ARIZONA TEMPORAL AND SPATIAL YIELD VARIABILITY

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Abstract:

Cotton yield and its market value are of prime concern to producers. Price fluctuation in time and space are governed by the world economy, environmental conditions and management practices. These parameters have a direct impact on farmer's investment decision for a short and long-term planning. The immediate concern for growers is the crop yield. The analysis of spatial and temporal yield variability is fundamentally important for growers and. The objective of this investigation is to describe the temporal yield variability of cotton in Arizona. Cotton yield in Arizona counties from 1935-1999 was used for semivariogram and fractal analysis. The semivariogram was calculated for each county for Pima and Upland cotton for different year interval (h). The slope of log(semivariogram vs log h was used to calculate fractal dimension D, an indication of variability pattern. D close to 1 indicates the likelihood of a long- term variation. A D close to 2 indicates a short-term variability. From 1935 to 1990 the cotton yield has increased two to three folds in every county. The increase in yield is the result of plant breeding, better plant and soil nutrient management, herbicide, insecticide use and irrigation technology. The increase in yield also increased the risk of temporal and spatial fluctuation. Fractal dimension increased from 1.473 in Maricopa to 1.794 in Graham County for Upland cotton. The Fractal dimension increased from 1.457 in Yuma County to 1.781 in Cochise County for Pima cotton. Small D value in Yuma County is indicative of long-term yield variability while higher D value in Graham County, indicates short-term variability. Fractal analysis appears to be a useful tool to quantify temporal variability. It has a potential application for agronomic research and production in assessing variability in soil and plant parameters.

Introduction

Farming practices, biotechnology, plant breeding had a major impact on yield improvement since a modern agriculture began. The existence of data collected over long period of time offers a unique opportunity to evaluate the influence of these parameters on yield pattern over time (Michelle et al., 1991). Spatial distribution and temporal dynamics of crop production are generally dependent upon environmental factors including climatic conditions, soil properties and farm practices.

Spatial variability technique has been used extensively in recent years in soil studies. Rochkstrom et al., (1999) reported that the landscape position related factors dominated yield variability and caused similar yield gradients along the slope. Orum et al., (1999) reported their work on spatial and temporal distribution in Aspergillus flavus strains composition in Yuma County (soil inhabiting fungus that produces aflatoxin in cotton seeds).

Fractal analysis helps us make a distinction between short-term and long-term variation for data collected in space or time (Eghball et al.1995). A comparison between ten crop yield from 1930-1990, Eghball et al., (1995) indicated that the crop which had the lowest year to year variation was rice while oat and soybean showed a greatest short term variation.

The production cost continue to increase while yield in Arizona as well as in cotton Beltwide tends to level off (Silvertooth 2000, personal communication) causing reduction in a profit margin for cotton growers. Eghball et al., (1995) studied the variability pattern of US 10 major crops. They found that the variability pattern was related to crops. We need to have an understanding how variability pattern is affected by the geographical locations in the state. The objective of this investigation is to describe the cotton variability pattern between eight counties in Arizona.

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Materials and Methods

Average yield of upland cotton (Gossypium *hirsutum* L.) and Pima cotton (Gossypium *barbadense* L.) was obtained from information provided in the USDA's *Agricultural Statistics* (USDA,1935-1999) to characterize yield variability. US and state average and Mohave, Yuma, Pinal, Cochise, Pima, Maricopa, Greenlee, Graham counties, Arizona for Upland and Cochise, Yuma, Pinal, Pima, Maricopa, and Graham counties, Arizona for Pima cotton were selected to characterize yield variability. These counties produce over 85% of the state upland cotton and 89% of the state Pima cotton.

Upland and Pima cotton vs years was plotted to (Fig. 1, 3 and 4). Regression coefficients were determined using proc. Reg (SAS version 7). These cotton yield values were used to characterize yield variability from 1935 to 1999 using semivariogram (Eghball and Power, 1995; Clark, 1979; Cressie, 1991) and fractal analysis (Eghball and Power, 1995).

Semivariogram

Equation $_h$ = (Xi-Xi+h)/2(n-h) Eq.1

is used to calculate the semivariogram (•) for the averaged yearly yield (1935-1999) Where and X_{i+h} are yield values separated by h and n is the number of points; n-h is the lag (the number of intervals. Iterations were performed using GS+ (Gamma Design) software.

Fractal analysis

- Fractal dimension often called characteristic dimension D defined D= 2- ½ [(log(semivariogram) vs log (lag H)] Eq.2 .

Results and Discussion

The average yield in Arizona and US (Fig.1) shows that yield increased from 1935 to 1990. The increase was more so for Pima cotton. The yield increase was the result of to advances made in education, agricultural practices and technologies.

In eight individual Arizona counties studied for upland cotton has increased two to three folds from 1935 to 1999 (Fig. 3 and 4). Conclusions made for AZ and US cotton yield apply to individual counties, the largest increase occurred from 1960-1990.This rapid increase in yield may be attributable to new varieties, more efficient cropping systems and irrigation technology. During the same period, Yuma, Maricopa, and Pinal Counties recorded the highest yield increase to the current yield average of 1154, 1141 and 1091 kg ha^{-1} for Upland respectively (Table 1). The averaged yield for Pima cotton in these three counties is 821, 709, 702 kg ha^{-1}, respectively (Table 2).

In these three counties, growers are planting more lucrative vegetable crops that allow them to invest in new machinery, irrigation and land management. However, the rate of yield increase that occurred earlier tended to level off. The combination of several parameters may be responsible for this leveling off in yield. Plant diseases, insect damages associated with climatic variation may be responsible.

But there is also the fact that market prices have been low in recent years, this suggests perhaps that cropping management has been focused on more lucrative crops which became dominant crops: cotton is planted early, defoliated and harvested early in order to accommodate the fall planting of vegetables. One of the yield components is the individual fiber weight, which can be directly associated with micronaire (Silvertooth, personal communication, 2000). According to Dr. Silvertooth the trend toward high micronaire is related to genetics, environment and crop management.

Fractal Analysis

Fractal analysis was used to describe yield variability pattern of Pima and Upland cotton in Arizona. Fractal dimension D varies from 1to 2 scale (Mondelbrot 1988). A small D-value approaching is an indication of long-term dominance variability. In contrary a large D-value near 2 indicates short term dominance variation (Eghball 1995).

Long-term dominance variation can be associated with the adoption of new technologies, changes in cultural practices, plant breeding and pest control. A short-time dominance variation can be associated with climatic variation between seasons.

The results of the semivariogram are given in Table 3 and Fig. 2, 5 and 6. These results are used to calculate the fractal dimension (D), which is a measure of noise in temporal variability. The fractal dimension is used to compare yield variability pattern of cotton in different counties in Arizona. Slopes in table 3 tend to be higher while fractal dimensions tend to be smaller in Yuma, Maricopa and Pinal counties as compared to the slopes obtained in the remaining counties. In these three counties there has been trend toward dominance of vegetable industry over time. The more lucrative vegetable industry allowed growers to invest in new machinery, land management and irrigation technology. Growers perhaps feel more comfortable in adopting new technology and new cultural practices.

Conclusion

Data provided by USDA's. Agriculture Statistics was used to describe yield variability pattern in the USA and Arizona from 1935 1999. Yield from 1935 to increased more than three folds as results of new varieties, fertilizer, pesticide use, irrigation an land management.

Linear regression, semivariogram and fractal analyses were used to describe the trend in yield and variability pattern in 65 years. Small D-values were observed in Yuma, Maricopa and Pinal counties indicating long term-variability associated with the adoption of new cultural practices over time. Large D-values in the remaining counties indicate a long term-variability. A short term-variability is associated with environmental phenomenon. These results are similar to those existing in literature (Eghball and Power, (1995), Eghball and Varvel (1997).

Fractal analysis appears to be a useful tool to quantify temporal variability. It has a potential application for agronomic research and production in assessing variability in soil and plant parameters.

Table 1. Regression coefficients of effect of time on Upland cotton and average yield of six Arizona counties from 1935 to 1999.

County	Intercept	Linear	Quadratic	R^2	CV	Mean Kg ha^{-1}
Yuma	19.25	59.40^{***}	-0.596^{***}	0.745	19.46	1154
Maricopa	306.09^{***}	0.41^{***}	-0.408^{***}	0.798	12.79	1141
Pinal	322.43^{***}	37.36^{***}	-0.336^{***}	0.738	15.23	1091
Pima	705.47^{***}	7.81^{*}	0.012	0.565	13.43	983
Graham	647.23^{***}	8.34^{*}	-0.020	0.472	14.33	897
Cochise	161.48^{*}	29.73^{***}	-0.324^{***}	0.453	26.53	693

$^{*, **, ***}$ Significant at the 0.1, 0.05 and 0.01 probability level, respectively.

Table 2. Regression coefficients of effect of time on Pima cotton and average yield of six Arizona counties from 1935 to 1999.

County	Intercept	Linear	Quadratic	R^2	CV	Mean
Yuma	-15.12	27.08 ***	-0.127 ***	0.821	20.50	821
Maricopa	98.67	24.89 ***	-0.169 *	0.690	22.00	709
Pinal	89.34	24.85 ***	-0.167 **	0.688	22.50	702
Graham	296.22 ***	13.75 ***	-0.072	0.591	18.97	660
Pima	237.42 **	21.89 ***	-0.236 **	0.422	21.58	646

*,**,*** Significant at the 0.1, 0.05, 0.01 probability level, respectively.

Table 3. Slope ($_h$) of regression line of log semivariogram vs log interval (year) and fractal dimension (D) of upland and Pima cotton, recorded in Yuma, Maricopa, Pinal, Cochise, Pima, Graham and Greenlee counties from 1935 to 1999.

	Upland		Pima	
County	$_h$	**D**	$_h$	**D**
Yuma	0.9450	1.527	1.085	1.457
Maricopa	1.0536	1.473	0.9140	1.543
Pinal	0.9845	1.508	0.9392	1.530
Cochise	0.6197	1.690	0.4381	1.781
Pima	0.5856	1.707	0.9996	1. 722
Graham	0.5940	1.794	0.684	1.556
Geenlee	0.6294	1.685	Parameters $_h$ and D for Pima Cotton: not estimated.	
Mohave	0.2150	1.892		

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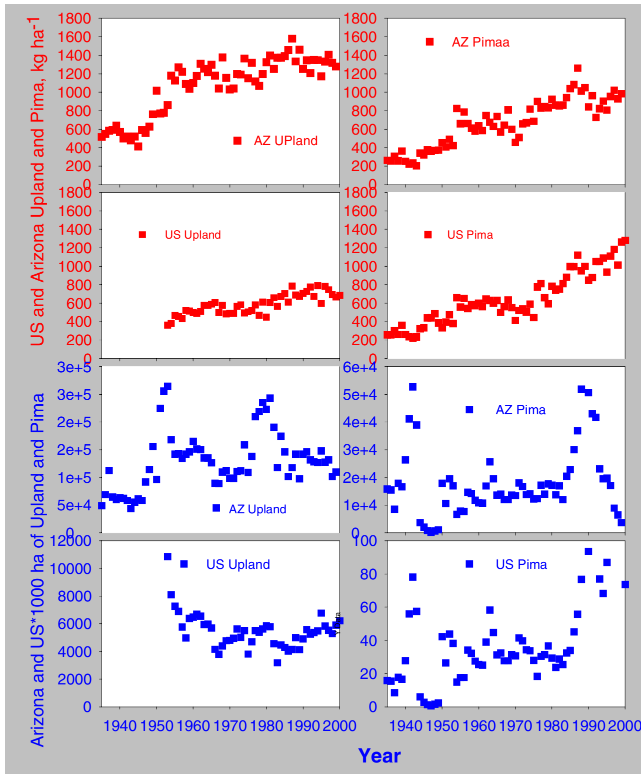

Figure 1. AZ and U.S. Upland and Pima cotton yield and area cropped to cotton from 1935 to 1999. (USDA Agric. Stat. 1999)

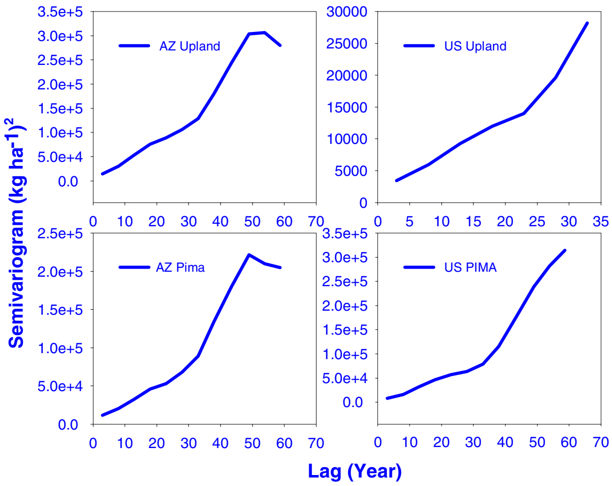

Figure 2. Semivariogram for the average Upland and Pima cotton yield for the state of Arizona the U.S. from 1935 to 1999. Note U.S. Upland cotton yield semivariogram was calculated for only a lag of 33 (year).

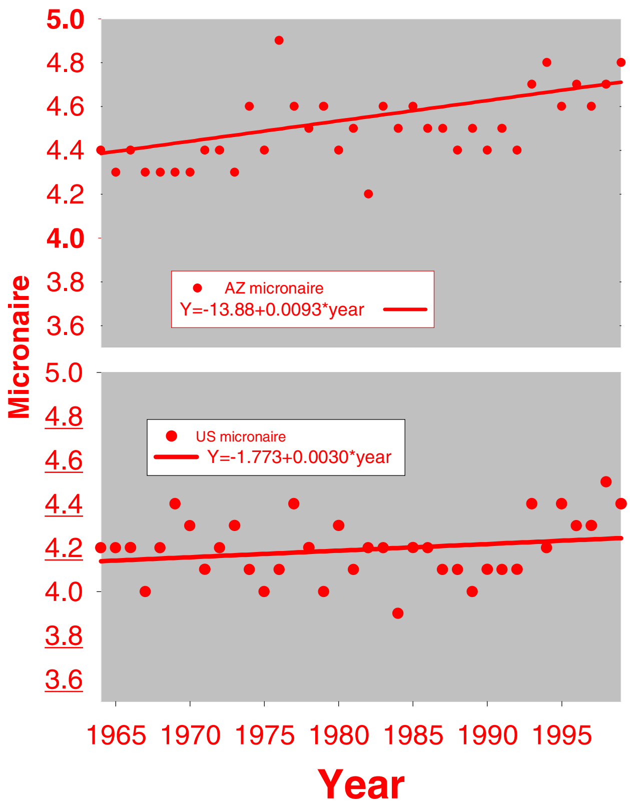

Figure 3. Average Micronaire of Arizona and U.S. from 1965 to 1999.

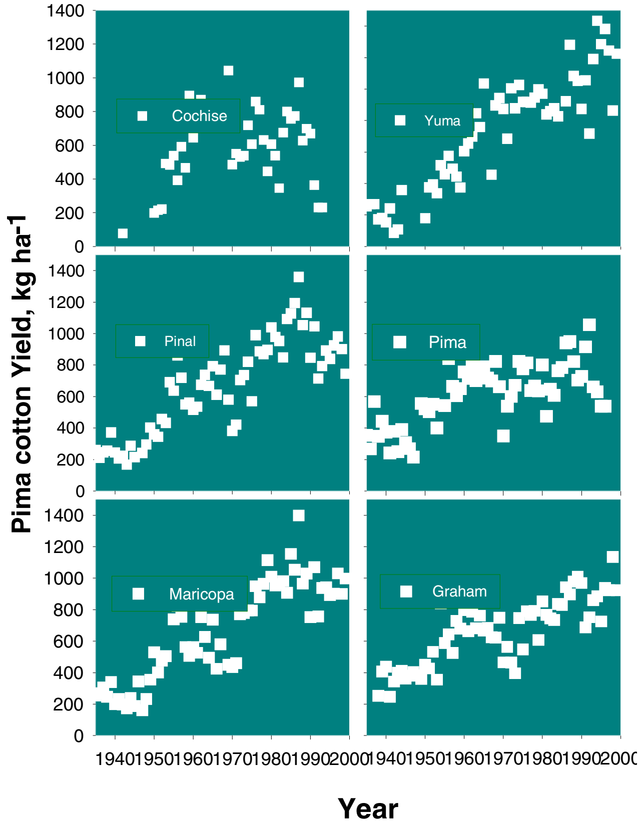

Figure 4. Pima Cotton yield from Cochise, Yuma, Pinal, Pima, Maricopa, Graham Counties, AZ from 1935 to 1999 (USDA Agric. Stat. 1999).

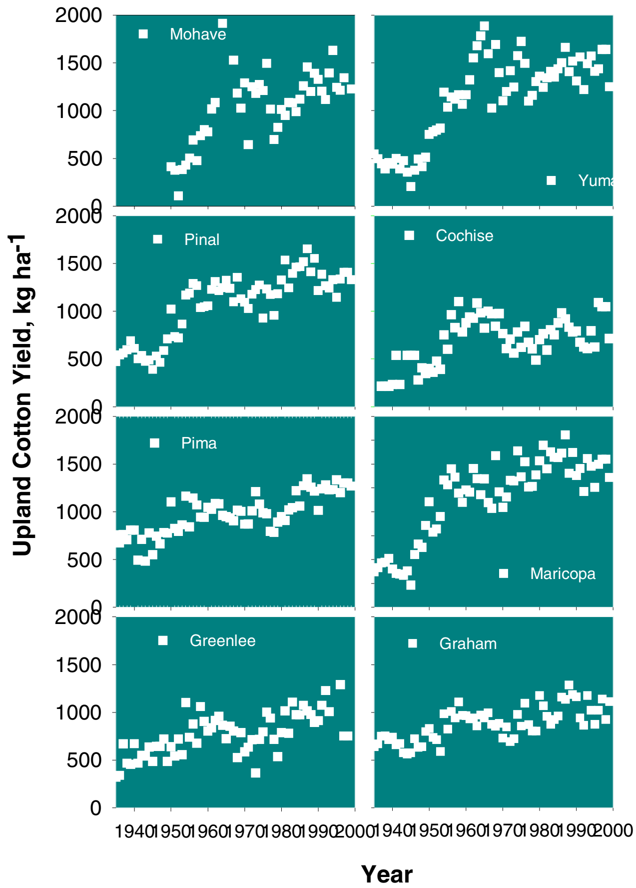

Figure 5. Average upland cotton yield for Mohave, Yuma, Pinal, Cochise, Pima, Maricopa, Greenlee, and Graham counties from 1935 to 1999 (USDA Agric. Stat. 1999).

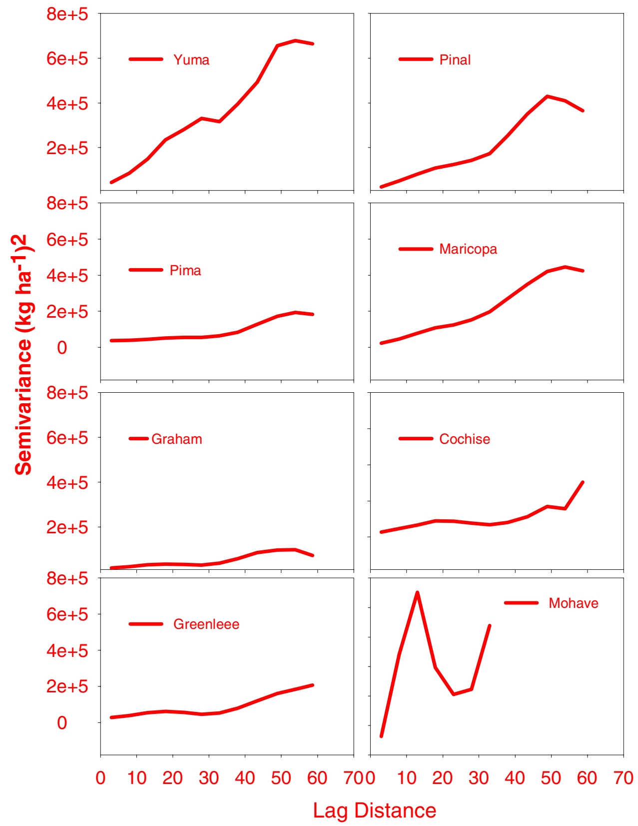

Figure 6. Semivariogram for the average Upland cotton yield for Yuma, Pinal, Pima, Maricopa, Graham and Cochise, Greenlee, Mohave counties AZ from 1935 to 1999.

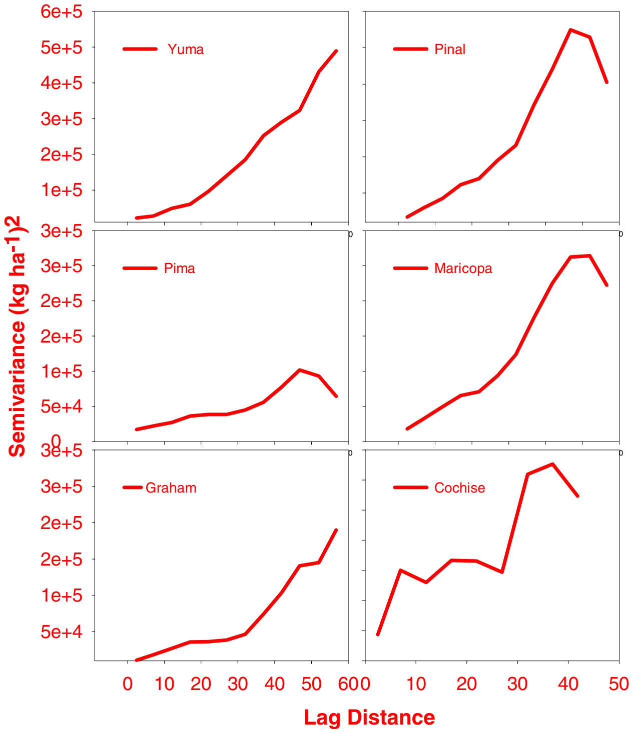

Figure 7. Semivariogram for the average Pima cotton yield for Yuma, Pinal, Pima, Graham, and Cochise counties AZ from 1935 to 1999.