# HISTORICAL TRENDS IN SOIL AVAILABLE PHOSPHORUS ACROSS ALBERTA[1]

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## ABSTRACT

Changes in agricultural practices have occurred over time and across Alberta. It is timely to assess if those changes have affected the amount of soil P. Alberta soil test results from 1963-67 and 1993-97 were analyzed to determine levels of available soil P across Alberta on an ecodistrict basis and to determine changes in available soil P that occurred over time. Soil available P for dryland annual crops did not change in 20 ecodistricts, increased in 15 ecodistricts, and decreased in 27 ecodistricts. Soil available P for dryland perennial crops did not change in 24 ecodistricts, increased in 7 ecodistricts, and decreased in 9 ecodistricts.

## INTRODUCTION

In recent years there has been growing attention to agricultural practices associated with the application and movement of soil phosphorus. The use of fertilizer has increased almost every year since 1945 (Goettel, 1987). Phosphorus fertilizer is added to the soil to provide an adequate supply of this essential nutrient to the crop. Phosphorus is essential for plant life and it ensures a series of functions ranging from the primary mechanisms for energy transfer to the encoding of genes (Wallingford, 1978). Phosphorus is removed from the soil by plant uptake. Different crops remove different amount of P from the soil. Because agricultural practices across the prairies regions have been changing over time it is timely to assess how the use of fertilizer is reflected in the amount of available P found in the soil. Although we recognize the importance and complexity of the different P forms found in the soil our discussion focuses on the form of soil P that is readily available for plant uptake and extractable using common tests employed by laboratories in Alberta. Because of the amount of available data measured from producer supplied samples and the scale of interest (ecodistrict level), an interactive GIS database was developed. This system provides an effective way to store and analyze large amounts of spatial and tabular data needed for the analysis (Schreier *et al.*, 1999)

## METHODOLOGY

We compiled a database with more than 100,000 phosphorus records for the agricultural areas of Alberta based on producer supplied samples. Data were extracted from two different databases that were compiled originally by the Soil and Feed Testing Lab[6] of the Alberta Agriculture Food and Rural Development (AAFRD) and by Norwest Labs (Edmonton, AB). In this paper we present an analysis of change in soil available phosphorus across Alberta using a portion of this database. We selected two five-year time periods 1963-67 and 1993-97 for comparison. Data recorded over the 1963-67 time period were obtained using the Miller and Axley method (Miller and Axley, 1956), while the data recorded during the 1993-97 time period were obtained using the Norwest modified Kelowna method (Ashworth and Mrazek, 1989). In order to reconcile the discrepancy in the measuring protocol we performed a simple regression analysis (SAS, 1990) using data collected by McKenzie *et al.* (1995). In their study, soil available P was measured for the same soil sample using a series of different extraction methods (McKenzie *et al.*, 1995). For our analysis we selected the measurements obtained using the Miller and Axley and the Norwest modified Kelowna methods. Because of the pH effect upon availability and extractability of P in the soil the data were stratified by three pH classes: acidic (<6.0), neutral (≥ 6.0 and < 7.5) and alkaline (>7.5).

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The intercept, coefficient and $R^2$ listed in Table 1 were used to adjust the measurements obtained using the Miller and Axley method to the Norwest modified Kelowna method. Student's *t* test was used to evaluate the difference between the means of ecodistricts. Displaying of this analysis, and of the calculated mean P concentration per ecodistrict was achieved using ArcView GIS 3.2 (ESRI Inc. Redlands, CA USA).

**Table 1.** Parameters of the regression analysis used to adjust the Miller and Axley method to the Norwest modified Kelowna method (data set from McKenzie *et al.*, 1995).

| | pH<6.0 | pH (≥ 6.0 and < 7.5) | pH >7.5 |
|---|---|---|---|
| INTERCEPT | 2.42 | 1.79 | 0.88 |
| COEFFICIENT | 0.81 | 0.96 | 4.87 |
| $R^2$ | 0.88 | 0.89 | 0.66 |
| N | 81 | 169 | 18 |

## RESULTS AND DISCUSSION

Spatial distribution of the mean available phosphorus concentration for an ecodistrict, varied across Alberta depending on the previous cultivated crop, i.e., annuals vs. perennials (Fig. 1a and 1b vs. Fig. 2a and 2b). Soil test P status for dryland annual crops has changed in most ecodistricts over the last 30 years (Fig. 3a). P for dryland annual crops did not change in 20 ecodistricts, increased in 15 ecodistricts, and decreased in 27 ecodistricts ($p>0.05$). Concentration of soil available P for dryland perennial crops did not change in 25 ecodistricts, increased in 7 ecodistricts, and decreased in 9 ecodistricts (Fig. 3b).

Historically the use of commercial fertilizer in both the U.S. and Canada increased during the 1950s, 1960s and 1970s primarily by higher application rates. An analysis of the data provided by Agriculture and Agri-Food Canada (Korol and Rattray, 1999) reveals that the phosphate sales in Alberta has increased at a lower rate than nitrogen sales. In particular, phosphate sales doubled from 1968 to 1998 while nitrogen sales increased 5 times over the same period. These data represent the volume sold by retailers within Alberta, and do not include inter-provincial purchases of fertilizers therefore these figures may not correspond exactly to the whole consumption (Korol and Rattray, 1999). In the attempt to link the changes in available soil P and the trend in fertilizer sales a more a complex data analysis should be carried out. A statistically significant decrease in P concentration for soils cultivated with annual crops, is located in the central part of the province while ecodistricts with a significant increase are more concentrated in the south (Fig. 3a). No regional trend is found in the distribution of those ecodistricts that had changes over time that were statistically non-significant. The number of ecodistricts that experienced no change for the perennial crops is evenly distributed across the province (Fig. 3b). Although a number of co-occurring factors should be considered it is possible that a higher use of N fertilizer results in a higher biomass per $m^2$. Therefore, if the amount of applied P fertilizer is not proportionally increased the net uptake of P per volume of soil increases because of the higher amount biomass produced causing a decrease in soil available P.

Regional estimates of available soil phosphorus indicate where application of P fertilizer might result in potential yield responses. When the soil available P concentration is less than 25 ppm an additional amount of P could result in higher yield (Tisdale *et al.*, 1993). Our findings reveal that for the 1993-97 time period, 45 ecodistricts for the annual and 34 for the perennial crops had a soil P concentration equal or lower than 25 ppm. This analysis allows mapping of the macro scale scenario of Alberta and it indicated that a high portion of land that is cultivated with perennial and annual crops may respond to higher P fertilizer application. Our findings however cannot be used to directly infer future yields as function of increased fertilization in those ecodistricts. Instead, a more refined analysis with the objective of verifying the potential for crop response at the field level should be implemented. For example, the current analysis of available soil P could be combined with a crop modelling exercise to include the potential effects of soil type, management and climate that are found in particular ecodistricts. Although model simulations provide results that resemble and not necessarily reproduce exactly the full field conditions, this methodology allows the evaluation of the relative responses as a function of different management practices. Other investigators used this approach to evaluate the general crop response to change in boundary conditions such as climate (Izaurralde *et al*., 1999; Phillips *et al*., 1996). A preliminary regional assessment of the potential increase in crop productivity as a result of more P application could be obtained through the use of similar models. However, our approach is meant to support regional assessments and not to replace detailed field testing procedures used to formulate recommendations that apply at a more detailed scale (e.g., single field). Regardless, our analysis shows that currently there are large areas of Alberta that have low to moderate soil P levels and soil testing is required to develop a nutrient management plan to encourage optimum economic crop production. Our mapping also identified areas across Alberta that could be considered during the development of nutrient management strategies. Elsewhere technical and institutional components have been considered during the development of nutrient management programs (Daniel *et al*., 1997). Among the wide variety of technical issues we identify the status of soil phosphorus levels to be a crucial one.

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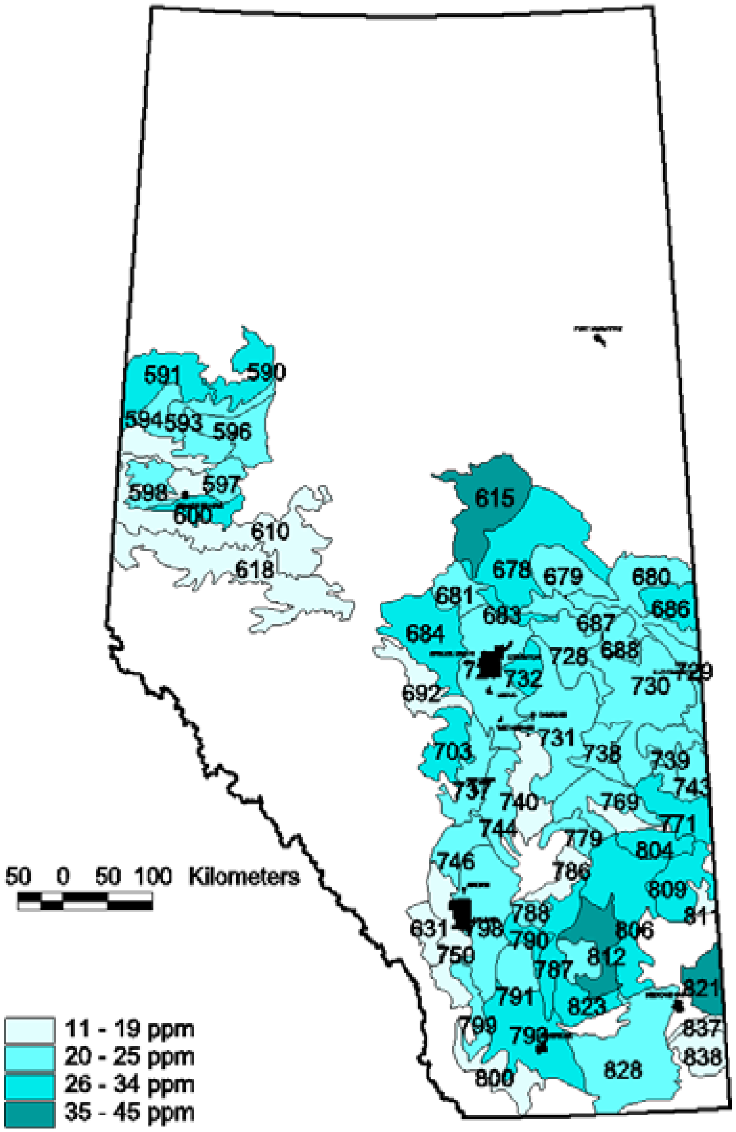

Figure 1a. Available P for non-irrigated annual crops from 1963-1967.

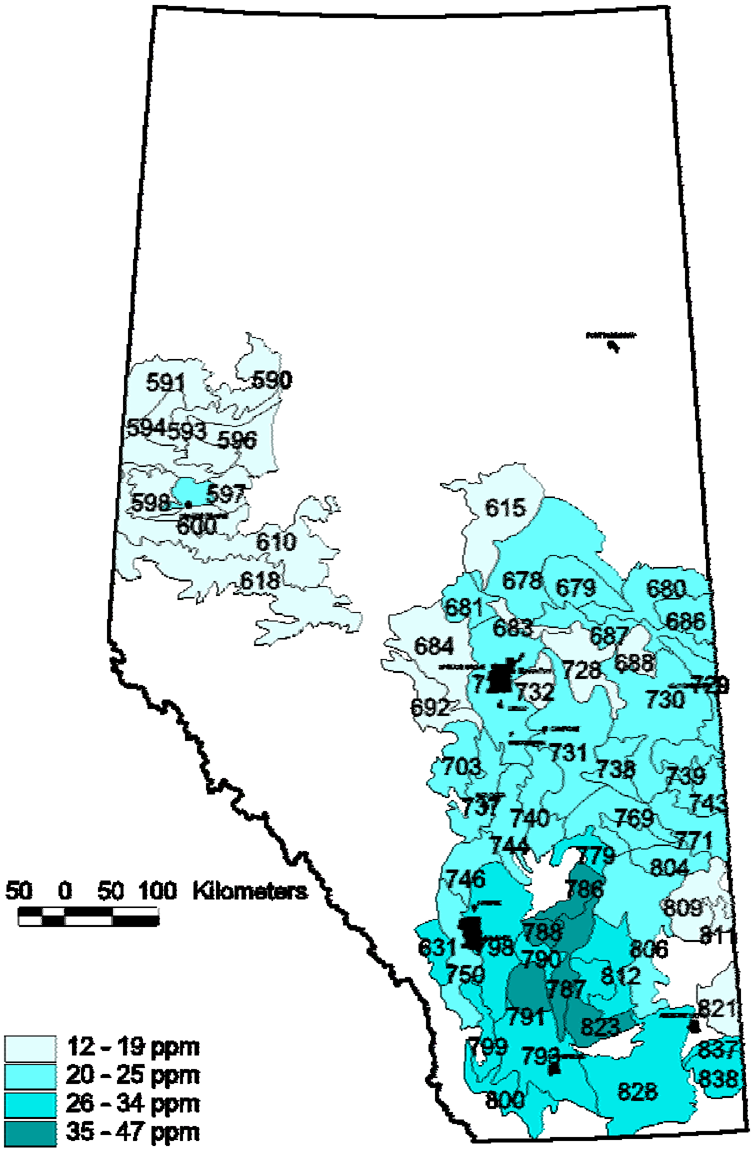

Figure 1b. Available P for non-irrigated annual crops from 1993-1997.

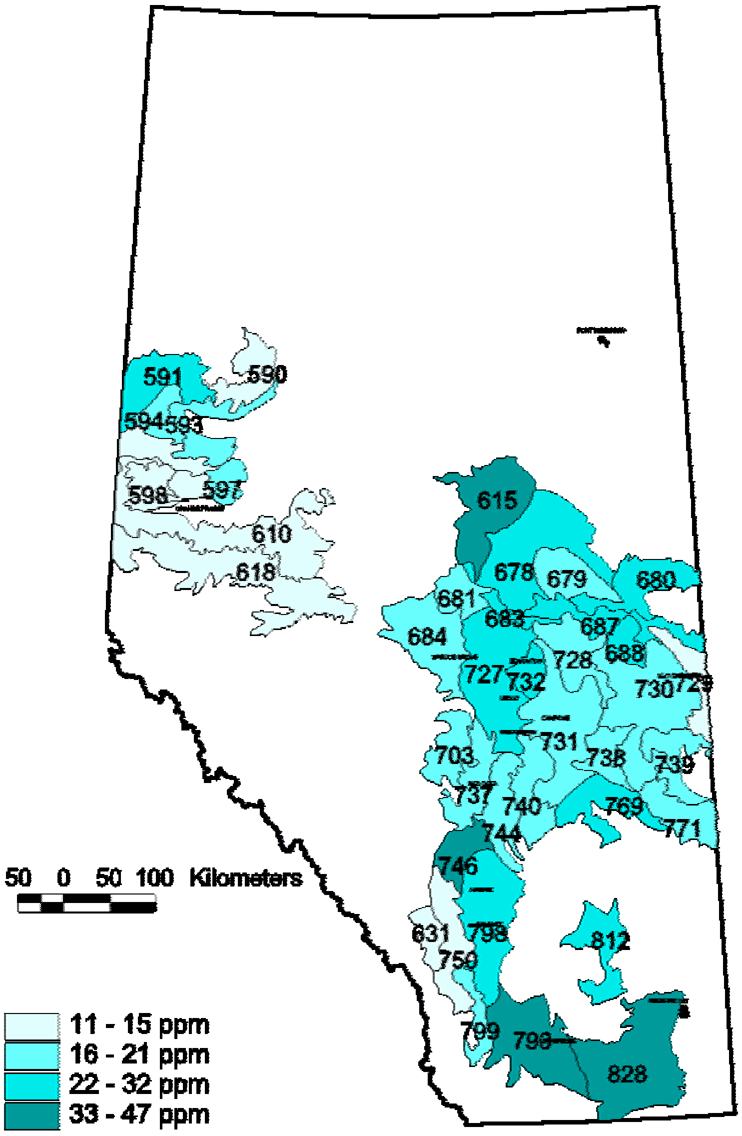

Figure 2a. Available P for non-irrigated perennial crops from 1963 to 1967.

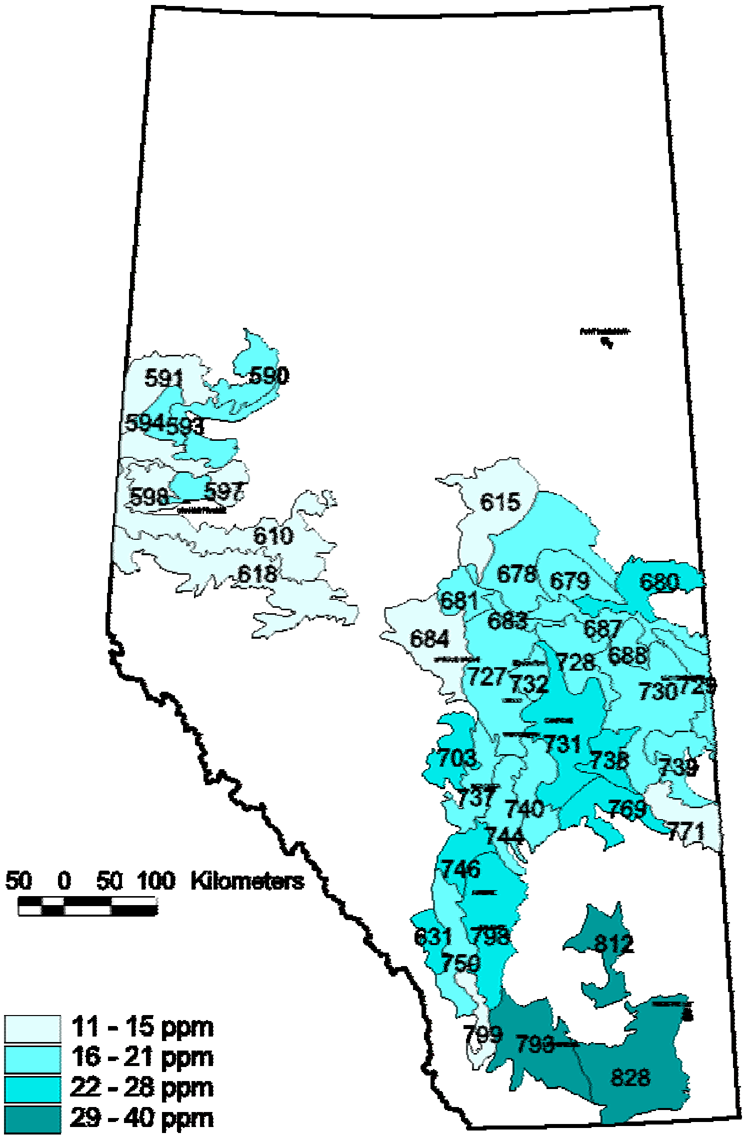

Figure 2b. Available P for non-irrigated perennial crops from 1993 to 1997.

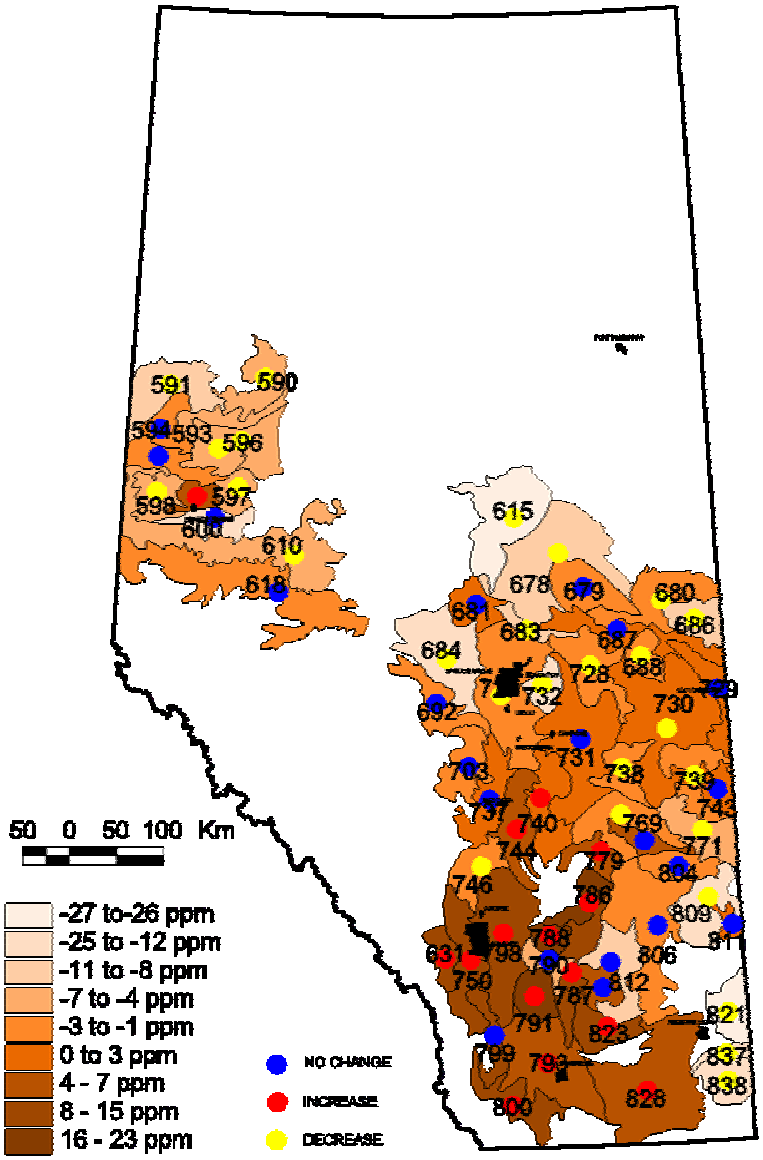

Figure 3a. Changes in available P for non-irrigated annual crops (1963-67 vs. 1993-97), (p>0.05)

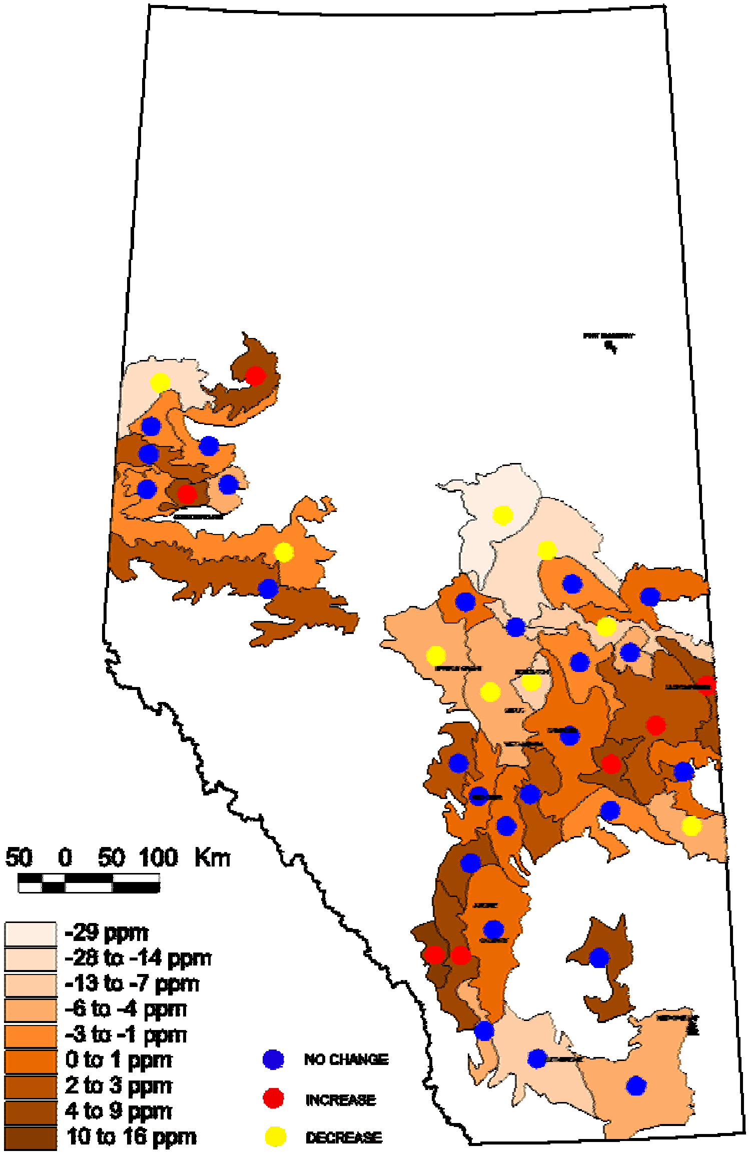

Figure 3b. Changes in available P for non-irrigated perennial crops (1963-67 vs. 1993-97), (p>0.05).