00	-36.37
Yuma	0.57	64.24**	19.89	22.58	15.45	-31.58
Potatoes						
Maricopa	0.04	742.00**	11.48	12.37	7.72	-37.59

Note: The first and second periods represent 1967-1978 and 1979-1990 respectively. **, * denotes that the variance in the second period is significantly different from that of the first period at 1 and 5 percent confidence levels, respectively (two tail test).

Table 5.3. Variability in Per Acre Yield by County and Crop

Items	Ranking	Mean				St. Dev.	
	(1=Lowest)	Overall	1st Period	2nd Period	Change (%)	Overall	1st Period
Pima Cotton (Lbs./Acre)							
Graham	1	658.21	559.83	756.58	35.14	152.12	83.64
Pima	2	629.75	600.17	659.33	9.86	123.20	95.31
Pinal	3	787.00	642.00	932.00	45.17	211.92	129.11
Maricopa	4	782.46	651.00	913.92	40.39	204.86	119.91
Yuma	5	822.84	778.25	867.44	11.46	121.98	172.85
Cochise	6	587.00	585.50	588.50	0.51	147.47	128.87
Upland Cotton (Lbs./Acre)							
Maricopa	1	1202.33	1115.83	1288.83	15.50	146.17	117.83
Pima	2	920.08	857.67	982.50	14.55	137.58	82.16
Pinal	3	1139.17	1017.33	1261.00	23.95	174.32	104.07
Graham	4	853.46	761.17	945.76	24.25	148.34	79.62
Cochise	5	680.53	669.43	691.64	3.32	122.59	81.74
Yuma	6	1242.03	1234.58	1249.48	1.21	208.65	267.53
All Wheat (Lbs./Acre)							
Maricopa	1	4804.59	4064.17	5545.01	36.44	875.79	254.82
Pinal	2	4262.08	3813.33	4710.83	23.54	605.74	283.71
Pima	3	4266.25	3768.33	4764.17	26.43	689.57	325.21
Graham	4	4449.58	3767.50	5131.67	36.21	952.50	211.36
Yuma	5	4960.74	4353.33	5568.14	27.91	801.74	753.13
Cochise	6	4064.58	3773.33	4355.83	15.44	980.30	302.62

Note: Ranking is based on variability coefficient 2 (overall level). The first and second periods represent 1967-1978 and 1979-1990 respectively.

Table 5.3 (Continued). Variability in Per Acre Yield by County and Crop

Items	St. Dev.	F-ratio	Variability (%)			
	2nd Period		Overall	1st Period	2nd Period	Change
Pima Cotton						
Graham	54.32	2.37	10.48	14.94	7.18	-51.94
Pima	79.58	1.43	13.64	15.88	12.07	-23.99
Pinal	92.64	1.94	13.96	20.11	9.94	-50.57
Maricopa	104.10	1.33	14.03	18.42	11.39	-38.17
Yuma	71.91	5.78**	15.74	22.21	8.29	-62.67
Cochise	111.34	1.34	20.06	22.01	18.92	-14.04
Upland Cotton						
Maricopa	79.52	2.20	8.18	10.56	6.17	-41.57
Pima	77.72	1.12	8.50	9.58	7.91	-17.43
Pinal	108.57	1.09	9.13	10.23	8.61	-15.84
Graham	93.25	1.37	9.94	10.46	9.86	-5.74
Cochise	75.11	1.18	11.28	12.21	10.86	-11.06
Yuma	70.47	14.41**	15.41	21.67	5.64	-73.97
All Wheat						
Maricopa	265.61	1.09	5.29	6.27	4.79	-23.60
Pinal	226.12	1.57	5.89	7.44	4.80	-35.48
Pima	277.27	1.38	6.93	8.63	5.82	-32.56
Graham	646.59	9.36**	10.57	5.61	12.60	124.60
Yuma	277.85	7.35**	11.19	17.30	4.99	-71.16
Cochise	966.99	10.21**	17.24	8.02	22.20	176.81

Note: The first and second periods represent 1967-1978 and 1979-1990 respectively. **, * denotes that the variance in the second period is significantly different from that of the first period at 1 and 5 percent confidence levels, respectively (two tail test).

Table 5.3 (Continued), Variability in Per Acre Yield by County and Crop

Items	Ranking	Mean				St. Dev.	
	(1=Lowest)	Overall	1st Period	2nd Period	Change (%)	Overall	1st Period
<u>Alfalfa Hay</u>							
(Tons/Acre)							
Maricopa	1	6.97	6.30	7.63	21.11	0.88	0.36
Yuma	2	7.32	6.64	8.01	20.63	1.01	0.42
Pinal	3	6.21	5.29	7.13	34.78	1.20	0.42
Cochise	4	5.69	3.53	5.85	65.72	0.65	0.35
Graham	5	5.82	5.60	6.03	7.68	0.64	0.60
Pima	6	5.91	5.42	6.40	18.08	0.91	0.52
<u>All Lettuce</u>							
(Cwt./Acre)							
Yuma	1	237.05	194.58	279.51	43.65	49.33	11.62
Pima	2	213.47	185.92	241.01	29.63	44.57	14.58
Pinal	3	212.81	187.16	238.46	27.41	43.51	15.20
Maricopa	4	224.88	195.11	254.65	30.52	51.20	22.32
Cochise	5	213.26	195.41	231.11	18.27	47.14	29.88
<u>Cauliflower</u>							
(Cwt./Acre)							
Yuma	1	115.80	110.41	121.18	9.75	26.24	16.95
Maricopa	2	67.42	49.92	84.92	70.11	21.76	5.84
<u>Potatoes</u>							
(Cwt./Acre)							
Maricopa	1	262.68	254.67	270.69	6.29	29.24	21.77

Note: Ranking is based on variability coefficient 2 (overall level). The first and second periods represent 1967-1978 and 1979-1990 respectively.

Table 5.3 (Continued). Variability in Per Acre Yield by County and Crop

Items	St. Dev. 2nd Period	F-ratio	Variability (%) Overall	1st Period	2nd Period	Change
Alfalfa Hay						
Maricopa	0.33	1.14	4.83	5.64	4.36	-22.70
Yuma	0.44	1.09	5.80	6.40	5.54	-13.44
Pinal	0.37	1.30	6.27	8.00	5.20	-35.00
Cochise	0.28	1.52	7.40	9.78	4.78	-51.12
Graham	0.22	7.75**	7.64	10.79	3.60	-66.64
Pima	0.53	1.05	8.72	9.60	8.34	-13.13
All Lettuce						
Yuma	20.96	3.26*	7.00	5.97	7.50	25.63
Pima	28.56	3.84*	10.39	7.84	11.85	51.15
Pinal	28.16	3.43*	10.40	8.12	11.81	45.44
Maricopa	40.06	3.22*	14.10	11.44	15.73	37.50
Cochise	40.05	1.80	16.20	15.29	17.33	13.34
Cauliflower						
Yuma	10.82	2.45	12.01	15.35	8.93	-41.82
Maricopa	12.76	4.78**	14.40	11.69	15.03	28.57
Potatoes						
Maricopa	25.93	1.42	8.92	8.55	9.58	12.05

Note: The first and second periods represent 1967-1978 and 1979-1990 respectively. **, * denotes that the variance in the second period is significantly different from that of the first period at 1 and 5 percent confidence levels, respectively (two tail test).

Pima cotton yield in Cochise County was related to its unstable weather relative to the other counties. Cochise County has more rain, a shorter growing season, and fewer heat units. Pima cotton yield variability was stable (10.48%) in Graham County due to better management practices. The variability of Pima cotton in yield per acre decreased between the two periods for all counties due to improved varieties and management practices.

Upland Cotton

Harvested acreage variability. In contrast to the variation of Pima cotton, upland cotton was less variable in harvested acreage due to its large production base. Of the six counties reviewed, upland cotton was the most variable in acreage harvested for Yuma County (25.51%) (Table 5-2). The source of harvested acreage variability for upland cotton in Yuma County is the same as that for Pima cotton (i.e. Yuma farmers had more alternative crops to grow due to its stable weather and longer growing season). Although the acreage harvested of upland cotton varied least in Pinal County in terms of the variability index, the trend of acreage harvested was steeply downward before 1967 (Appendix D, Figure 2, Panel E). This reduced harvested acreage in upland cotton in Pinal County resulted from farmers' high participation in the governmental crop control program at the beginning of the 1960's.

Harvested acreage variability of upland cotton declined for all but Pinal and Pima counties between the two periods. Similar to the fluctuation at the state level, every county had a big jump in acreage harvested during the period 1975-1983 due to increased foreign demand for upland cotton. The acreage harvested of upland cotton returned to the 1970's level again after 1983 due to relatively stable world market for upland cotton. The higher harvested acreage variations of upland cotton for Pinal County was due to the fact that Pinal cotton farmers on a relative basis, have allocated more traditional upland cotton acreage to Pima cotton in recent years when Pima cotton prices were high. This recently harvested acreage fluctuation is illustrated by Appendix D, Figure 2, Panel E.

Yield variability. Per acre yield was the highest in Yuma County (15.4%) and lowest in Maricopa County (8.18%) for upland cotton. The large per acre yield fluctuations of upland cotton in Yuma County are the same as for Pima cotton. The relatively constant level variability in Maricopa County was probably related to the large upland cotton production base. Maricopa County had the most upland cotton acreage in all the selected counties. Since 1960, the acreage harvested of upland cotton in Maricopa County has been always above 100,000 acres.

Per acre upland cotton yield varied less in period two for all counties. Reduced variability of upland cotton unit yield was attributable to improved new pest and disease resistant varieties and other farming technologies.

<u>Wheat</u>

Harvested acreage variability. Variability in harvested acreage was the highest (68.7%) in Cochise County and lowest (35.2%) for Yuma county. Increased water costs in Cochise County in the 1970's, due to the oil crisis and increasing pumping lifts, led to these fluctuations. Wheat acreage was also variable in Graham and Pima counties. The relative stability of harvested acreage in Yuma County was probably attributable to its stable weather and inexpensive water.

The variability of wheat in acreage harvested declined for all counties between the two periods except for Maricopa County (Table 5-2). Reduced variability in wheat acreage resulted from the stable international wheat market after 1982. Another explanation for declining variability might be the selection of the two study periods. The greatest fluctuation in harvested acreage took place during 1973-1977, my first period, due to increased foreign demand. Increased variation in wheat acreage in Maricopa County was related to the construction of a local wheat storage and processing facility in the late 1970's. Maricopa County was the only county that had a sharp increase (i.e. reached 120,000 acres) in wheat acreage after 1979. However, unprofitable wheat production discouraged Maricopa wheat growers from keeping a large percent of their land for wheat in the 1980's. Since 1985 wheat acreage has averaged approximately at 30,000 acres in Maricopa County (Appendix D, Figure 3, Panel C).

Yield variability. Per acre yield was the most variable (17.24%) in Cochise County and least variable (5.29%) in Maricopa County over the past 24 years. The divergence in wheat yield variability between Maricopa and Cochise counties was largely due to their different climatic conditions. As noted in Table 5.1, the elevation of Cochise County is 1000-2000 feet higher than that of Maricopa County. The wheat growing season for wheat is reduced by one month for each additional 1,000 feet in elevation. The climate is more unstable at higher elevation as well. This explains why the variance of wheat yield increased significantly only in Cochise and Graham counties.

Alfalfa Hay

Harvested acreage variability. Alfalfa hay had the lowest variability in acreage harvested at both the aggregated (5.7%) and county levels (from 5.59 to 17.9%). Alfalfa hay acreage was the most variable in Pima County. Variability of alfalfa hay was the lowest (5.59%) in Yuma County. In recent years alfalfa hay production has been shifting from other counties to the Yuma area due to relatively cheaper water. Harvested acreage has been doubled in Yuma County in the past three decades.

Variability of alfalfa hay in acreage harvested increased dramatically (by 130%) in Pima and Cochise counties between the two periods. This increasing variation in alfalfa hay harvested acreage was probably related to the low number of acres planted and increasing water costs.

Yield variability. Maricopa County had the lowest yield variation (4.83%) and Pima County had the highest yield variation (8.72%) for alfalfa hay (Table 5-2). This variability difference between Maricopa and Pima counties probably resulted from statistical inaccuracy since Maricopa County had more than 10 times acreage of alfalfa hay than Pima County. Alfalfa hay yields fluctuated less across all selected counties between the two periods. Reduced variability in per acre yield were probably attributed to improved alfalfa cultivars such as UC-Cargo and Mesilla. Furthermore, improved alfalfa farming practices also played a role in stabilizing alfalfa hay yield under Arizona's relatively stable growing conditions.

Lettuce

Harvested acreage variability. Variability in harvested acreage was high in Cochise (32.04%) and Pinal (30.9%) counties, and relatively low in Yuma County (11.44%). The variation in Cochise County was likely due to its small base acreage. Pinal County had about 3,000 acres of lettuce land in 1965. In 1970 a sharp increase of acreage harvested took place in Pinal County due to higher prices in 1969. Since 1974 the acreage harvested in Pinal County has been declining continuously due to increasing water costs. Maricopa and Yuma counties dominate lettuce production in Arizona. However, in the past two decades, the acreage harvested has been trending downward in Maricopa County due to the urbanization in Phoenix area. But, lettuce acreage has continuously increased in Yuma County due to its inexpensive water, stable weather, market window and a longer history of lettuce farming. These factors explain why variability in acreage harvested declined in Yuma and increased in Pinal County between the two periods.

Yield variability. Of the three major lettuce producing counties (Yuma, Maricopa, and Pinal Counties), lettuce per acre yield was the most variable in Maricopa County and least variable in Yuma County over the last 24 years. Maricopa County produced both spring and fall lettuce while Yuma County produced only western lettuce (the same season as fall lettuce). During the period of 1982 and 1983, higher spring lettuce prices (due to pest infestations in neighboring states) induced high lettuce yields in Arizona. This spring lettuce fluctuation also led to more fluctuations in western lettuce and fall lettuce.

The variability of lettuce per acre yield increased significantly between the two periods across all the selected counties. From visual inspection of the lettuce production data, one can see that the yield of all lettuce was stable before 1978 for all selected counties. Since 1978, two big yield leaps have taken place across all counties (Appendix D, Figure 4-5). The first sharp rise in spring lettuce yield, around 1982, and the second sharp rise in 1988 for all lettuce (especially western lettuce) were probably due to pest infestations and unfavorable weather. Higher lettuce prices often led to higher per acre yield when neighboring states had more serious pest infestations and unfavorable weather in lettuce production.

Variability Comparison between State and County Levels

Comparing the variability between state and county levels, one can see that the variability of major Arizona field crops at county levels is generally higher in both acreage harvested and yield per acre than that at the state level (Figure 1 and 3). This finding provides the evidence that the variability of the random term in an aggregated series is a function of both the number of individual farms of the series comprised and the correlation between farms (Eisgruber and Schuman, 1963). If the correlation coefficient between individual farms is equal to one, the number of individual farms that make up the aggregate is irrelevant and the variance of a crop at the state level should be equal to that at individual county level. Since the correlation coefficient between individual farms is not always equal to one, the variability at the state level should be lower than that at county levels. The divergence in variability between state and county suggests that the variability analyses in this study can provide the variability information at only the state and county levels. One can not use these variability information at the aggregated level as a substitute for the variability information at farm levels.

By examining Figure 5-1, one can find that the variability of harvested acreage in wheat, upland cotton, and alfalfa hay at county levels is close to the variability at the state level for all the selected counties. This implies that the acreage harvested of these crops was probably influenced by a common factor respectively across Arizona. For example, the common variability source for wheat and upland

Figure 5-1, Variability in Harvested Acreage for Major Arizona Field Crops at State and County Levels (1967-1990)

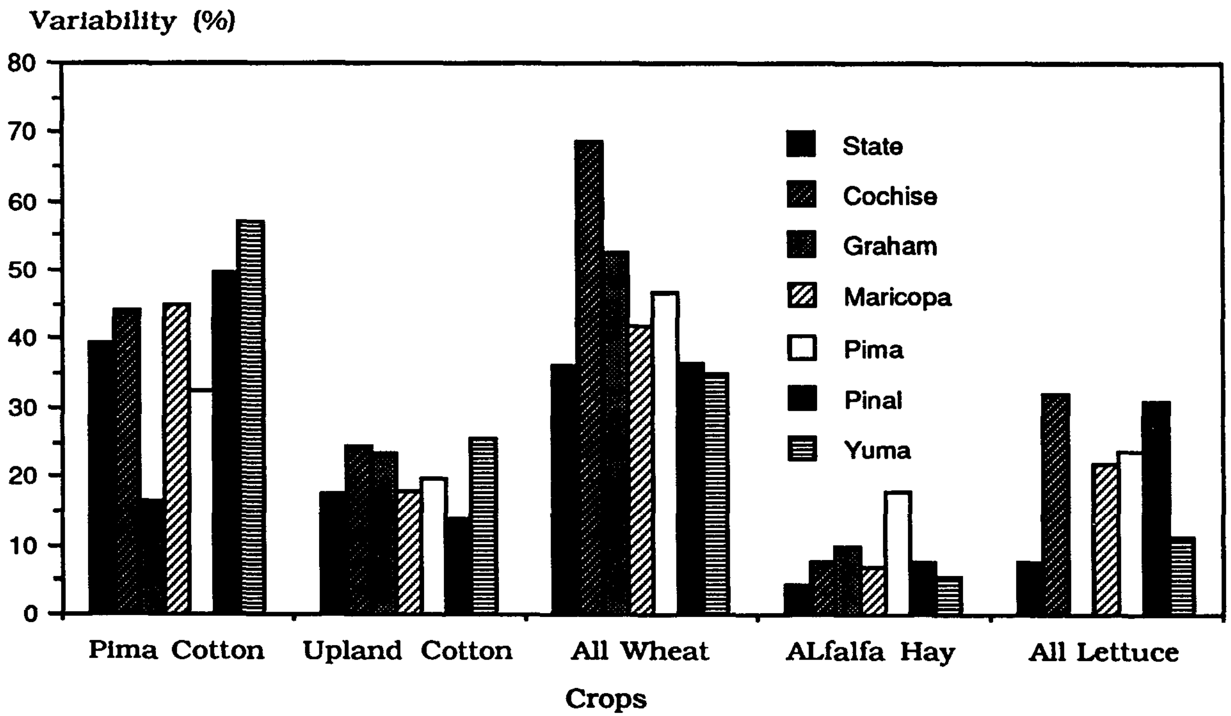


Figure 5-2, The Percent Change of Variability in Harvested Acreage at State and County Levels (1967-1978 and1979-1990)

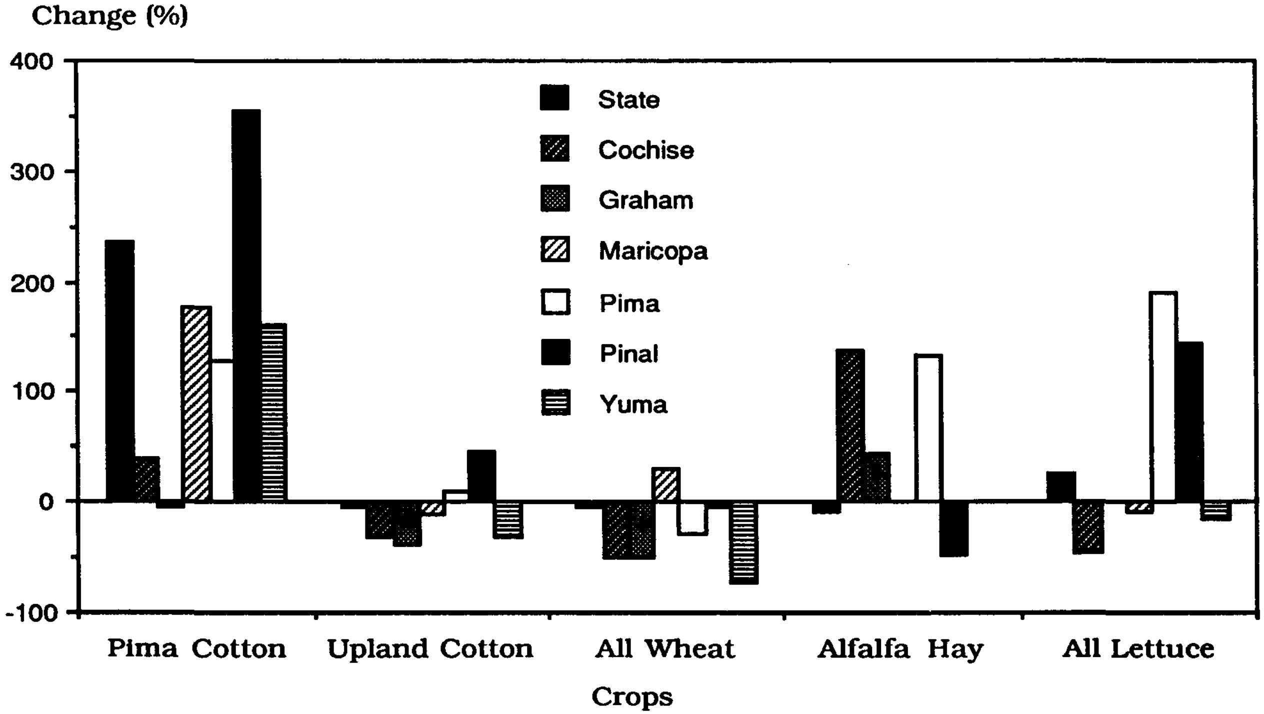


Figure 5-3, Variability in Per Acre Yield for Major Arizona Field Crops at State and County Levels (1967-1990)

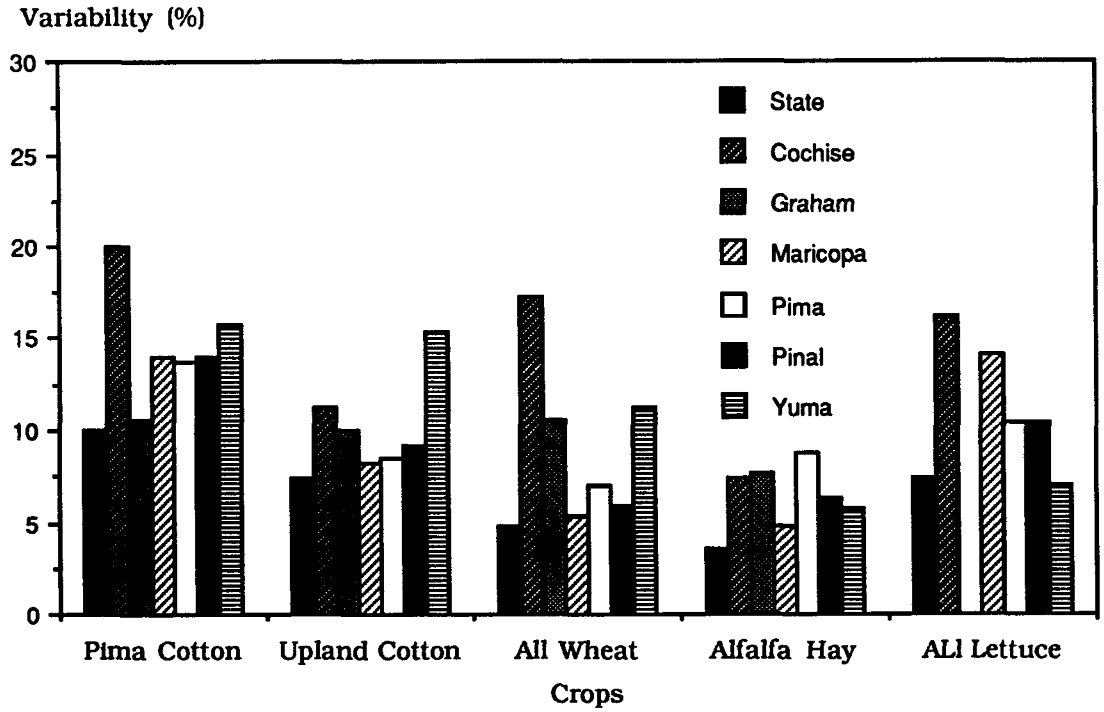
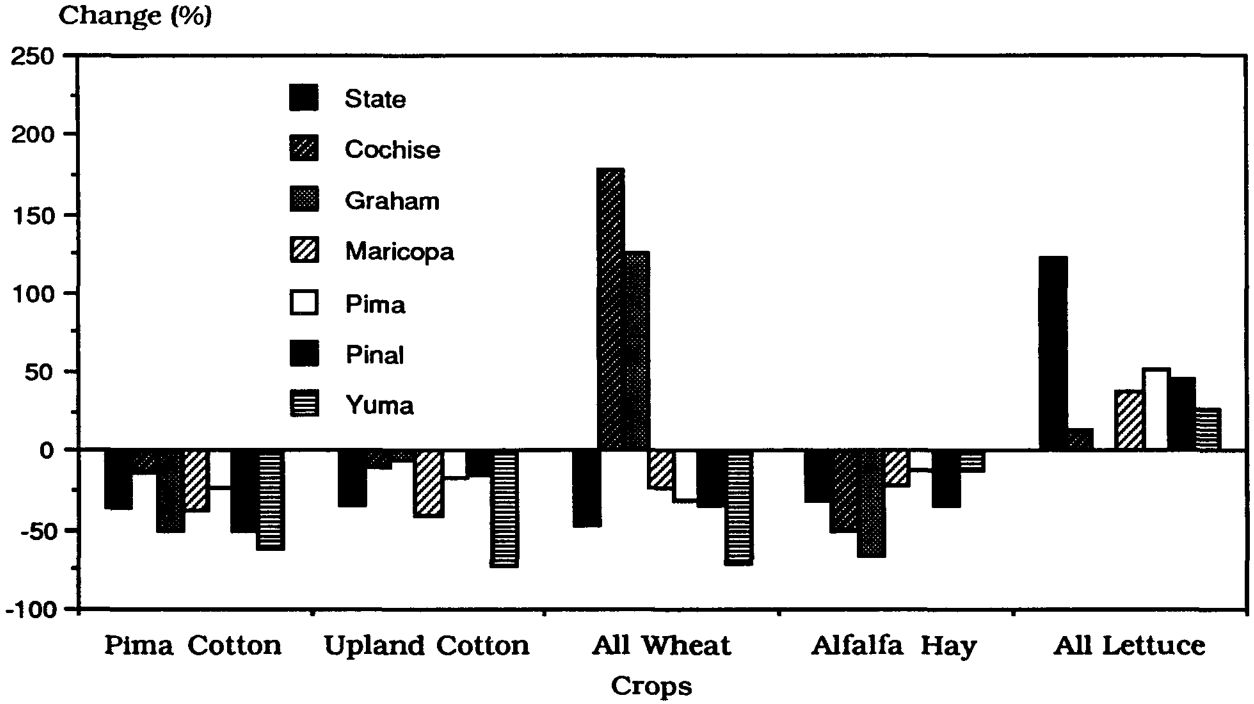


Figure 5-4, The Percent Change of Variability in Per Acre Yield at State and County Levels (1967-1978 and1979-1990)



cotton was the the fluctuation of world market in the 1970's (due to the oil crisis, devaluation of the dollar, and increased demand by other countries). Second, the variability of Pima cotton acreage varied greatly across Arizona. This suggests that Pima cotton is sensitive to some regional factors such as local weather, soil, and management practices. The variability of Pima cotton in harvested acreage at the state level was lower than that of all counties except for Graham and Pima counties. The lower variation of Pima cotton in harvested acreage in Graham County was due to its long history of cultivating Pima cotton. Third, lettuce fluctuates greatly at the county level in harvested acreage. This large variations in lettuce acreage harvested was attributed to the divergence of lettuce growing environment conditions.

The variability changes of major Arizona field crops in harvested acreages between the two periods are presented in Figure 5-2. Pima cotton varied more in period one than period two for all counties except for Graham County. Graham County has a long Pima cotton tradition. But, changes in variability are not always in the same direction state and county levels for other crops. For example, the variability of upland cotton declined in acreage harvested between the two periods at the state level while it increased in Cochise, Graham, Maricopa, and Yuma County. The divergence of variability change direction was probably due to a different climate and crop producers' experience with certain crops.

The comparison of per unit yield variability is presented in Figure 5-3. As compared with Figure 5-1, per acre yield varied much less than harvested acreage for major Arizona field crops. As supported by Eisgruber and Schuman, the per acre yield variability at the state level is lower than that at county levels. The change in per acre yield variability is presented in Figure 5-4. Yield variability changes are all in the same direction except for wheat. Wheat yield variability increased between the two periods in Cochise and Graham County while it declined at the state and other counties.

In summary, major Arizona field crops varied greatly from county to county although the variations of these crops are also different at the state level. Harvested acreage variability of these crops are not only related to government programs and uncertain market demand for these goods but also strongly related to the natural environment where crops grow. This explains why different counties have different variations for the same crop. The divergence of yield variability for these crops between counties is mostly attributed to different climate, elevations, and farmers' crop management experience in the individual counties. The variability at the state level is lower that at county levels due to the aggregation effect.

6. SUMMARY AND CONCLUSIONS

Agriculture is different from other industries in its biological characteristics and its special relationship with the environment such as weather, soil, pests, and diseases. Since the 1950's, researchers and economists have studied variability in crop production. Variability is defined as the unexplainable random deviation from crop producers' expectations. Although these previous studies concentrated on different crops, regions, and time periods, their main efforts were to estimate the variability faced by crop producers, to find the causes of crop production variability, and to propose management strategies to cope with this uncertainty. Past studies have enriched risk and management theory and provided useful and practical information to crop producers.

In variability estimation, the most important calculation is to find a relative variability base (i.e. expectation or the current level). There are many ways to compute decision maker's expectations. Young found that the constantly adjusted weighted moving average (CAWMA) and the equally weighted moving average were two more reliable techniques in computing the relative variability base. The CAWMA model not only reflects a decision maker's personal risk perception and *ex post* disappointments (due to the deviation of the actual value from the expected outcome), but also weights information differently. Young's empirical study indicated that the results generated by the equally weighted moving average model were extremely close to the results of the CAWMA model. Young strongly recommended the equally weighted moving average technique in variability estimation due to its simplicity.

In recent years, Hazell has utilized the variance decomposition technique to analyze variability in crop production. His method decomposes total variance into ten components to analyze how each component influences the total variance. Hazell's method was extensively used in worldwide foodgrain variability studies in the 1980s.

Early variability studies focused on domestic crop production. These studies indicated that crop biological characteristics and local environmental conditions have a large impact on the variations of crop production. Wildermuth and Gum found that Pima cotton yield per acre was the most variable in Maricopa County and least variable in Pinal County. Yield per acre for upland cotton was the most variable in Cochise County but stable in Pinal County.

Past studies provided the evidence that the variability of crop production was related to farm size and degree of diversification. The wheat variability study in Montana showed that a farmer on a small farm with a history of poor yield had a better chance to pay his cash costs than a farmer on a large farm with a history of poor yields. Small farms with poor management and a lower yield record could deal with risk better than their large neighboring farms, since small farms with a poor yield record probably had more crop diversification.

Variability of crop production can be affected by government intervention. The variability study of Texas rice and cotton production showed that U.S. government agricultural programs increased uncertainty for rice and cotton producers (Richardson and Knutson). However, the more stable grain production of China in the past three decades was mainly attributable to government control (Stone and Zhong).

Variability of crop production was correlated with modern inputs such as higher yielding varieties, manufactured fertilizers, pesticides, and herbicides. But, there is a long debate whether modern inputs make crop production more or less variable. The impact on variation in crop production varied considerably by crops and regions.

Past variability studies in crop production have two major shortcomings. First, none of the studies selected harvested acreage variability as an independent variable. They ignored the fact that acreage harvested (or planted acreage) is greatly influenced by government farm programs and market uncertainty, and total production is equal to the product of harvested acreage and per unit yield. Second, most of the past studies concentrated on variability at only the state level and failed to examine variability at county levels. Also, most of these studies used just one analytical technique to measure variability and failed to analyze how variability changes between different time periods.

To overcome the weaknesses of past studies, this research project treated harvested acreage variability as one of the most important indexes, and adopted four different analytical techniques to estimate the variability in harvested acreage, per acre yield, and nominal and real prices for seven major Arizona field crops at different time periods. The variability analyses were completed for both state and county levels. The results in this study show that the variabilities of major Arizona field crop production were related to the instability of markets, government interventions, infestations of pests and diseases, producers' crop management experience, and climatic conditions due to geographical location.

First, crops covered by government programs, such as Pima cotton, upland cotton, and wheat, had relatively higher harvested acreage variability than non-government program crops. Among these three crops, Pima cotton was the most variable in harvested acreage. This high variation in acreage harvested was attributed to favorable Pima cotton prices in recent years (due to cotton promotion program and increasing demand), the introduction of new varieties, and more efficient cotton seed distribution. The sources of higher harvested acreage variability for upland cotton and wheat were the heavy foreign demand in the mid-1970's, and government farm programs in the 1960's, 70's and early 80's. Crops not related to government programs such as alfalfa hay and vegetable crops had much lower variations in harvested acreage. These non-government program crops were chiefly affected by domestic market variations. Yet, government intervention in agriculture also had an indirect influence on the harvested acreage variability of these crops because of the competitive relationship in land use between government and non-government crops.

Comparing period one (1967-1978) and period two (1979-1990), the variability of harvested acreage in Pima cotton increased significantly in the second period due to the higher price incentive. Improved farm technologies such as new varieties and irrigation made Pima cotton farming more profitable, and encouraged more planted acreage. The variability of other six crops changed slightly in acreage harvested between the two study periods.

Yield per acre was generally less variable than harvested acreage for all selected crops due to Arizona's relatively stable weather, irrigation and steadily improving farming techniques. Among the seven selected crops, alfalfa hay was the least variable in yield per acre. The stability of alfalfa hay per acre yield was due to the fact that alfalfa yield is stable so long as water is available (i.e. biological property). Cauliflower per acre yield was the most variable due to pest infestations such as whitefly. Per acre Pima cotton yield was relatively more variable when compared to upland cotton and wheat because of pest infestations (i.e. pink bollworm) and unfavorable weather in recent years. In general, vegetable crops were more variable than other crops, except Pima cotton, in yield per acre since vegetable crops required more specialized management skills and were more sensitive to pests, disease, and climatic uncertainty.

The variability of major Arizona field crops in per acre yield declined for all the standard field crops and increased for all vegetable crops between the two periods, 1967-1978 and 1979-1990. The declining variations in per acre yield for standard crops were attributed to Arizona's dependence on irrigation, new pest and disease resistant varieties, and improved farming technologies. The increasing variability in yield per acre for vegetable crops was chiefly due to pest infestations and unfavorable weather in recent years. "Potential yield" (i.e. the extra yield harvested by growers due to high market prices) was one of the most important variability sources for vegetable crops, especially lettuce.

Since 1960 nominal prices of major Arizona field crops have been trending upward (expect cauliflower for the period of 1982 to 1990) due to inflation, and real price levels have declined. Among seven selected field crops, lettuce was the most variable in both nominal and real prices. The large variation in lettuce prices was mainly caused by pest infestations and unfavorable weather in 1982 and 1988. Pima cotton had also a relatively higher price variability since the cotton promotion program in the mid-1980's led to an increased demand for Pima cotton.

The real price variability increased for all vegetable crops while it declined for standard field crops (except upland cotton, which increased slightly) between the two periods. The increased price variability of vegetable crops was due to the fact that vegetable products are difficult to store. The prices of vegetable crops were determined by market forces. Furthermore, vegetable crops were more sensitive to pest infestations and weather than other crops. The declining price variations in standard field crops were attributable to the more stable world market in recent years and government intervention.

The findings at the state level suggest that researchers concerned with measuring variability of crop production should consider a wider range of variability sources such as harvested acreage rather than just per acre yield and prices. Harvested acreage varied greatly in major Arizona field crop production. Second, the findings in this study also question if government farm programs really stabilize crop production, because government policies were one of the main causes of variability over the last 24 years. Third, the findings suggest that vegetable (e.g. lettuce and cauliflower) per acre yield variability was more related to pest infestations and unfavorable weather. And pest infestation and unfavorable weather influence variability in per acre yield through price fluctuations. The increased variability for lettuce production is a new challenge for plant scientists and agronomists in breeding more pest and disease resistant varieties for lettuce growers.

Comparing the variability at different aggregated levels, the variability in both harvested acreage and per acre yield at the state level is generally lower than that at county levels for major Arizona field crops due to "aggregated effect". Crops with a larger variation in harvested acreage and per unit yield at the state level were also variable at the county levels overall, but the variability of these crops varied greatly with specific counties. The variability differences between counties resulted mostly from divergent environmental conditions (i.e. precipitation, elevation, and freeze dates), irrigation, and crop growers' cultivation experience.

Both Pima cotton and upland cotton were the most variable in harvested acreage and yield per acre in Yuma County. This was because Yuma crop growers had more alternative crops to select from due to a longer growing season, cheaper water, and because growers had less experience with cotton. Pima cotton was the least variable in both harvested acreage and yield per acre in Graham County since local cotton growers had a longer history in Pima cotton cultivation.

Wheat and lettuce were the most variable in both harvested acreage and per unit yield in Cochise County. Cochise County has a higher elevation, and irrigation mostly depends on relatively high cost groundwater. Both wheat and lettuce were the least variable in yield per acre in Yuma County due to stable weather.

Alfalfa hay was the least variable in acreage harvested and per acre yield at both the state and county levels. Pima County had a relatively higher acreage variability for alfalfa hay based on estimations. This large variation was probably due to the fact that Pima County had very few acres planted in alfalfa. Alfalfa hay was the least variable in harvested acreage for Yuma County and in yield per acre for Maricopa County.

Comparing variability between harvested acreage and yield per acre, harvested acreage generally varied more than per acre yield for all selected crops over the last 24 years. However, the variability of harvested acreage was larger in the second period than that of the first period for Pima cotton and lettuce in most selected counties. The variability of Pima cotton harvested acreage increased for all but Graham County due to the higher price incentive in recent years. The variability of lettuce acreage harvested in Pima and Pinal counties increased between the two periods since these two counties had a small amount of lettuce planted.

Second, per acre yield variability decreased for Pima cotton, upland cotton, alfalfa hay, and wheat across all selected counties (Cochise and Graham were excluded for wheat) due to improved technologies such as irrigation, new varieties, and more manufactured inputs. The increased variability of wheat in Cochise and Graham counties was mainly attributed to unstable weather. The variability of lettuce increased across all the selected counties, chiefly due to the "potential yield" related to higher lettuce prices in the 1980's.

The findings at the county levels suggest that there is a large divergence in variability between the state and county levels. This divergence implies that there is probably also a large difference in variability between state and farm levels or between county and farm levels. Therefore, we should not use aggregated information as a substitute for the variability information of individual farms. Second, environmental conditions, irrigation, and farmers' cultivation experience greatly influenced the variations in crop production. The impact of government farm programs and fluctuations of the market on crop production can be reduced or aggravated by these regional factors. This implies that policy makers should take these factors into consideration if they want to design successful national or state agricultural policy.

In summary, a clear overall picture can be drawn for the variability of major Arizona field crops over the last three decades. First, all the selected crops do not have the same variations in Arizona. Pima cotton, wheat, and upland cotton had higher variability than alfalfa hay and vegetable crops in acreage harvested due to government farm programs and an uncertain world market for cotton and wheat. Yet, vegetable crops had higher variability in yield per acre than standard field crops except for Pima cotton because vegetable production requires more skills due its greater sensitivity to pests, disease, and uncertain climate. Higher variability in per acre yield for Pima cotton was attributed to pink bollworm's infestations and unfavorable weather in recent years. Vegetable crops had higher variability in prices (nominal prices) than standard field crops since vegetables are perishable. Lettuce was the most variable in prices due to whitefly infestations in 1988.

Second, the variability of most major Arizona field crops has not increased between the two periods, 1967-1978 and 1979-1990. The change in variability varied with different crops, counties, and the indexes selected. The change in variability of harvested acreage was slight for all crops except Pima cotton. Pima cotton harvested acreage was more variable in second period than the first period because higher prices in recent years have encouraged more planted acreage. The variability in per acre yield declined for all the standard field crops but increased for all vegetable crops. The variability in prices harvested changed slightly between the two periods for all crops except for lettuce. Higher price variability for lettuce was related to the supply shortage of lettuce in 1988 due to pest infestations.

Third, the variability at county levels is higher than that at the state level due to the aggregation effect. Variability indexes varied greatly from county to county. Harvested acreage variability at the county levels is not only related to uncertain market conditions and government intervention, but also is strongly related to the natural environment where crops grow and crop growers' cultivation experience. In other words, the divergence of per acre yield variability between different counties was mainly attributed to different climates and farmers' cultivation experience for certain crops. Generally, a county with a higher elevation, higher water costs, and a shorter history in crop cultivation tends to have larger yield variation (e.g. Cochise County). Conversely, a county with low elevation, stable weather, inexpensive water, and longer crop cultivation history has low yield variability (e.g. Yuma County).

How does one put this study to use? A practical way is to release this variability information to agricultural extension agencies or farm consulting agencies at both the state and county levels in Arizona. The purpose of this approach is to educate and inform these agricultural support organizations concerning the variability in major Arizona field crop production. This information may help crop growers make more informed farming decisions.

This study examined the variability of major Arizona field crop production for the past 24 years, but further work needs to be done in order to obtain a clearer and more thorough picture of the variability in Arizona agriculture. First, we should analyze how those critical factors (e.g. government policy, location, pest infestations, and weather) affect the variability of crop production using more complex analytical procedures. Second, a sensitivity analysis is needed to test how the division of sub-periods can influence the changes of variability between different time periods. Third, further study in risk management is needed in order to cope with the higher variations in cotton and lettuce production. And finally, a broad range of crops such as fruits and animal products, at the state, county, and farm levels, should be selected for variability studies in order to get an overall picture of production variability for Arizona agriculture.

APPENDIX A

TSP Program for Variability Estimation[1]

```
option output B:St.doc
create a 1957 1990
read (w,b2) B:st1.wk1 yr whhd whpd whrpd whyd  alfhd alfpd alfrpd
alfyd  uphd uppd uprpd upyd  pihd pipd pirpd piyd  lethd letpd letrpd
letyd  cauhd caupd caurpd cauyd  pothd potpd potrpd potyd

for %1 %2 1967 1978 1979 1990 1967 1990
smpl %1 %2
for %0 whh whp whrp why  alfh alfp alfrp alfy  uph upp uprp upy  pih
pip pirp piy  leth letp letrp lety  cauh caup caurp cauy  poth potp
potrp poty

ls %0d c yr ar(1)

genr r1=resid
genr e=@se
genr m=@meandep
genr s=@sddep
genr r2=%0d-m
genr cv=s/m

      genr vc1=e/m

      genr v=@var(%0d)
genr x=@movav(%0d,3)
      genr r3=(%0d-x)

genr g1=r3^2
genr h1=@sum(g1)/11
genr h2=@sum(g1)/23

genr b1=sqr(h1)
genr b2=sqr(h2)
```

---

(1) This program was designed to compute four different variability indexes: conventional coefficient of variation, linear time trend, equally moving average, and running median, for the period 1967-1978, 1979-1990, and 1967-1990, at state level. Programs for county level variability estimations are similar to this program.

```
genr vc21=b1/m
genr vc22=b2/m

pon
smpl 1970 1970
print %0d m s v
print %0d cv vc1 vc21 vc22
smpl 1980 1980
print %0d m s v
print %0d cv vc1 vc21 vc22
smpl %1 %2
poff
next
next

    for %3 %4 1968 1978 1979 1989 1968 1989
smpl %3 %4
for %0 whh whp whrp why  alfh alfp alfrp alfy  uph upp uprp upy  pih
pip pirp piy  leth letp letrp lety  cauh caup caurp cauy  poth potp
potrp poty

    genr  n=@mean(%0d)

    genr  min=%0d(-1)
genr  min=(%0d<min)*%0d+(%0d>=min)*min
genr  min=(%0d(1)<min)*%0d(1)+(%0d(1)>=min)*min

genr  max=%0d(-1)
genr  max=(%0d>max)*%0d+(%0d<=max)*max
genr  max=(%0d(+1)>max)*%0d(+1)+(%0d(+1)<=max)*max

genr  Sum=%0d(-1)+%0d+%0d(+1)
genr Med=sum-min-max

genr  r4=%0d-med


genr  g2=r4^2
genr  i1=@sum(g2)/10
genr  i2=@sum(g2)/21
genr  d1=sqr(i1)
genr  d2=sqr(i2)
genr vc31=d1/n
genr vc32=d2/n

pon
smpl 1970 1970
```

```
print %0d vc31 vc32 n d1 d2
smpl 1980 1980
print %0d vc31 vc32 n d1 d2
smpl %3 %4
poff

next
next
exit
```

APPENDIX B

The Change Direction of Variability Generated
by Four Techniques between 1967-1978 and 1979-1990[1]

Table 1, The Change Direction of Variability in Major Arizona Field Crops at State Level (1967-1978 and 1979-1990)

Crops	Harvested Acreage				Yield per Harvested Acre			
	CV	VC1	VC2	VC3	CV	VC1	VC2	VC3
Pima Cotton	+	+	+	+	-	-	-	-
Upland Cotton	-	+	-	+	-	-	-	-
All Wheat	-	-	-	-	-	-	-	-
Alfalfa Hay	-	-	-	-	-	-	-	-
All Lettuce	+	+	+	+	+	+	+	+
Cauliflower	+	-	-	-	+	-	+	+
Potatoes	-	-	-	-	+	+	+	+

[1]These tables present the change direction of variability indexes estimated from the four different techniques between the periods of 1967-1978 and 1979-1990. CV, VC1, VC2, and VC3 denote the variability indexes estimated by the long-term mean, linear time trend, moving average, and running median. The symbol: "+", "-", and "0" denotes the variability "increased", "decreased", or "remained unchanged" between the two periods. VC3 refers to the periods of 1968-1978 and 1979-1989 due to two observations losses.

Table 1 (Continued), The Change Direction of Variability in Major Arizona Field Crops at State Level (1967-1978 and 1979-1990)

Crops	Nominal Prices				Real Prices			
	CV	VC1	VC2	VC3	CV	VC1	VC2	VC3
Pima Cotton	-	-	-	-	-	-	-	-
Upland Cotton	-	-	-	+	+	-	+	-
All Wheat	-	-	-	-	-	-	-	-
Alfalfa Hay	-	-	-	0	-	-	-	-
All Lettuce	+	+	+	+	+	+	+	+
Cauliflower	-	+	-	+	+	+	+	+
Potatoes	-	-	-	-	-	-	+	-

Table 2, The Change Direction of Variability in Major Arizona Field Crops at County Levels (1967-1978 and 1979-1990)

Crops	Harvested Acreage				Yield per Harvested Acre			
	CV	VC1	VC2	VC3	CV	VC1	VC2	VC3
Pima Cotton								
Cochise	+	+	+	+	-	-	-	-
Graham	+	-	-	+	-	-	-	-
Maricopa	+	+	+	+	-	-	-	-
Pima	+	+	+	+	-	-	-	-
Pinal	+	+	+	+	-	-	-	-
Yuma	+	+	+	+	-	-	-	-
Upland Cotton								
Cochise	-	-	-	+	-	-	-	-
Graham	-	-	-	+	+	-	-	-
Maricopa	-	-	-	+	-	-	-	-
Pima	+	+	+	+	+	-	-	+
Pinal	+	+	+	+	-	-	-	-
Yuma	-	-	-	+	-	-	-	-
All Wheat								
Cochise	-	-	-	-	+	+	+	+
Graham	-	-	-	-	+	+	+	-
Maricopa	+	+	+	-	-	-	-	-
Pima	-	-	-	-	-	-	-	-
Pinal	-	-	-	-	-	-	-	-
Yuma	-	-	-	-	-	-	-	-

Table 2 (Continued), The Change Direction of Variability in Major Arizona Field Crops at County Levels (1967-1978 and 1979-1990)

Crops	Harvested Acreage				Yield per Harvested Acre			
	CV	VC1	VC2	VC3	CV	VC1	VC2	VC3
Alfalfa Hay								
Cochise	+	+	+	+	-	-	-	+
Graham	+	+	+	+	-	-	-	-
Maricopa	-	-	-	-	-	-	-	-
Pima	+	+	+	+	+	+	-	-
Pinal	-	-	-	+	+	-	-	-
Yuma	+	-	+	-	-	-	-	+
All Lettuce								
Cochise	-	-	-	-	-	+	+	+
Maricopa	-	+	-	+	+	+	+	+
Pima	+	+	+	+	+	+	+	-
Pinal	+	+	+	-	+	+	+	+
Yuma	+	-	-	-	+	+	+	-
Cauliflower								
Maricopa	-	-	-	-	+	+	+	+
Yuma	-	-	-	-	-	-	-	-
Potatoes								
Maricopa	-	-	-	-	+	+	+	+

APPENDIX C

Variability Indexes Estimated by different techniques[1]

Table 1, Variability of Major Arizona Field Crops at State Level: 1967-1990, 1967-1978, and 1979-1990

Items	Coefficient of Variation (CV, %)				Variability Coefficient 1 (VC1, %)			
	Overall	Period 1	Period 2	Change	Overall	Period 1	Period 2	Change
<u>Harvested Acreage</u>								
Pima Cotton	85.22	10.54	77.32	633.59	57.93	15.95	54.34	240.69
Upland Cotton	33.92	33.40	32.32	-3.23	24.51	21.14	21.40	1.23
All Wheat	54.41	61.31	39.36	-35.80	47.71	54.05	31.48	-41.76
Alfalfa Hay	13.65	8.46	5.33	-37.00	5.70	5.89	5.03	-14.60
All Lettuce	13.00	10.79	15.07	39.67	9.95	6.12	10.72	75.16
Cauliflower	83.12	25.61	44.56	73.99	17.68	16.00	13.72	-14.25
Potatoes	33.55	25.17	12.94	-48.59	16.40	13.36	12.39	-7.26
<u>Yield per Acre</u>								
Pima Cotton	22.57	19.92	13.51	-32.18	13.46	17.11	12.41	-27.47
Upland Cotton	11.86	10.68	7.58	-29.03	9.32	11.68	7.60	-34.93
All Wheat	17.14	11.88	6.08	-48.82	4.13	5.28	2.77	-47.54
Alfalfa Hay	11.44	7.53	6.05	-19.65	3.66	4.90	2.91	-40.61
All Lettuce	21.11	8.13	11.06	36.04	9.41	4.04	9.67	139.36
Cauliflower	32.00	9.94	11.60	16.70	13.75	10.51	10.37	-1.33
Potatoes	11.50	9.81	12.78	30.28	11.30	10.03	13.62	35.79

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(1) CV, VC1, VC2, and VC3 are estimated by the Long-term Mean, Linear Time Trend, Simply Moving Average, and Running Median respectively. Overall, Period 1, and Period 2 represent the period of 1967-1990, 1967-1978, and 1979-1990 respectively. However, Overall, and Period 1 and 2 represent 1968-1989, 1968-1978 and 1979-1989 respectively for Running Median due to two observations losses.

Table 1 (Continued). Variability of Major Arizona Field Crops at State Level: 1967-1990, 1967-1978, and 1979-1990

Items	Variability Coefficient 2 (VC2, %)				Variability Coefficient 3 (VC3, %)			
	Overall	Period 1	Period 2	Change	Overall	Period 1	Period 2	Change
Harvested Acreage								
Pima Cotton	39.56	12.15	40.61	234.24	46.63	11.19	49.11	338.87
Upland Cotton	17.43	18.18	17.42	-4.18	15.35	13.11	17.19	31.12
All Wheat	36.32	41.76	27.38	-34.43	25.01	30.17	13.67	-54.69
Alfalfa Hay	4.23	4.52	4.12	-8.85	2.53	2.74	2.29	-16.42
All Lettuce	7.53	6.82	8.57	25.66	6.02	5.62	6.72	19.57
Cauliflower	16.13	14.16	13.86	-2.12	7.41	10.73	6.13	-42.87
Potatoes	11.86	12.45	9.77	-21.53	9.72	10.64	6.35	-40.32
Yield per Acre								
Pima Cotton	10.02	13.03	8.17	-37.30	6.01	11.88	6.45	-45.71
Upland Cotton	7.40	9.25	6.00	-35.14	7.72	9.96	5.92	-40.56
All Wheat	4.79	6.65	3.46	-47.97	1.84	2.36	1.50	-36.44
Alfalfa Hay	3.56	4.37	2.98	-31.81	2.06	2.78	1.44	-48.20
All Lettuce	7.37	3.89	8.61	121.34	5.99	5.89	6.11	3.74
Cauliflower	10.17	9.52	10.11	6.20	7.81	6.58	7.97	21.12
Potatoes	9.35	8.60	10.34	20.23	11.33	7.19	14.48	101.39

Table 1 (Continued), Variability of Major Arizona Field Crops at State Level: 1967-1990, 1967-1978, and 1979-1990

Items	Coefficient of Variation (CV, %)				Variability Coefficient 1 (VC1, %)			
	Overall	Period 1	Period 2	Change	Overall	Period 1	Period 2	Change
Nominal Price								
Pima Cotton	30.90	38.37	8.47	-77.93	17.93	23.66	9.31	-60.65
Upland Cotton	32.36	38.43	10.09	-73.74	14.75	15.99	10.95	-31.52
All Wheat	33.58	38.37	11.22	-70.76	17.55	21.57	11.46	-46.87
Alfalfa Hay	36.92	35.89	10.91	-69.60	10.67	12.94	9.09	-29.75
All Lettuce	42.91	25.06	35.78	42.78	32.90	18.56	38.15	105.55
Cauliflower	30.59	28.19	14.44	-48.78	12.46	7.93	9.69	22.19
Potatoes	40.05	39.87	22.34	-43.97	17.75	21.85	15.50	-29.06
Real Price								
Pima Cotton	26.09	24.06	18.79	-21.90	23.14	24.38	10.83	-55.58
Upland Cotton	23.43	19.63	22.50	14.62	16.66	16.81	14.49	-13.80
All Wheat	23.96	22.30	22.00	-1.35	18.19	20.25	11.59	-42.77
Alfalfa Hay	15.32	16.21	13.59	-16.16	11.61	12.83	10.07	-21.51
All Lettuce	26.49	17.34	32.51	87.49	24.38	16.52	35.32	113.80
Cauliflower	20.68	7.98	25.72	222.31	10.81	7.20	8.39	16.53
Potatoes	19.30	20.26	14.40	-28.92	19.89	18.69	14.39	-23.01

Table 1 (Continued). Variability of Major Arizona Field Crops at State Level: 1967-1990, 1967-1978, and 1979-1990

Items	Variability Coefficient 2 (VC2, %)				Variability Coefficient 3 (VC3, %)			
	Overall	Period 1	Period 2	Change	Overall	Period 1	Period 2	Change
Nominal Price								
Pima Cotton	12.70	19.88	7.89	-60.31	11.68	19.26	5.81	-69.83
Upland Cotton	10.75	13.41	9.46	-29.46	7.83	6.44	8.35	29.66
All Wheat	12.89	16.59	11.08	-33.21	8.16	10.89	6.81	-37.47
Alfalfa Hay	9.86	12.32	8.73	-29.14	4.44	4.37	4.37	0.00
All Lettuce	28.27	14.97	31.23	108.62	24.38	14.97	26.51	77.09
Cauliflower	8.73	9.68	8.29	-14.36	5.48	4.31	5.88	36.43
Potatoes	16.32	19.97	14.62	-26.79	14.15	22.19	9.73	-56.15
Real Price								
Pima Cotton	16.53	19.79	9.34	-52.80	17.45	22.31	3.08	-86.19
Upland Cotton	11.13	11.16	11.55	3.49	6.56	6.98	6.22	-10.89
All Wheat	13.07	14.70	10.91	-25.78	7.33	9.05	4.40	-51.38
Alfalfa Hay	8.83	9.69	8.15	-15.89	6.12	7.30	4.78	-34.52
All Lettuce	20.85	13.44	29.41	118.82	19.91	15.38	25.66	66.84
Cauliflower	7.07	5.63	9.12	61.99	6.60	6.41	7.18	12.01
Potatoes	16.69	16.67	17.47	4.80	13.20	14.81	11.41	-22.96

Table 2. Variability of Harvested Acreage by Crop and County: 1967-1990, 1967-1978, and 1979-1990

Items	Coefficient of Variation (CV, %)				Variability Coefficient 1 (VC1, %)			
	Overall	Period 1	Period 2	Change	Overall	Period 1	Period 2	Change
Pima Cotton								
Cochise	66.14	64.70	70.24	8.56	58.16	43.73	72.41	65.58
Graham	33.90	20.39	33.61	64.84	23.54	22.07	20.31	-7.97
Maricopa	84.15	32.27	78.94	144.62	65.70	20.62	62.00	200.68
Pima	49.03	22.59	63.60	181.54	44.97	21.28	57.99	172.51
Pinal	126.00	15.88	98.29	518.95	71.86	15.57	57.08	266.60
Yuma	96.58	61.65	81.38	32.00	76.41	18.27	76.66	319.59
Upland Cotton								
Cochise	42.54	46.28	39.97	-13.63	31.36	34.13	24.85	-27.19
Graham	40.59	40.96	30.34	-25.93	33.65	40.30	19.65	-51.24
Maricopa	36.69	39.93	31.11	-22.09	25.27	22.73	21.44	-5.68
Pima	31.52	22.28	39.85	78.86	27.77	22.51	23.75	5.51
Pinal	24.06	19.43	28.44	46.37	20.17	11.94	21.01	75.96
Yuma	52.30	55.27	43.35	-21.57	34.77	38.25	25.76	-32.65
All Wheat								
Cochise	125.36	68.45	62.43	-8.79	88.67	70.45	27.99	-60.27
Graham	85.69	113.49	63.67	-43.90	68.17	91.78	40.21	-56.19
Maricopa	59.69	58.56	63.40	8.27	53.64	50.30	55.58	10.50
Pima	78.09	78.82	55.17	-30.01	57.90	63.25	43.90	-30.59
Pinal	62.04	62.38	61.71	-1.07	48.12	45.10	41.75	-7.43
Yuma	48.17	65.55	15.77	-75.94	46.21	60.72	14.88	-75.49

Table 2 (Continued), Variability of Harvested Acreage by Crop and County: 1967-1990, 1967-1978, and 1979-1990

Items	Variability Coefficient 2 (VC2, %)				Variability Coefficient 3 (VC3, %)			
	Overall	Period 1	Period 2	Change	Overall	Period 1	Period 2	Change
Pima Cotton								
Cochise	44.21	37.24	51.61	38.59	25.60	22.73	29.95	31.76
Graham	16.40	17.08	16.27	-4.74	14.78	12.73	16.12	26.63
Maricopa	44.95	17.10	47.09	175.38	47.02	21.86	48.95	123.92
Pima	32.50	18.20	41.44	127.69	25.82	16.46	32.39	96.78
Pinal	49.85	9.83	44.67	354.43	55.12	12.64	50.59	300.24
Yuma	57.01	21.73	56.24	158.81	66.00	3.33	67.59	1929.73
Upland Cotton								
Cochise	24.30	29.56	20.42	-30.92	12.39	11.09	13.81	24.53
Graham	23.44	31.15	19.36	-37.85	20.67	14.88	22.59	51.81
Maricopa	17.96	19.47	17.42	-10.53	16.12	13.08	18.15	38.76
Pima	19.73	19.38	21.08	8.77	20.92	20.58	22.41	8.89
Pinal	13.98	11.33	16.58	46.34	12.90	9.51	16.02	68.45
Yuma	25.51	32.13	22.20	-30.91	17.20	17.11	17.28	0.99
All Wheat								
Cochise	68.72	53.17	26.39	-50.37	31.00	24.03	6.81	-71.66
Graham	52.56	73.45	35.88	-51.15	25.76	34.83	18.72	-46.25
Maricopa	41.95	37.46	48.45	29.34	25.32	28.70	21.95	-23.52
Pima	46.60	49.76	34.71	-30.25	24.41	26.33	15.37	-41.63
Pinal	36.35	37.49	36.14	-3.60	27.00	31.86	19.00	-40.36
Yuma	35.22	47.69	13.12	-72.49	26.75	35.19	8.63	-75.48

Table 2 (Continued). Variability of Harvested Acreage by Crop and County: 1967-1990, 1967-1978, and 1979-1990

Items	Coefficient of Variation (CV, %)				Variability Coefficient 1 (VC1, %)			
	Overall	Period 1	Period 2	Change	Overall	Period 1	Period 2	Change
Alfalfa Hay								
Cochise	14.07	5.81	18.98	226.68	9.39	4.32	13.06	202.31
Graham	20.23	12.22	21.79	78.31	12.36	10.48	13.10	25.00
Maricopa	33.08	16.32	10.62	-34.93	8.42	7.89	6.75	-14.45
Pima	22.17	8.46	31.24	269.27	21.10	8.59	31.69	268.92
Pinal	21.24	16.81	11.28	-32.90	8.44	9.97	5.83	-41.52
Yuma	12.00	10.16	10.85	6.79	7.00	6.97	6.44	-7.60
All Lettuce								
Cochise	38.86	51.88	25.18	-51.46	37.45	49.27	24.45	-50.38
Maricopa	71.38	46.65	40.50	-13.18	11.95	8.66	21.29	145.84
Pima	61.55	28.51	34.73	21.82	28.58	22.07	23.21	5.17
Pinal	88.34	41.19	45.57	10.63	31.32	22.75	30.27	33.05
Yuma	32.27	21.41	22.07	3.08	13.28	15.93	11.78	-26.05
Cauliflower								
Maricopa	20.69	22.35	17.63	-21.12	21.26	21.10	17.28	-18.10
Yuma	105.67	64.34	47.80	-25.71	19.44	31.01	14.93	-51.85
Potatoes								
Maricopa	34.47	24.44	9.31	-61.91	15.73	13.82	10.12	-26.77

Table 2 (Continued), Variability of Harvested Acreage by Crop and County: 1967-1990, 1967-1978, and 1979-1990

Items	Variability Coefficient 2 (VC2, %)				Variability Coefficient 3 (VC3, %)			
	Overall	Period 1	Period 2	Change	Overall	Period 1	Period 2	Change
Alfalfa Hay								
Cochise	7.73	4.50	10.64	136.44	3.44	1.31	5.01	282.44
Graham	9.78	8.35	12.03	44.07	7.17	5.21	9.73	86.76
Maricopa	7.11	6.99	6.97	-0.29	2.91	3.23	1.14	-64.71
Pima	17.90	10.68	24.88	132.96	3.41	6.91	18.28	164.54
Pinal	7.54	8.85	4.63	-47.68	4.03	4.01	4.24	5.74
Yuma	5.59	5.68	5.72	0.70	2.63	3.06	2.09	-31.70
All Lettuce								
Cochise	32.04	42.47	23.18	-45.42	23.27	25.09	22.77	-9.25
Maricopa	21.77	20.10	18.46	-8.16	6.57	4.61	12.22	165.08
Pima	23.82	16.64	48.34	190.50	4.49	3.98	4.86	22.11
Pinal	30.90	24.14	58.90	143.99	12.72	10.68	9.23	-13.58
Yuma	11.44	12.93	10.74	-16.94	7.18	9.58	5.89	-38.52
Cauliflower								
Maricopa	15.83	18.86	12.00	-36.37	22.69	29.77	10.41	-65.03
Yuma	19.89	22.58	15.45	-31.58	5.57	12.44	4.09	-67.12
Potatoes								
Maricopa	11.48	12.37	7.72	-37.59	9.95	10.68	7.14	-33.15

Table 3. Variability of Per Acre Yield by Crop and County: 1967-1990, 1967-1978, and 1979-1990

Items	Coefficient of Variation (CV, %)				Variability Coefficient 1 (VC1, %)			
	Overall	Period 1	Period 2	Change	Overall	Period 1	Period 2	Change
Pima Cotton								
Cochise	25.12	26.08	25.29	-3.03	25.73	27.13	23.26	-14.26
Graham	23.11	22.48	14.13	-37.14	14.50	22.78	6.75	-70.37
Maricopa	26.18	26.92	15.22	-43.46	19.43	22.01	16.73	-23.99
Pima	19.56	20.37	18.50	-9.18	17.75	20.31	17.66	-13.05
Pinal	26.93	26.90	14.48	-46.17	18.55	26.37	14.82	-43.80
Yuma	14.82	17.89	9.90	-44.66	10.61	10.74	10.20	-5.03
Upland Cotton								
Cochise	18.01	19.23	17.46	-9.20	16.44	16.80	14.52	-13.57
Graham	17.38	13.04	14.02	7.52	12.24	14.05	11.80	-16.01
Maricopa	12.16	12.54	7.27	-42.03	10.14	13.17	7.98	-39.41
Pima	14.95	12.74	14.08	10.52	11.02	11.61	10.89	-6.20
Pinal	15.30	11.27	10.64	-5.59	12.32	11.25	11.10	-1.33
Yuma	16.80	23.19	7.57	-67.36	17.46	25.00	6.24	-75.04
All Wheat								
Cochise	24.12	10.74	29.58	175.42	23.53	6.27	29.13	364.59
Graham	21.41	9.93	16.79	69.08	13.12	6.82	16.02	134.90
Maricopa	18.23	10.42	8.61	-17.37	5.40	5.67	4.53	-20.11
Pima	16.16	13.84	8.94	-35.40	7.75	9.37	7.30	-22.09
Pinal	14.21	13.37	5.54	-58.56	6.43	7.77	5.63	-27.54
Yuma	16.16	15.30	5.56	-63.66	10.34	11.92	4.51	-62.16

Table 3 (Continued), Variability of Per Acre Yield by Crop and County: 1967-1990, 1967-1978, and 1979-1990

Items	Variability Coefficient 2 (VC2, %)				Variability Coefficient 3 (VC3, %)			
	Overall	Period 1	Period 2	Change	Overall	Period 1	Period 2	Change
Pima Cotton								
Cochise	20.06	22.01	18.92	22.23	-14.04	27.71	16.35	-41.00
Graham	10.48	14.94	7.18	12.27	-51.94	17.65	8.18	-53.65
Maricopa	14.03	18.42	11.39	12.66	-38.17	13.92	12.18	-12.50
Pima	13.64	15.88	12.07	10.73	-23.99	11.42	10.60	-7.18
Pinal	13.96	20.11	9.94	9.60	-50.57	13.84	6.98	-49.57
Yuma	15.74	22.21	8.29	8.38	-62.67	9.86	7.29	-26.06
Upland Cotton								
Cochise	11.28	12.21	10.86	13.46	-11.06	17.21	9.79	-43.11
Graham	9.94	10.46	9.86	8.49	-5.74	12.40	4.79	-61.37
Maricopa	8.18	10.56	6.17	8.87	-41.57	10.67	7.62	-28.58
Pima	8.50	9.58	7.91	5.83	-17.43	4.35	6.94	59.54
Pinal	9.13	10.23	8.61	9.71	-15.84	12.51	7.76	-37.97
Yuma	15.41	21.67	5.64	13.03	-73.97	17.90	5.73	-67.99
All Wheat								
Cochise	17.24	8.02	22.20	6.64	176.81	3.63	8.25	127.27
Graham	10.57	5.61	12.60	3.75	124.60	4.70	3.18	-32.34
Maricopa	5.29	6.27	4.79	2.42	-23.60	2.96	2.11	-28.72
Pima	6.93	8.63	5.82	3.41	-32.56	3.59	3.40	-5.29
Pinal	5.89	7.44	4.80	2.85	-35.48	3.88	1.98	-48.97
Yuma	11.19	17.30	4.99	3.09	-71.16	4.43	2.06	-53.50

Table 3 (Continued). Variability of Per Acre Yield by Crop and County: 1967-1990, 1967-1978, and 1979-1990

Items	Coefficient of Variation (CV, %)				Variability Coefficient 1 (VC1, %)			
	Overall	Period 1	Period 2	Change	Overall	Period 1	Period 2	Change
Alfalfa Hay								
Cochise	11.42	13.15	9.35	-28.90	9.18	11.69	5.82	-50.21
Graham	10.96	14.73	4.32	-70.67	10.07	14.81	4.29	-71.03
Maricopa	12.59	10.28	6.13	-40.37	5.95	5.57	4.14	-25.67
Pima	15.45	12.54	13.57	8.21	11.07	9.63	10.48	8.83
Pinal	19.34	11.75	12.51	6.47	6.98	9.51	5.26	-44.69
Yuma	13.77	11.17	9.34	-16.38	7.50	9.12	6.63	-27.30
All Lettuce								
Cochise	22.11	22.96	19.05	-17.03	19.28	18.66	20.77	11.31
Maricopa	22.77	14.25	20.69	45.19	20.47	14.23	21.78	53.06
Pima	20.88	13.58	17.90	31.81	13.57	11.77	12.24	3.99
Pinal	20.45	13.36	18.27	36.75	15.09	12.04	14.65	21.68
Yuma	20.81	8.16	10.74	31.62	9.81	6.65	9.72	46.17
Cauliflower								
Maricopa	32.28	13.44	19.60	45.83	16.89	12.37	17.91	44.79
Yuma	22.66	32.09	9.08	-71.70	16.18	18.04	9.35	-48.17
Potatoes								
Maricopa	11.13	9.71	11.89	22.45	10.65	10.02	12.54	25.15

Table 3 (Continued). Variability of Per Acre Yield by Crop and County: 1967-1990, 1967-1978, and 1979-1990

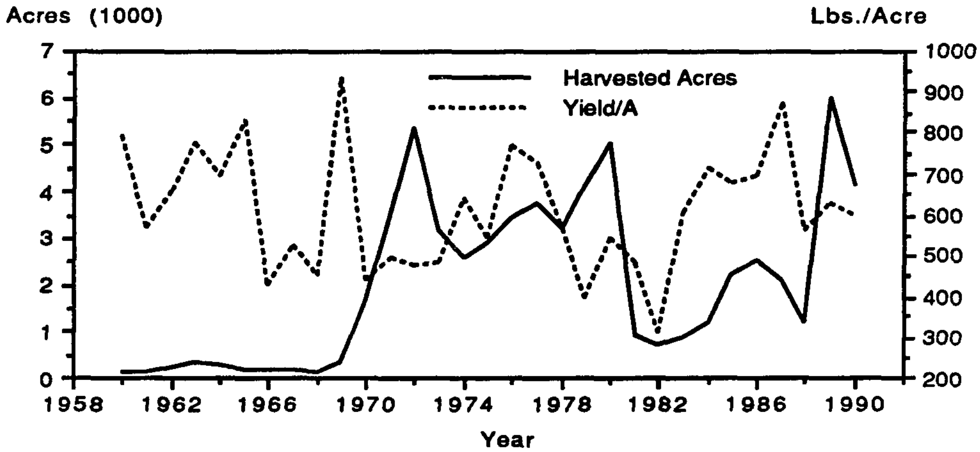
Items	Variability Coefficient 2 (VC2, %)				Variability Coefficient 3 (VC3, %)			
	Overall	Period 1	Period 2	Change	Overall	Period 1	Period 2	Change
Alfalfa Hay								
Cochise	7.40	9.78	4.78	3.94	-51.12	3.74	4.27	14.17
Graham	7.64	10.79	3.60	6.00	-66.64	7.86	4.16	-47.07
Maricopa	4.83	5.64	4.36	2.18	-22.70	3.40	0.58	-82.94
Pima	8.72	9.60	8.34	8.64	-13.13	12.17	4.87	-59.98
Pinal	6.27	8.00	5.20	3.88	-35.00	6.00	1.92	-68.00
Yuma	5.80	6.40	5.54	6.13	-13.44	5.23	6.91	32.12
All Lettuce								
Cochise	16.20	15.29	17.33	11.09	13.34	9.40	12.54	33.40
Maricopa	14.10	11.44	15.73	16.87	37.50	11.58	19.73	70.38
Pima	10.39	7.84	11.85	6.53	51.15	9.40	4.25	-54.79
Pinal	10.40	8.12	11.81	9.59	45.44	8.93	10.23	14.56
Yuma	7.00	5.97	7.50	6.15	25.63	7.56	5.41	-28.44
Cauliflower								
Maricopa	14.40	11.69	15.03	8.40	28.57	6.85	8.80	28.47
Yuma	12.01	15.35	8.93	9.55	-41.82	11.65	7.99	-31.42
Potatoes								
Maricopa	8.92	8.55	9.58	10.71	12.05	7.15	13.48	88.53

APPENDIX D

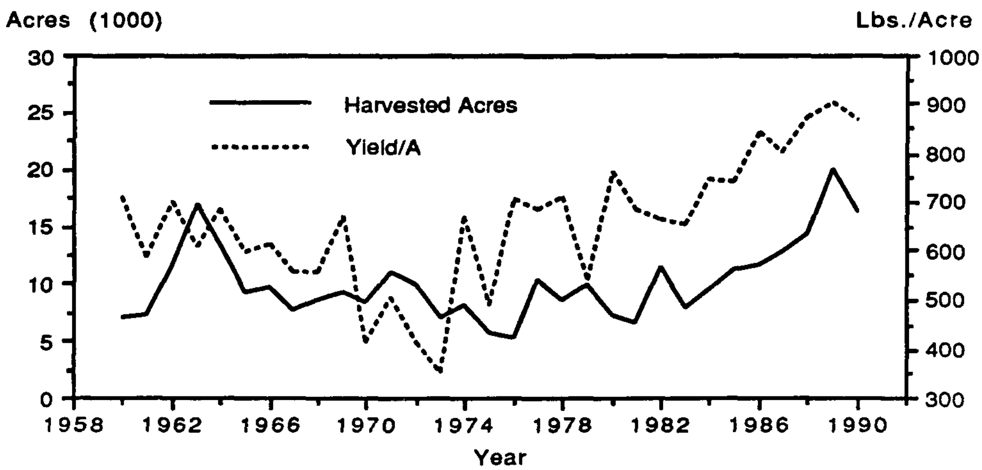
Harvested Acreage and Per Acre Yield of Major Arizona Field Crops at County Levels (1960-1990)

Figure 1, Pima Cotton

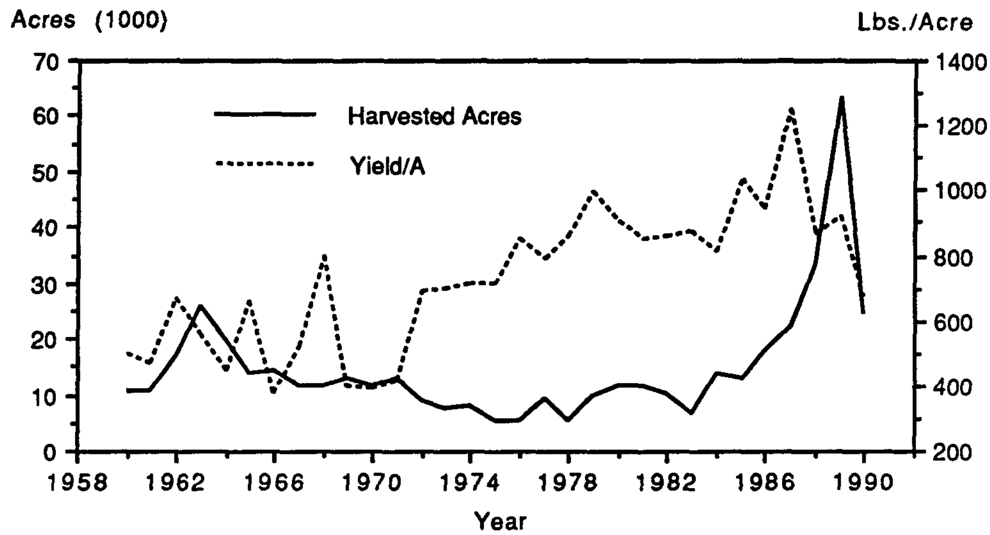
Panel A, Cochise County



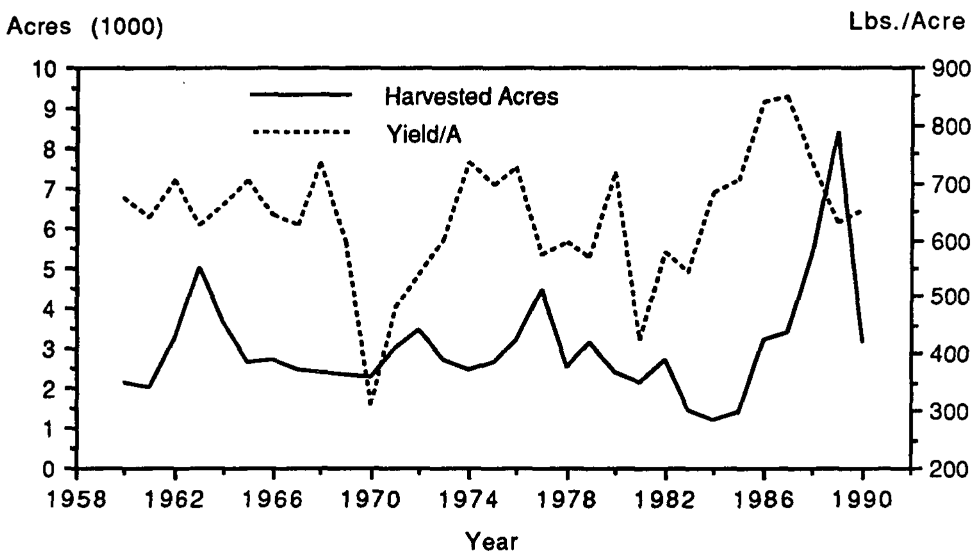
Panel B, Graham County



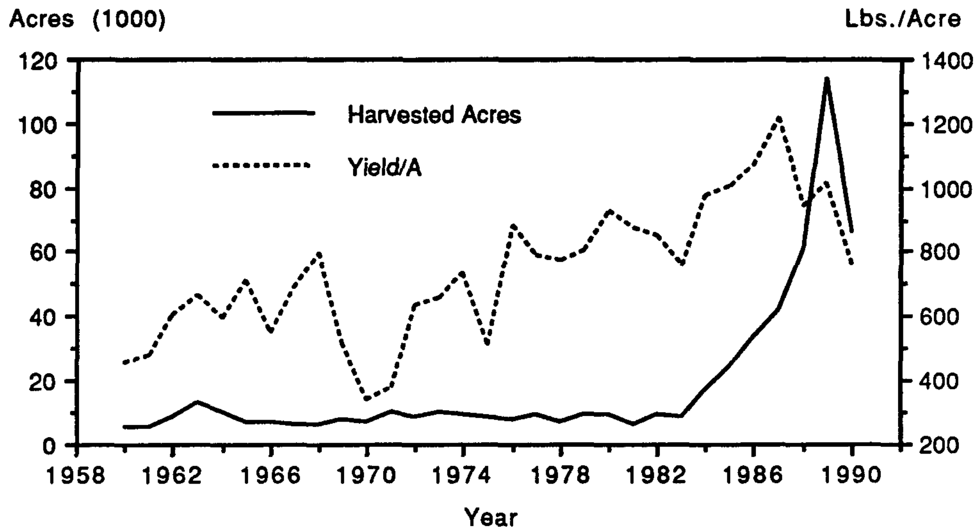
Panel C, Maricopa County



Panel D, Pima County



Panel E, Pinal County



Panel F, Yuma County

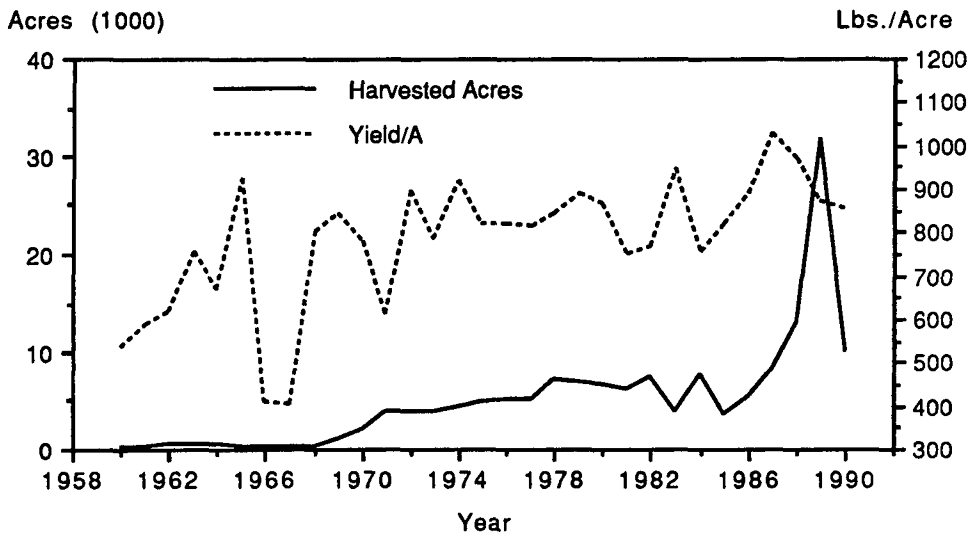
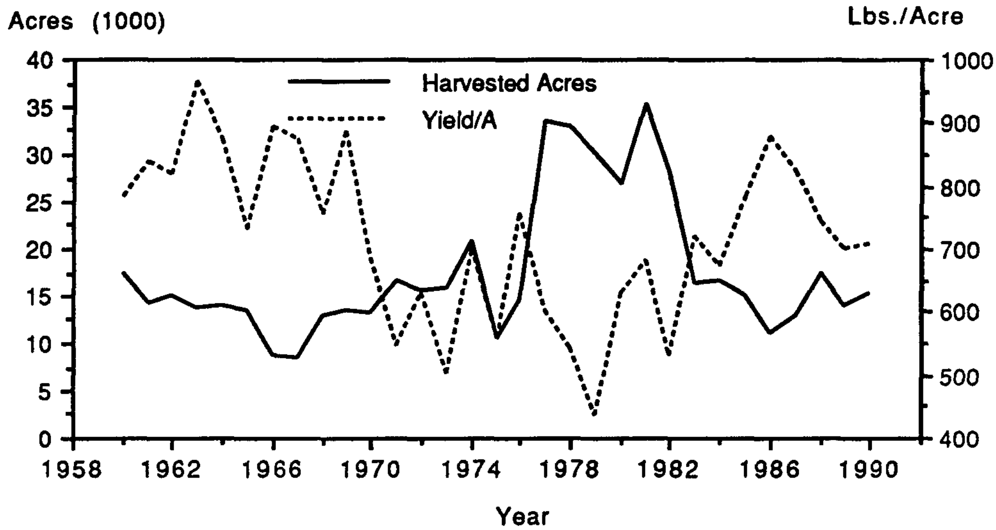
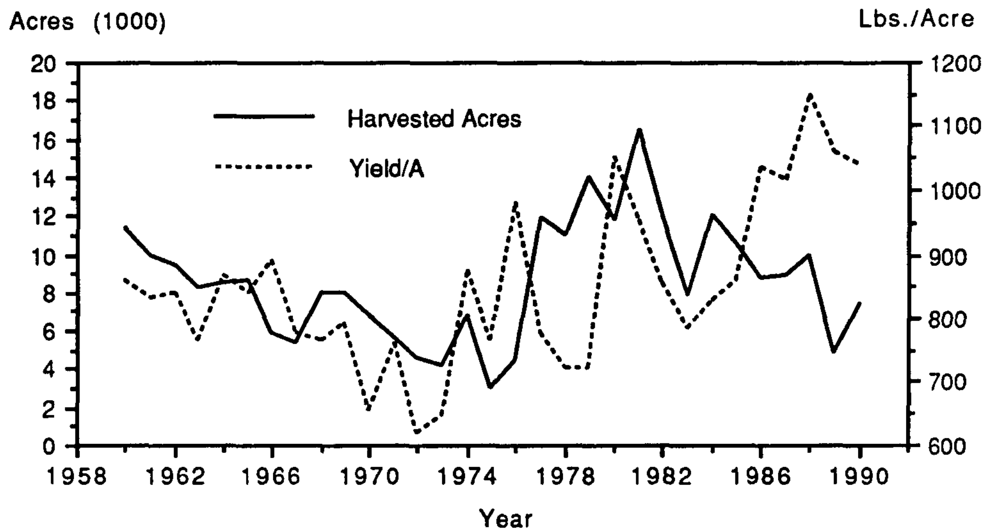


Figure 2, Upland Cotton

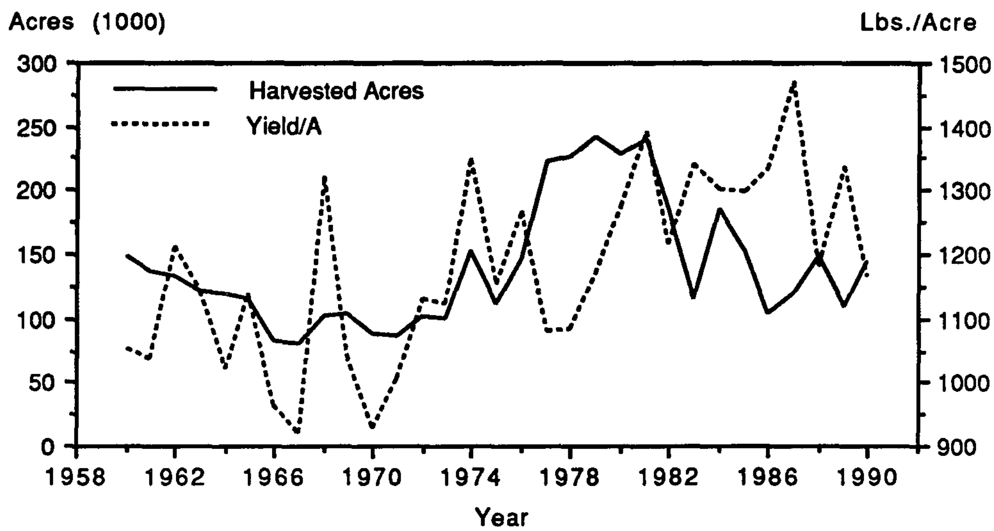
Panel A, Cochise County



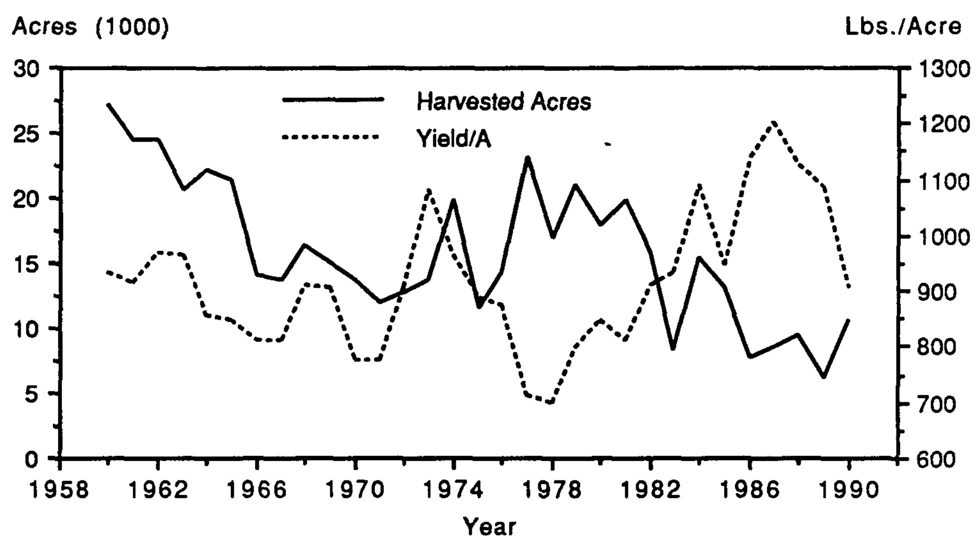
Panel B, Graham County



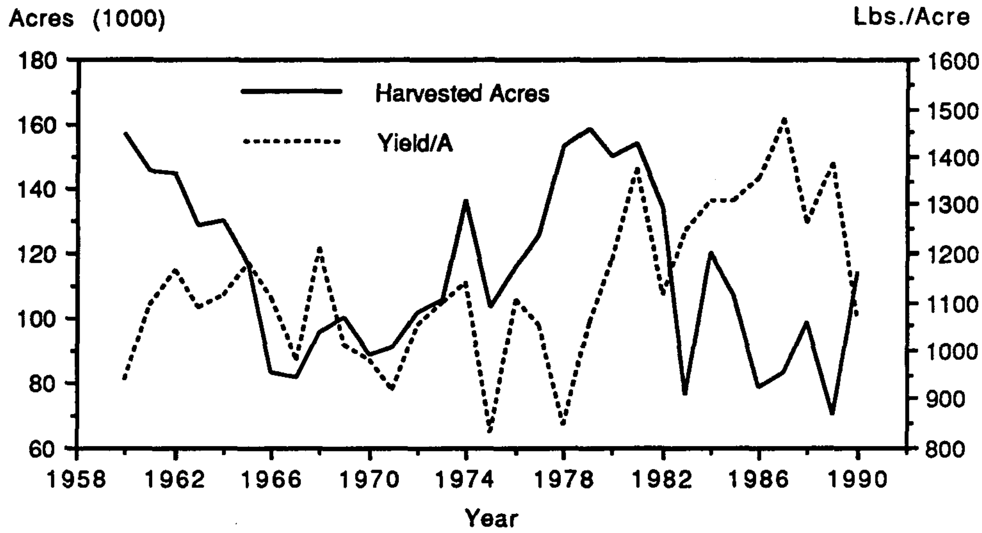
Panel C, Maricopa County



Panel D, Pima County



Panel E, Pinal County



Panel F, Yuma County

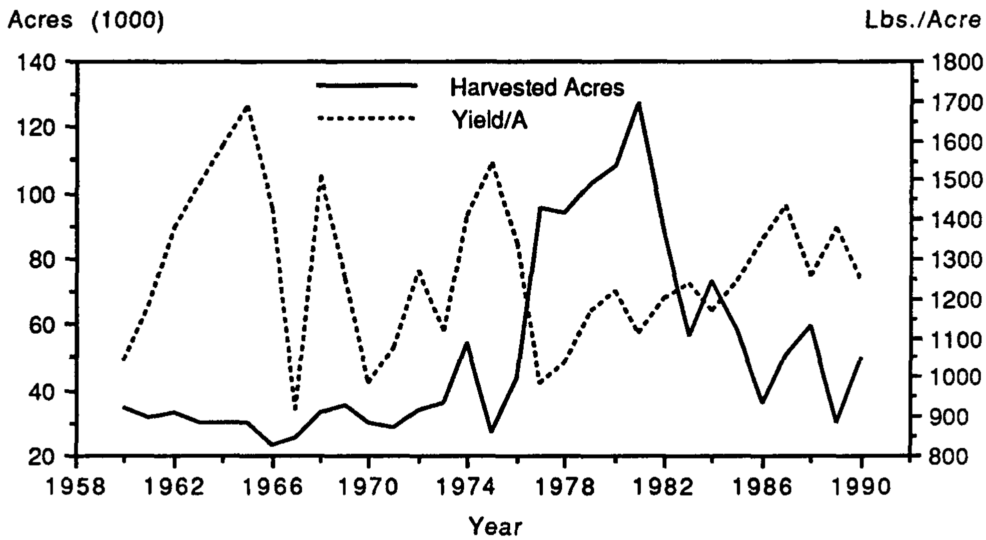
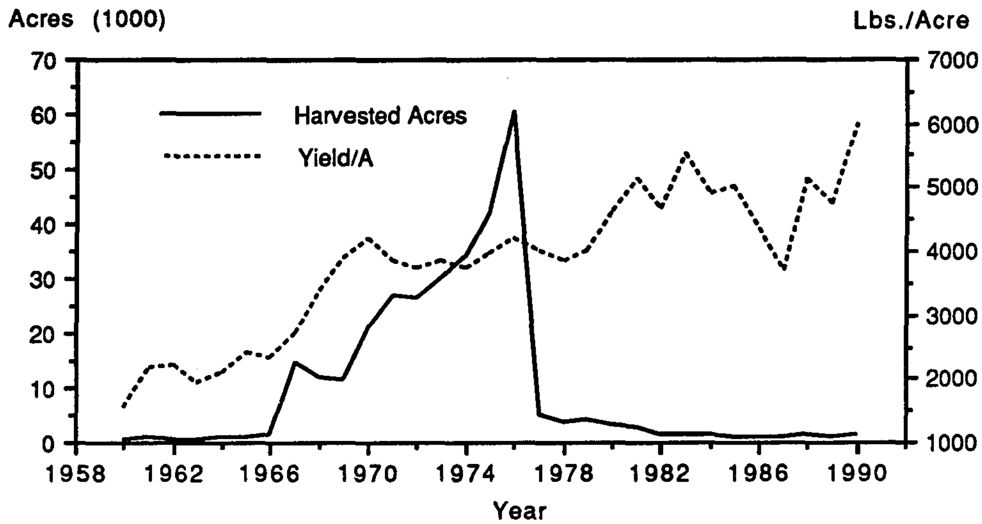
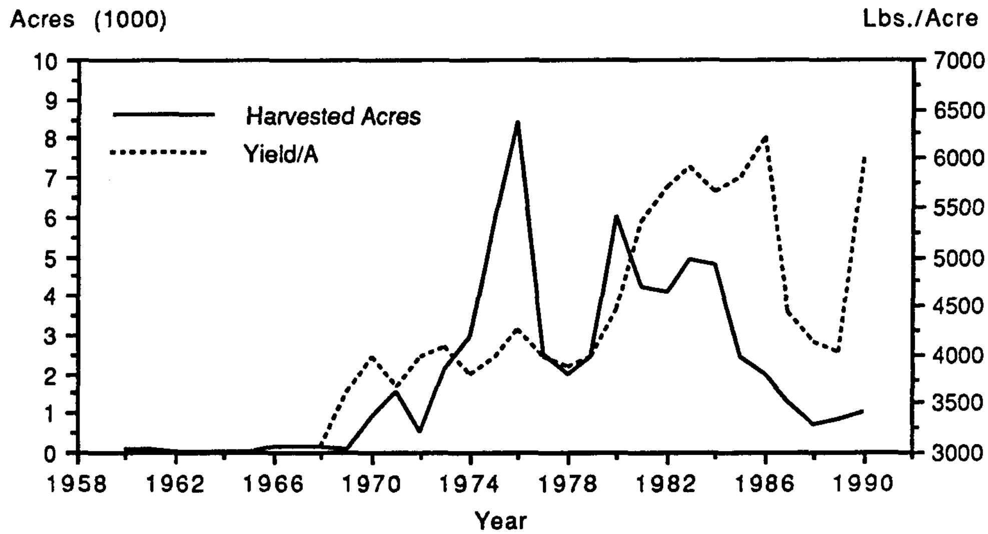


Figure 3, All Wheat

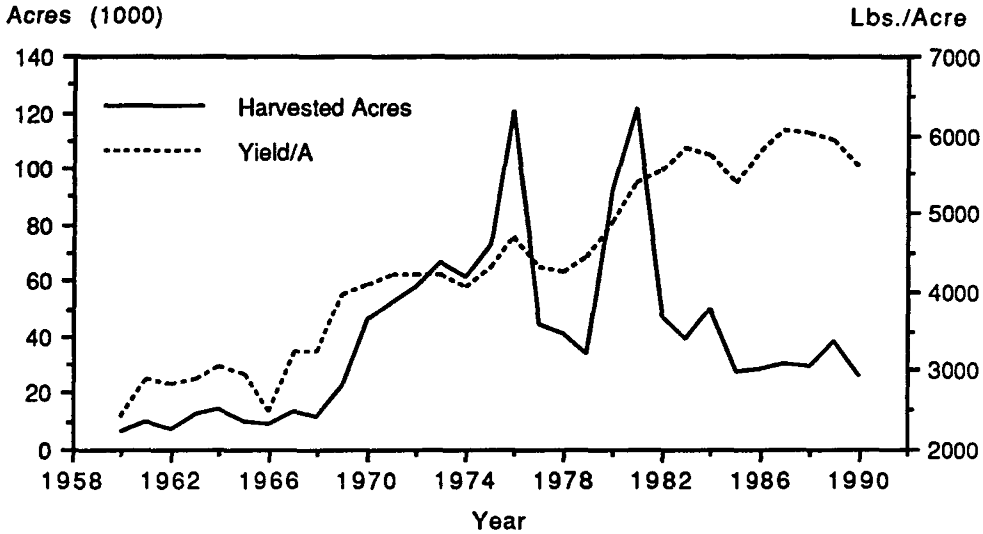
Panel A, Cochise County



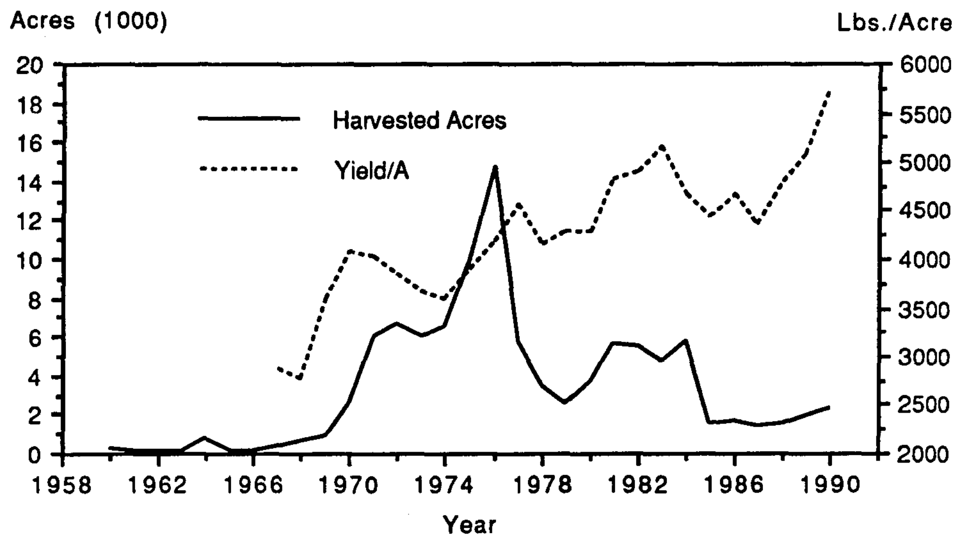
Panel B, Graham County



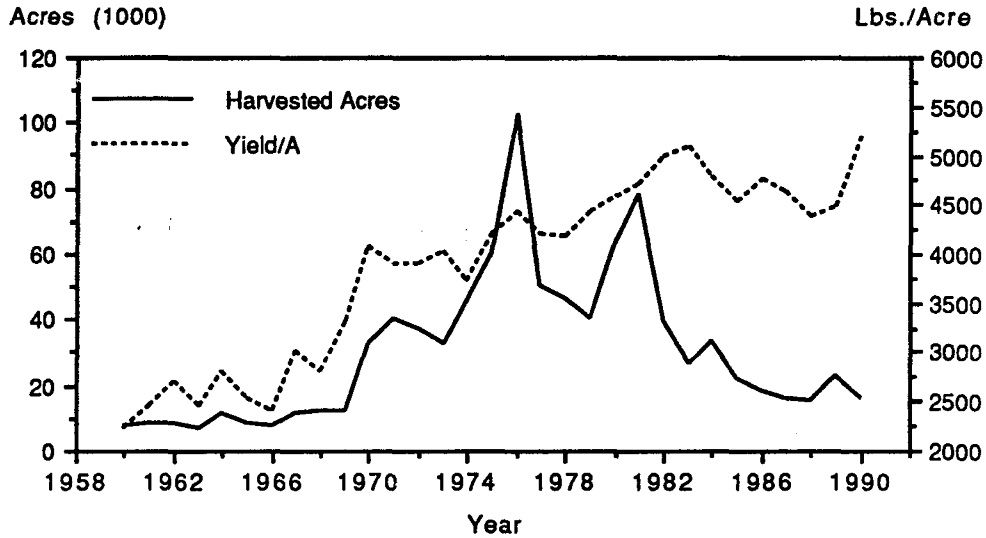
Panel C, Maricopa County



Panel D, Pima County



Panel E, Pinal County



Panel F, Yuma County

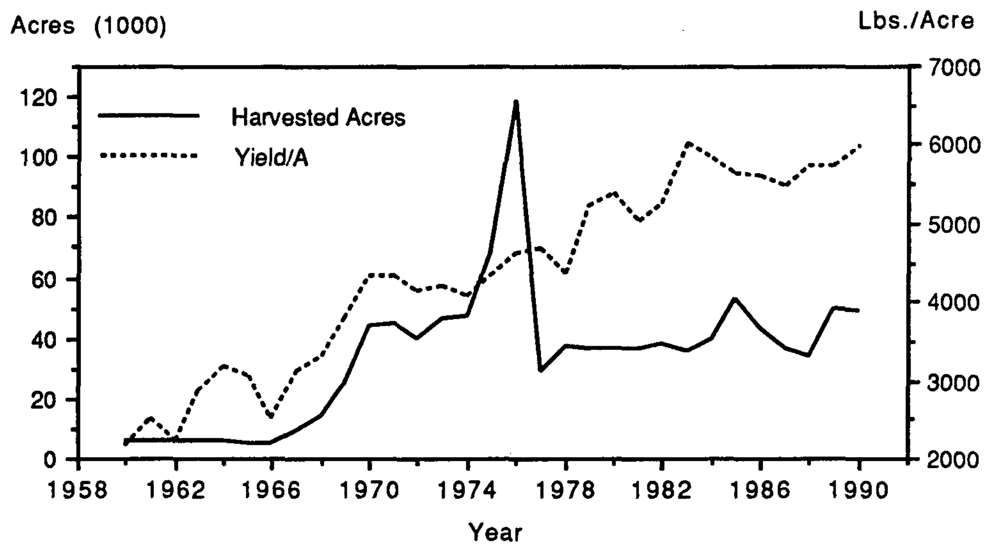
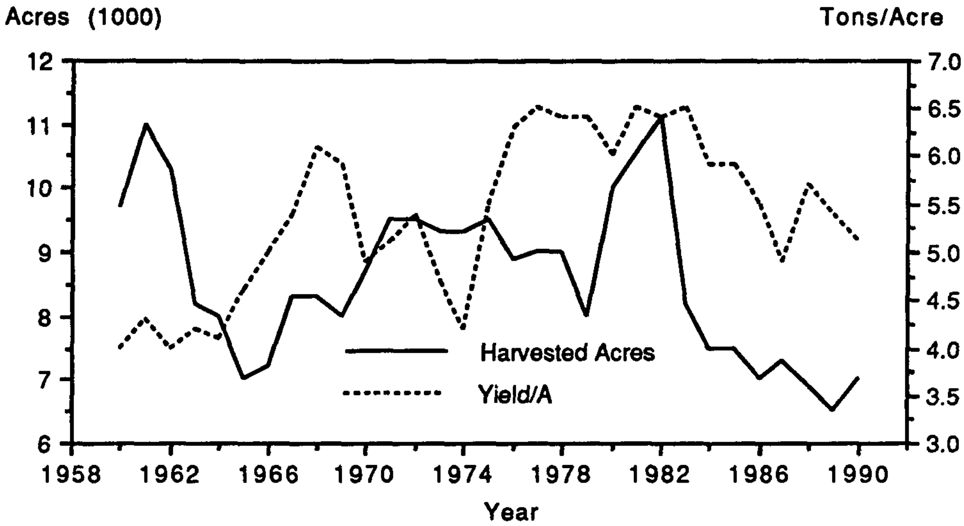
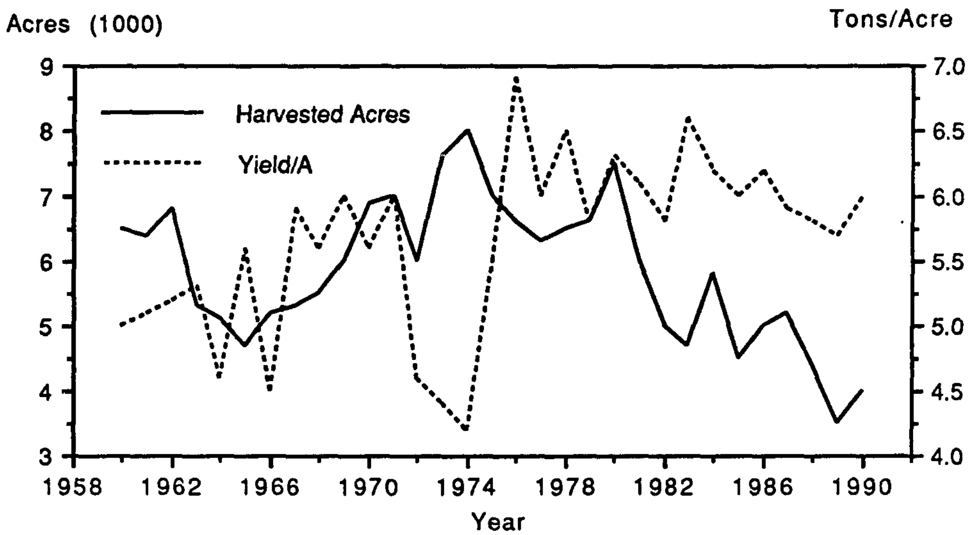


Figure 4, Alfalfa Hay

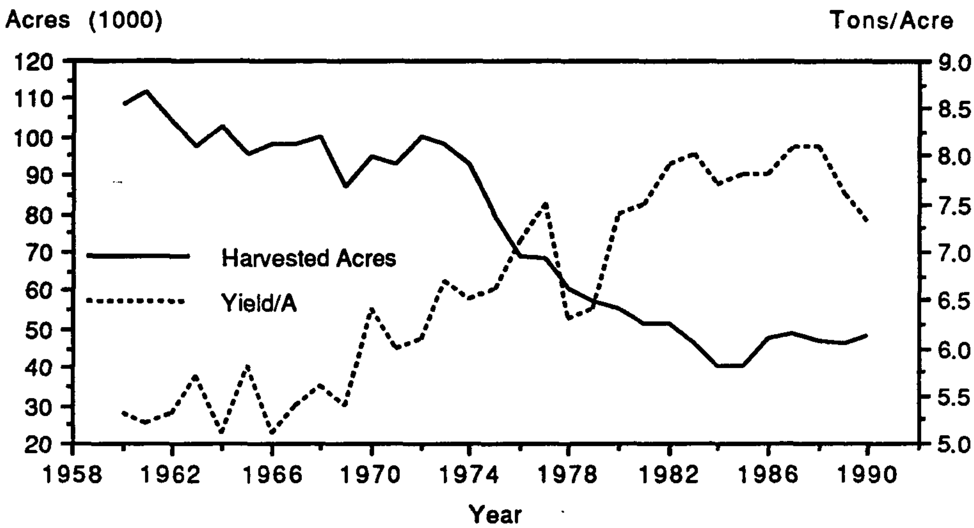
Panel A, Cochise County



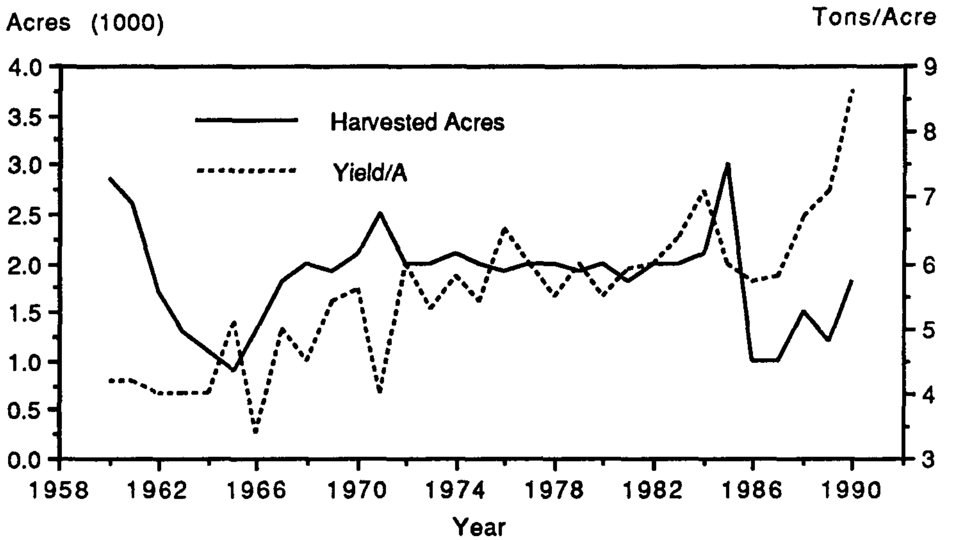
Panel B, Graham County



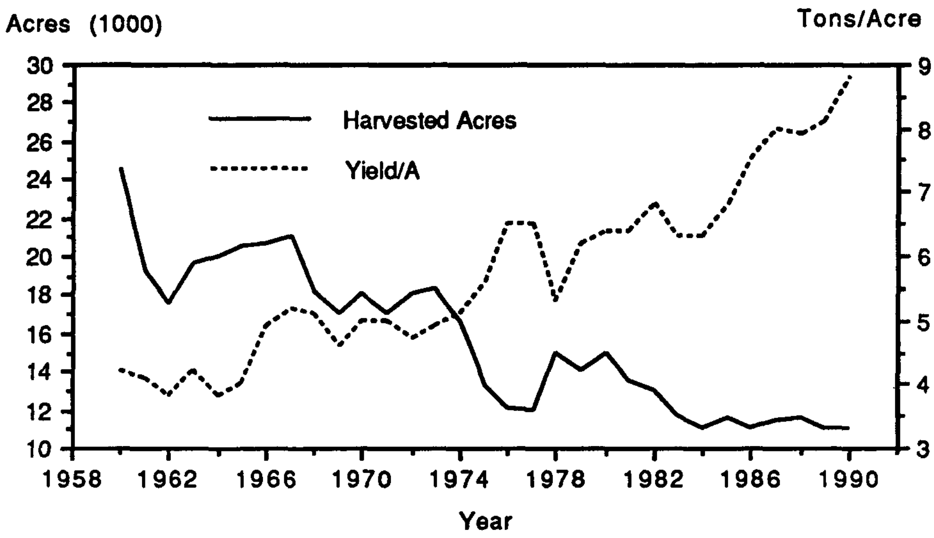
Panel C, Maricopa County



Panel D, Pima County



Panel E, Pinal County



Panel F, Yuma County

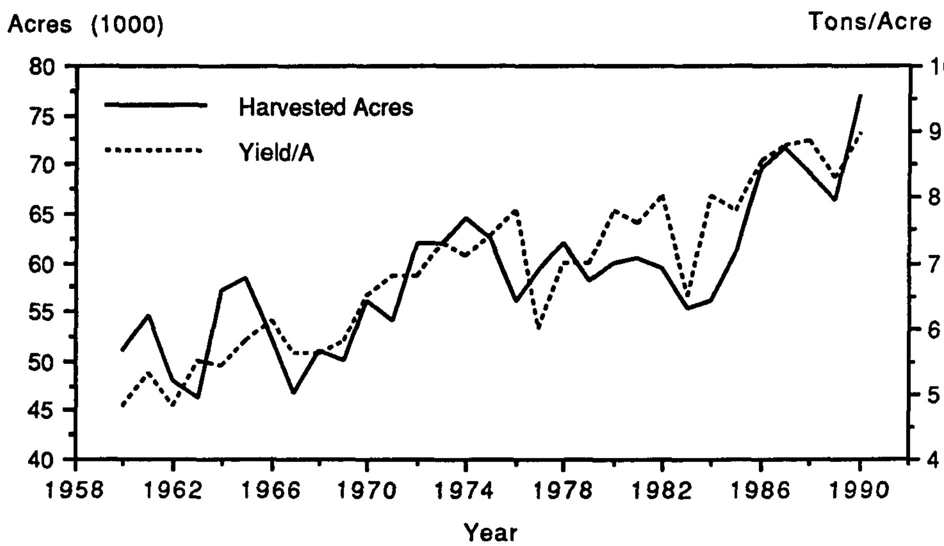
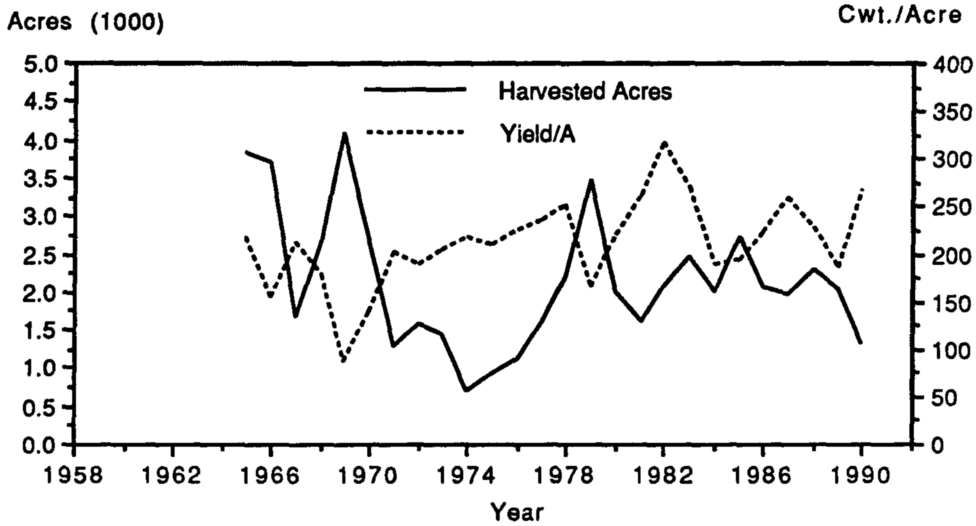
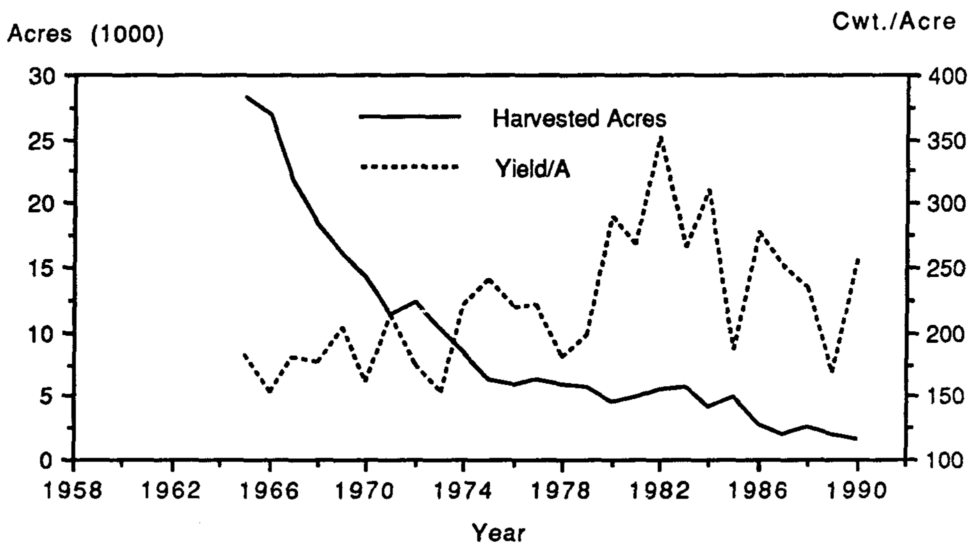


Figure 5, All Lettuce

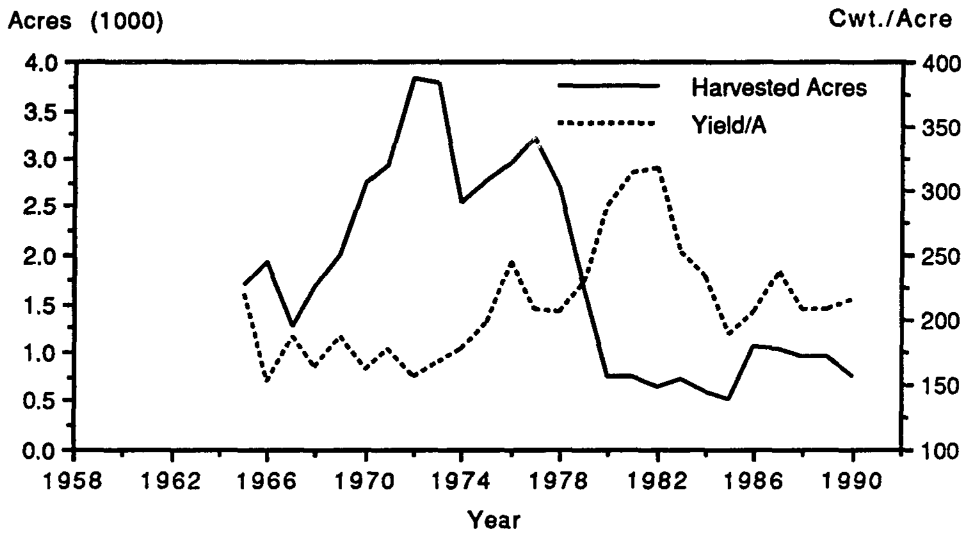
Panel A, Cochise County



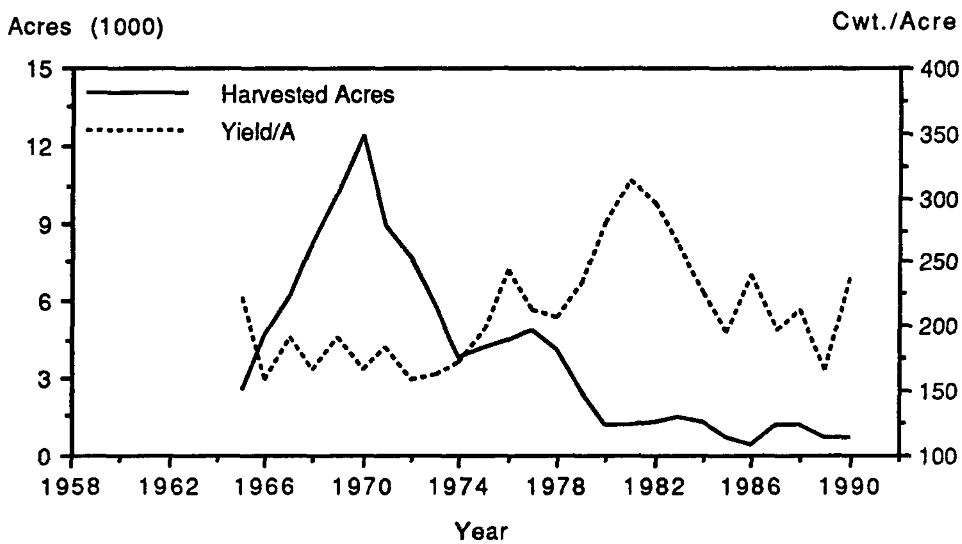
Panel B, Maricopa County



Panel C, Pima County



Panel D, Pinal County



Panel E, Yuma County

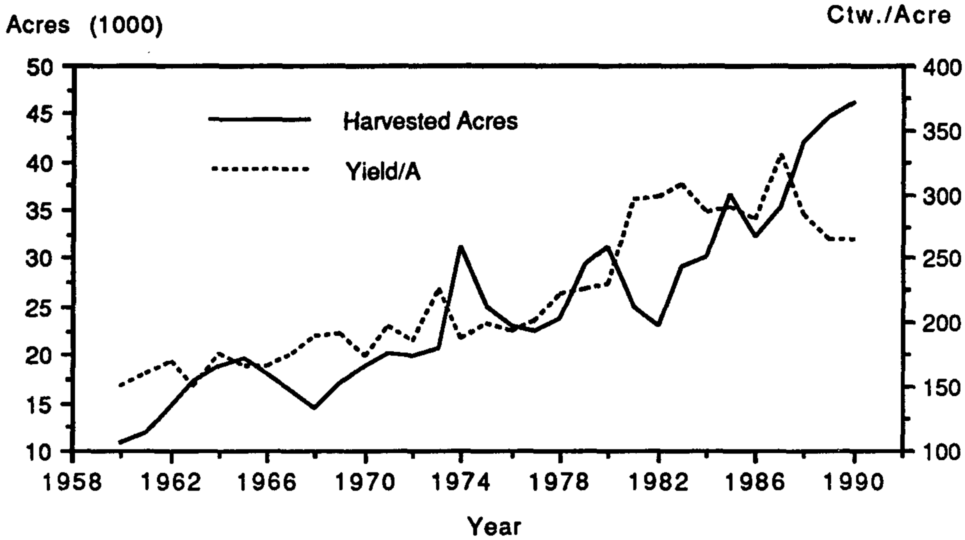
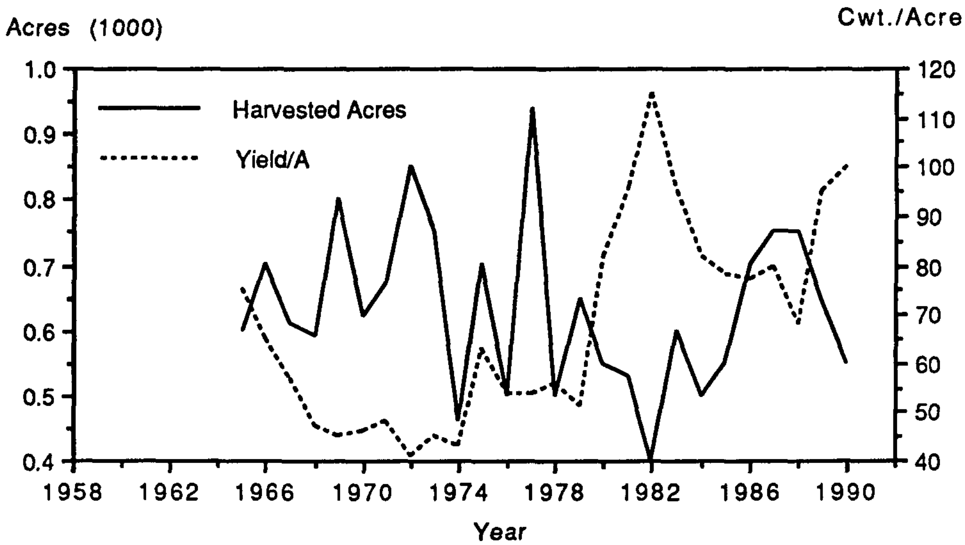


Figure 6, Cauliflower

Panel A, Maricopa County



Panel B: Yuma County

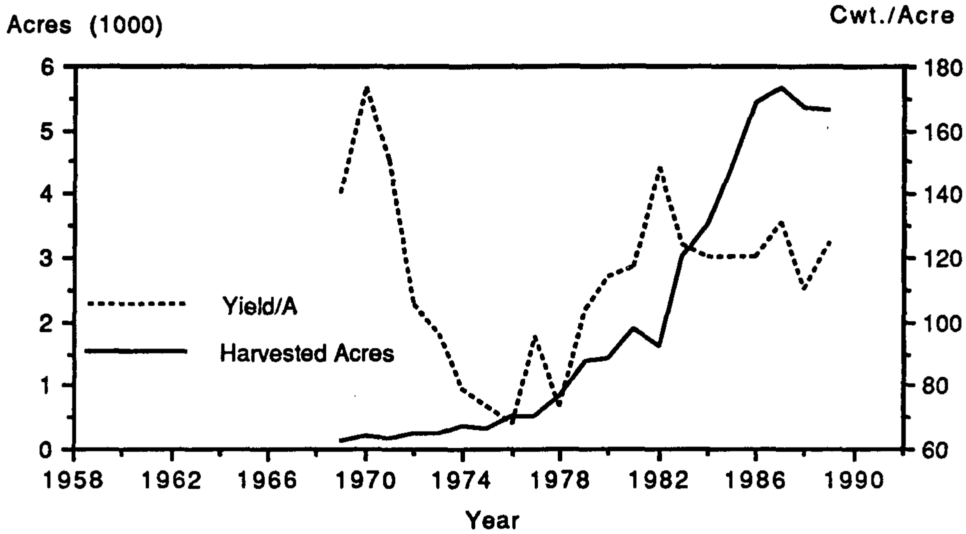
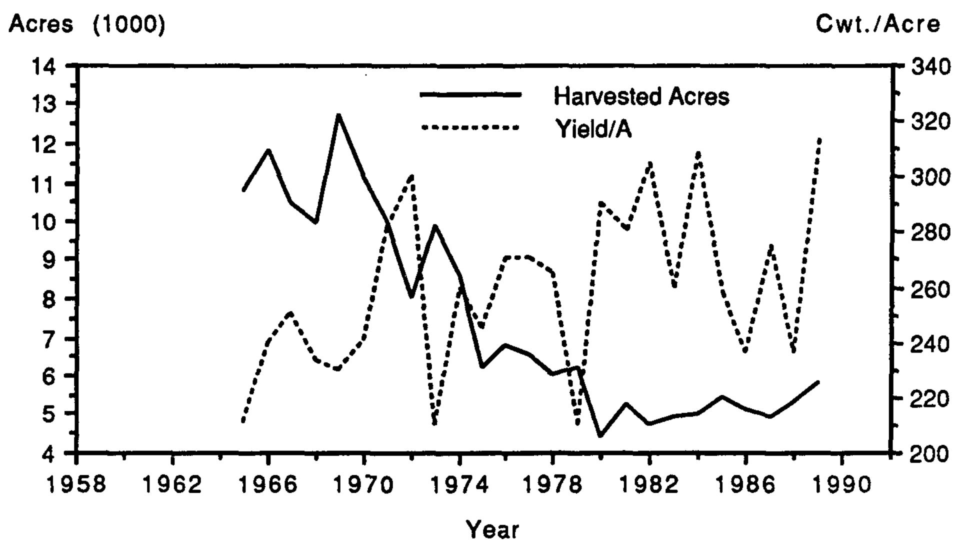


Figure 7, Potatoes

Panel A, Maricopa County



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