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RESPONSE OF SOIL ORGANIC MATTER TO CROP MANAGEMENT

Semiarid Prairie Agricultural Research Centre

(SPARC)

Swift Current, Saskatchewan

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INTRODUCTION

The main goal of crop rotation studies is usually to determine the most efficient and economic system for producing food and fibre products. But, if they are of sufficient duration, they can answer important questions related to soil and water quality, soil productivity, and soil conservation. Scientists with Agriculture and Agri-Food Canada have been conducting crop rotation studies on the Canadian prairies since the 1890s. During this period, more than 68 separate studies have been initiated, but less than 20 are on-going. The Swift Current "old rotation experiment", which was established in 1967, is the most comprehensive research effort of its type, and is the only ongoing rotation study in the Brown soil zone of western Canada. It involves the input of soil scientists, hydrologists, agronomists, plant scientists, agrometeorologists, microbiologists, economists, and others. The data and information generated by this study reflect the combined performance from using the generally recommended production technologies and practices with respect to crop varieties, soil management techniques, fertilization, and herbicide use. The results have been extremely valuable, providing producers in the semiarid prairie of southwestern Saskatchewan and southeastern Alberta with the necessary information to make decisions on rotation lengths, crop types and sequences, and fertilizer use practices that maximized economic returns. The experiment also provides scientists with an important historical data base on which to determine and compare short-term and long-term consequences of rotation length, summerfallow substitute crops, and N and P fertilizers on crop yields, grain protein, N and P uptake by the plants, and on changes in soil chemical, physical, and biological properties. Further, it provides scientists with a base to explain or model soil-plant-weather interactions and the reasons for departures from the expected or normal behavior.

One of the most recent concerns of Canadians is the phenomenon of global warming and the so-called "greenhouse effect". A significant factor related to the latter is carbon (C) dynamics and consequently soil organic C. Fortuitously, the latter is one of the soil components that we have monitored in our rotation study, almost from its inception (Campbell and Zentner 1993). In this report we summarize and discuss some of our findings regarding the influence of the rotations on soil organic C and total N in the 0- to 15-cm depth of soil up to 1993. Changes were minimal in the 15- to 30-cm depth. *[Note: The following abbreviations apply throughout: F = summerfallow, W = hard red spring wheat, Flx = flax, Rye = fall rye, Lent = grain lentil, Cont = continuous cropping, N + P refer to application of nitrogen and phosphorus fertilizers].*

RESULTS

Statistical analyses of the data showed significant effect of the various rotation and fertilizer treatments on organic C and total N in the 0- to 15-cm depth of soil. However, there was no significant effect of time (between 1976 and 1993) on C, though there tended to be an interaction between treatment and sampling time ($P < 0.17$) on total N.

Effect on Average Organic C and Total N

The land on which this test was set up in 1967 had been in fallow-wheat (F-W), mostly receiving 11-48-0 for most of the previous 30 to 40 years. Therefore, if we assume that organic C and total N for F-W (N + P) were in a steady state, then we can conclude that F-W-W (P) and Cont W (P) have maintained organic C over the years, while F-W-W (N) (received no P in 26 yr) and F-flax-W (F-Flx-W) (N + P) have both resulted in decreased organic C (Fig. 1a). The decrease in C due to witholding P from F-W-W was 2.1 Mg ha^{-1} and for F-Flx-W (N + P) it was 3.6 Mg ha^{-1}. The

Fig 1(a). Organic C in 9 cropping systems at Swift Current
(averaged over 28 yr period)

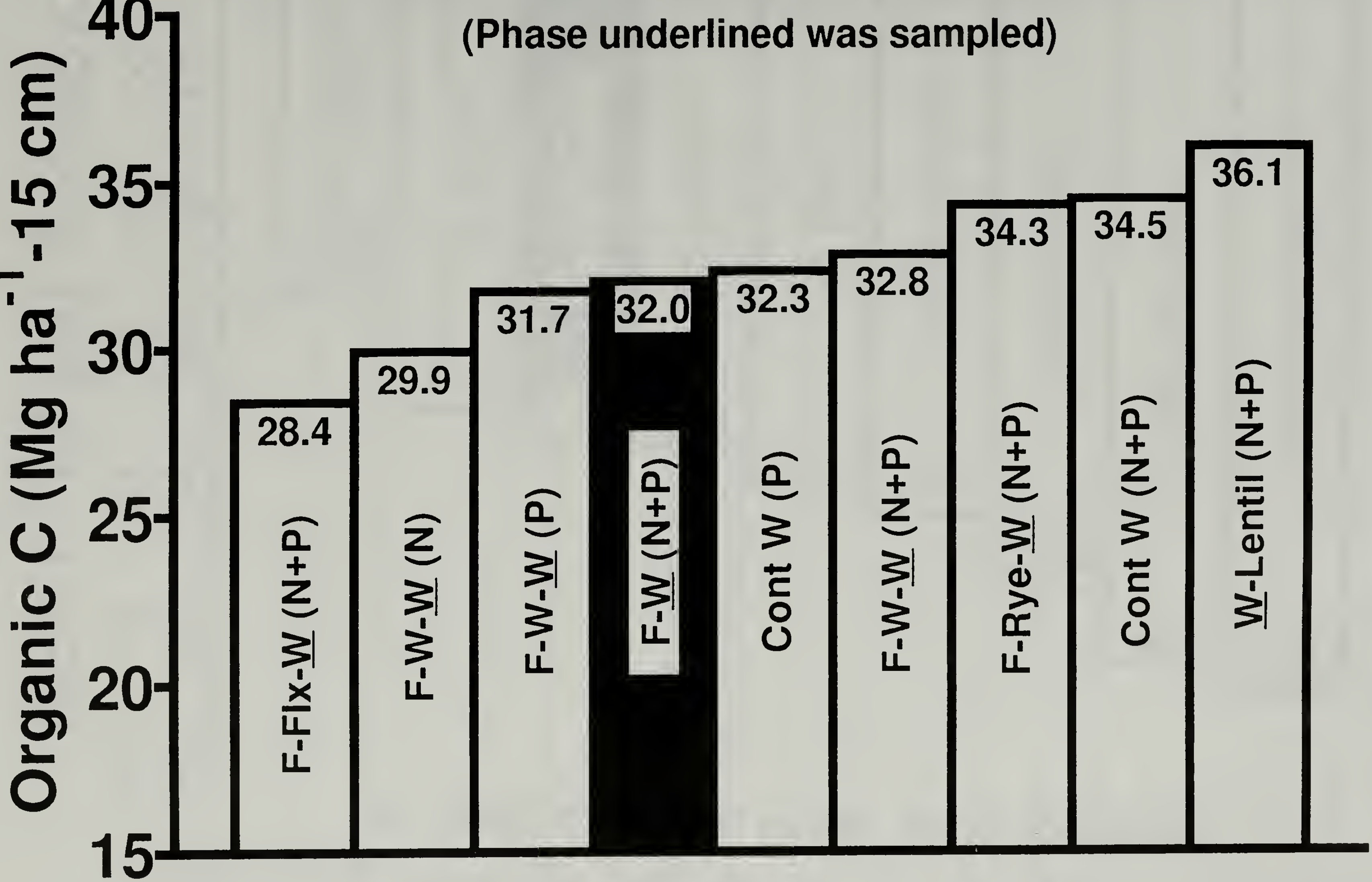
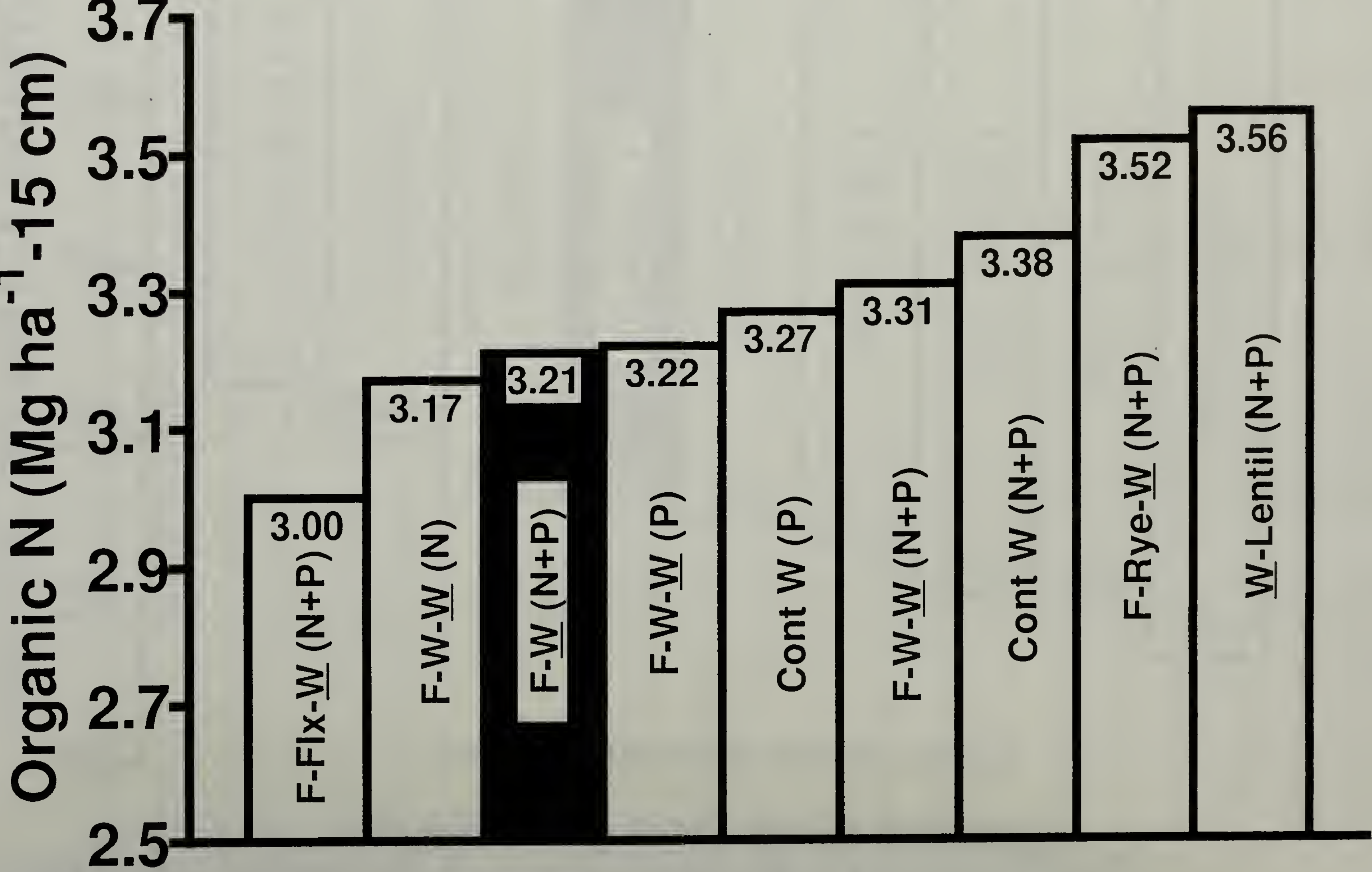


Fig 1 (b) Average organic N in 9 cropping systems at Swift Current (over 28 yr period)



flax provides less residues than wheat and its residues are much more difficult to decompose; they also tend to blow off the field (Campbell and Zentner 1993). The positive influence of fertilizer and cropping frequency resulted in a slight increase in organic C (0.8 Mg C ha^{-1}) for F-W-W (N + P) compared with F-W (N + P). Further, when a fall-seeded cereal replaced one year of spring-seeded cereal in the 3-yr rotation, there was significant improvement in C, with a gain of 2.3 Mg C ha^{-1} for F-Rye-W (N + P) compared with F-W (N + P). A similar increase was experienced when the land was cropped annually and properly fertilized [Cont W (N + P)], presumably due to greater inputs of crop residues and less frequent tillage. But, the greatest increase in C was obtained by including a lentil pulse crop in rotation with wheat [W-Lent (N + P)] [this was done starting in 1979 on land that was Cont W (N + P) from 1967-1978]. The lentil system gained 4.1 Mg C ha^{-1} compared with F-W (N + P). The results for total N (Fig. 1b) generally mimicked those for organic C. On a relative basis [compared to F-W (N + P)], we can expect the well-fertilized F-Flx-W system to reduce organic C and total N by about 10% (Table 1). Inclusion of a fall-seeded cereal instead of spring-seeded cereal in a well-fertilized system will increase organic C and N by about 6%. Annual spring cereals with proper fertilization will increase organic C and N by about 9%, and alternating spring wheat with grain lentil in a well-fertilized continuous cropping system will increase them by about 12%.

Changes in Organic C and Total N Over Time

Although the variance analysis showed time was not significant, there were some trends with time for some treatments, particularly for total N. Thus, we examined some apparent treatment effects over time.

Table 1. Organic C and total N stored in 0- to 15-cm depth over 28-yr period - Values[z] relative[y] to F-W (N + P) = 1.0

	Relative Ranking	
Rotation and fertilization	C	N
F-W (N + P)	1.00	1.00
F-Flx-W (N + P)	0.89	0.93
[x]F-W-W (N)	0.93	0.99
F-W-W (P)	0.99	1.00
[x]Cont W (P)	1.01	1.02
[x]F-W-W (N + P)	1.03	1.03
F-Rye-W (N + P)	1.07	1.05
[x]Cont W (N + P)	1.08	1.10
W-Lent (N + P)	1.13	1.11

z Values averaged over sampling time which was not significant ($P < 0.10$).

y This land was cropped to F-W for the previous 30-40 yr before rotation experiment initiated.

x Rotations sampled by U.S. Environmental Protection Agency in 1993.

(i) Effect of fertilizer

Despite some "noise" in the organic C results (Fig. 2a) and, to a lesser extent, for total N (Fig. 2b), there is no doubt that proper fertilization has maintained organic C and total N at higher levels in F-W-W systems than in absence of N or P. No doubt this is related to reduced yields and thus crop residue input (5% less yield when no N applied and 10% less yield when no P applied for the stubble crop).

In the Cont W system, applying N and P increased organic C and total N for the first 15 yr, but severe drought in 1984, 1985 and 1988 resulted in crop failure for stubble crops. Since then, Fig 2(a). Effect of N and P fertilizer on C in 0-15 cm depth of a fallow-wheat-wheat rotation at Swift Current

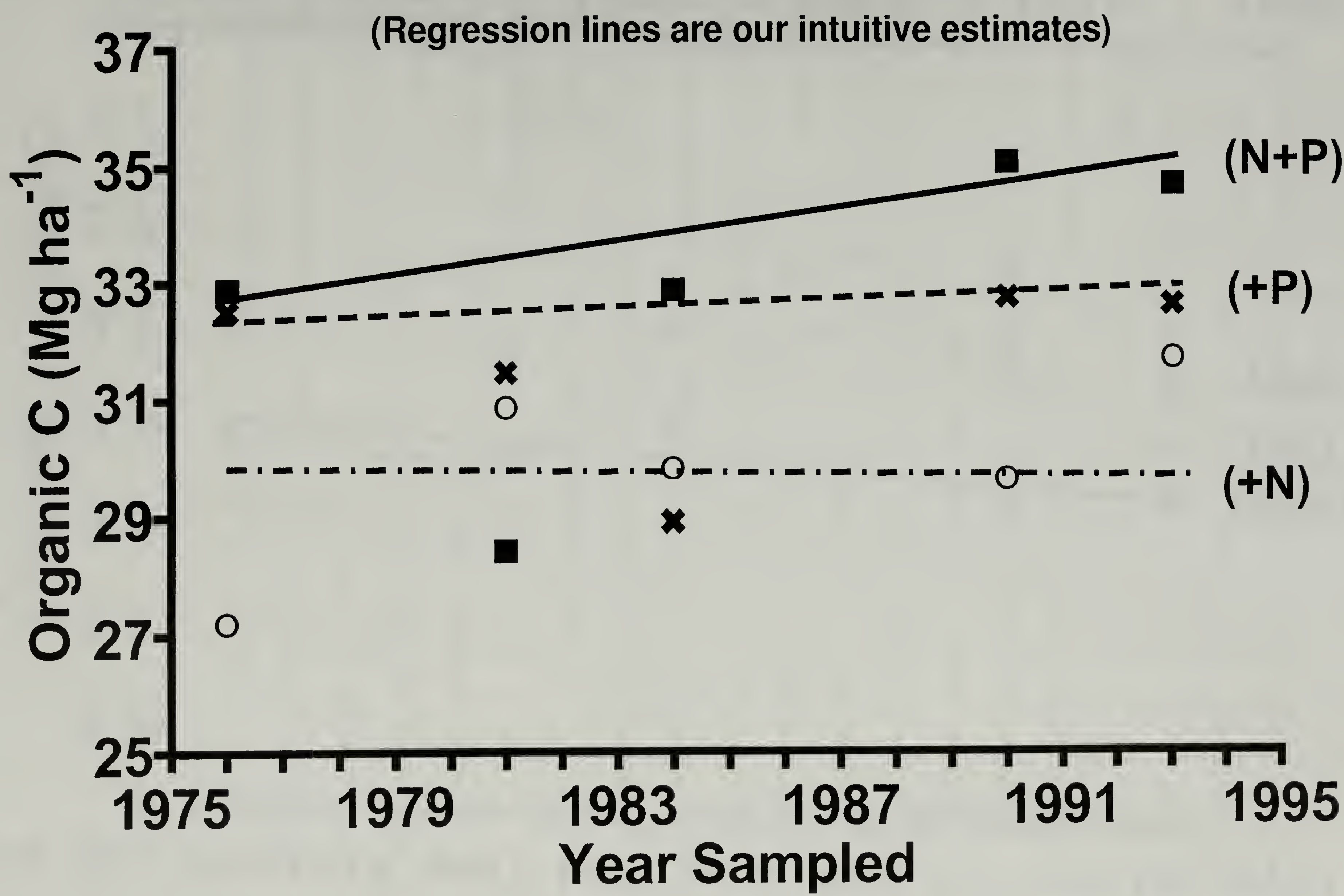
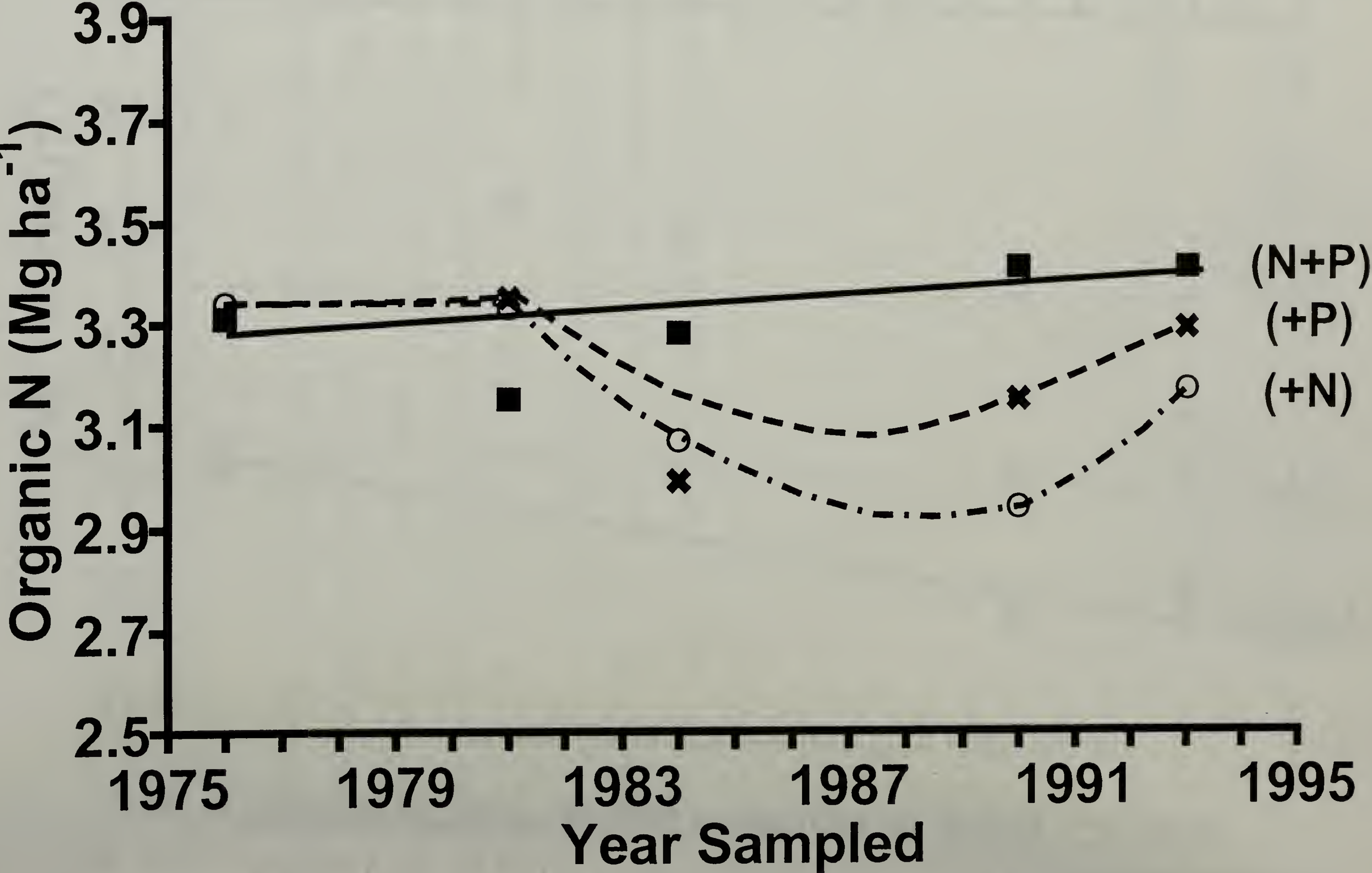


Fig 2(b). Effect of N and P fertilizer on total N in 0-15 cm depth of a fallow-wheat-<u>wheat</u> rotation at Swift Current



organic C and total N has dropped and has remained low, being similar to that for Cont W receiving no N (Fig. 2c and 2d). This latter behaviour is surprising because yields since 1989 have been significantly higher for the well-fertilized system.

(ii) Effect of crop type

Unquestionably, the presence of flax in a rotation, replacing spring wheat, gradually decreases organic C and total N, while the fall-seeded cereal gradually increases them (Fig. 3a and 3b). Campbell and Zentner (1993) have discussed possible reasons for these trends, including more efficient use of N by fall rye and less efficient use of N by flax; the lower crop residues and less decomposable nature of flax compared with wheat, and the tendency for flax straw to bunch up and blow off the fields after harvest. The grain lentil took a few years to provide a positive influence on organic C and total N (Fig. 3c and 3d). This increase was despite W-Lent providing less C inputs than Cont W because lentil produces less crop residues than wheat (Campbell et al. 1992). However, because of the much narrower C/N ratio of the lentil residues this material would be more efficiently used by microorganisms to build soil organic matter (Biederbeck et al. 1996).

(iii) Effect of cropping frequency

Both the organic C and total N data were "noisy" in this comparison (Fig. 4a and 4b). Nonetheless, based on our best estimate, organic C and total N increased slightly in the well-fertilized F-W-W (N + P) while the opposite was the case in the F-W (N + P) system. Well-fertilized Cont W, though much higher than the fallow-containing systems up to 1981, has since decreased and remained constant at a level slightly lower than F-W-W (N + P), but higher than F-W (N + P).

Fig 2(c). Effect of N and P fertilizer on organic C in 0-15 cm depth of a Cont W at Swift Current

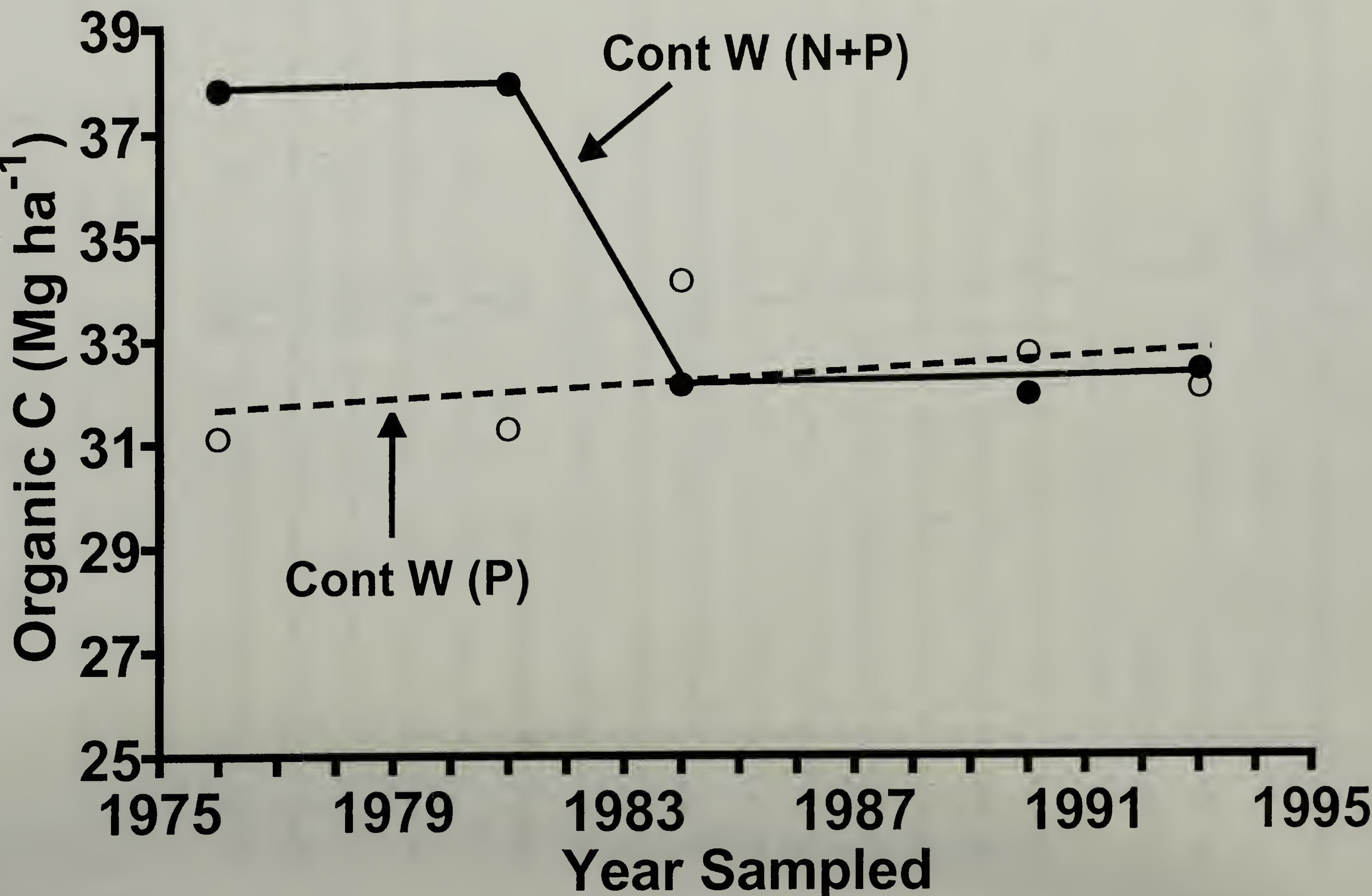


Fig 2(d). Effect of N and P fertilizer on total N in 0-15 cm depth of a Cont W at Swift Current

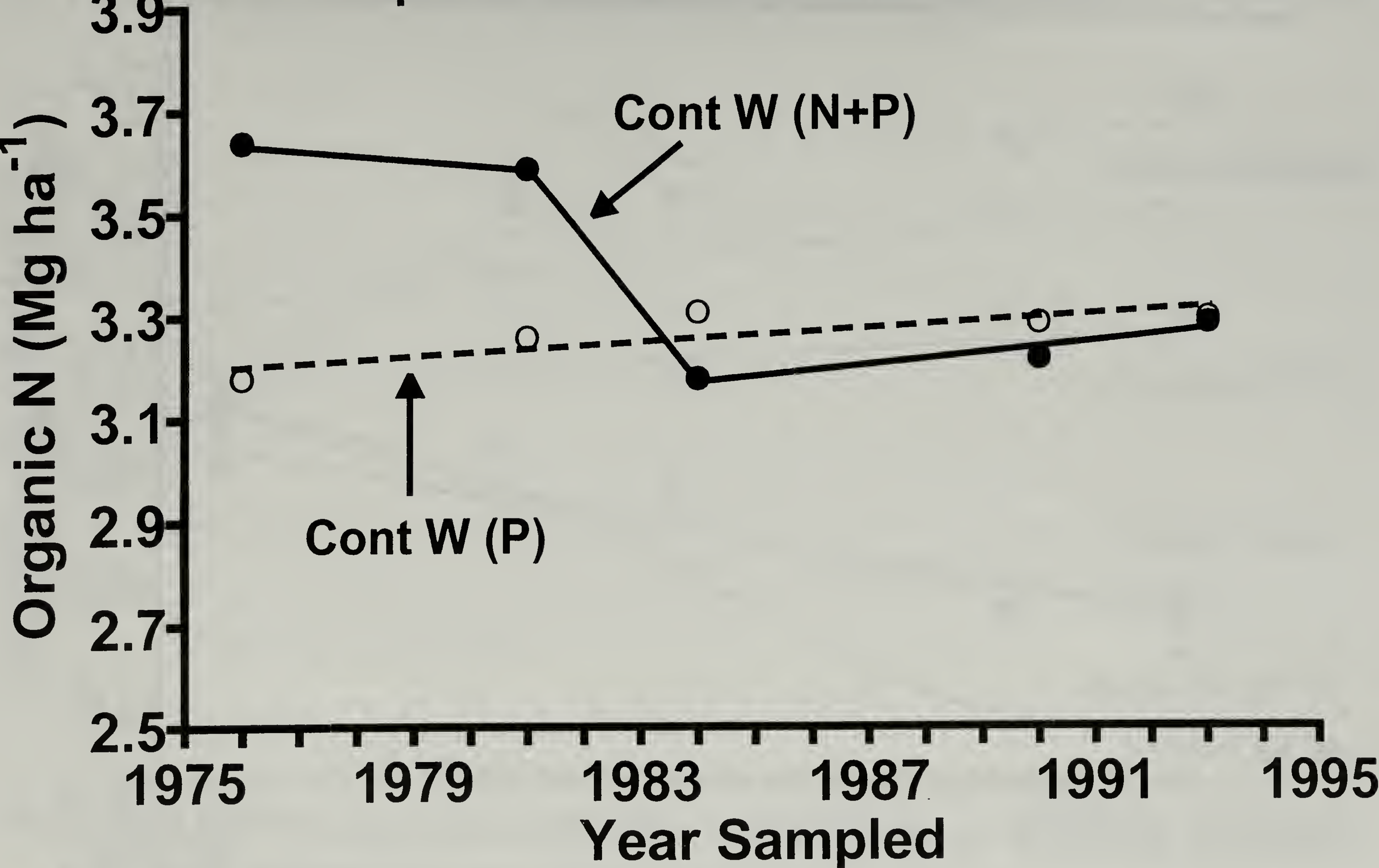


Fig 3(a). Effect of fall-seeded cereal and oilseed on C in 0-15 cm depth of a fallow-crop-crop rotation at Swift Current

(Regression lines are our intuitive estimates)

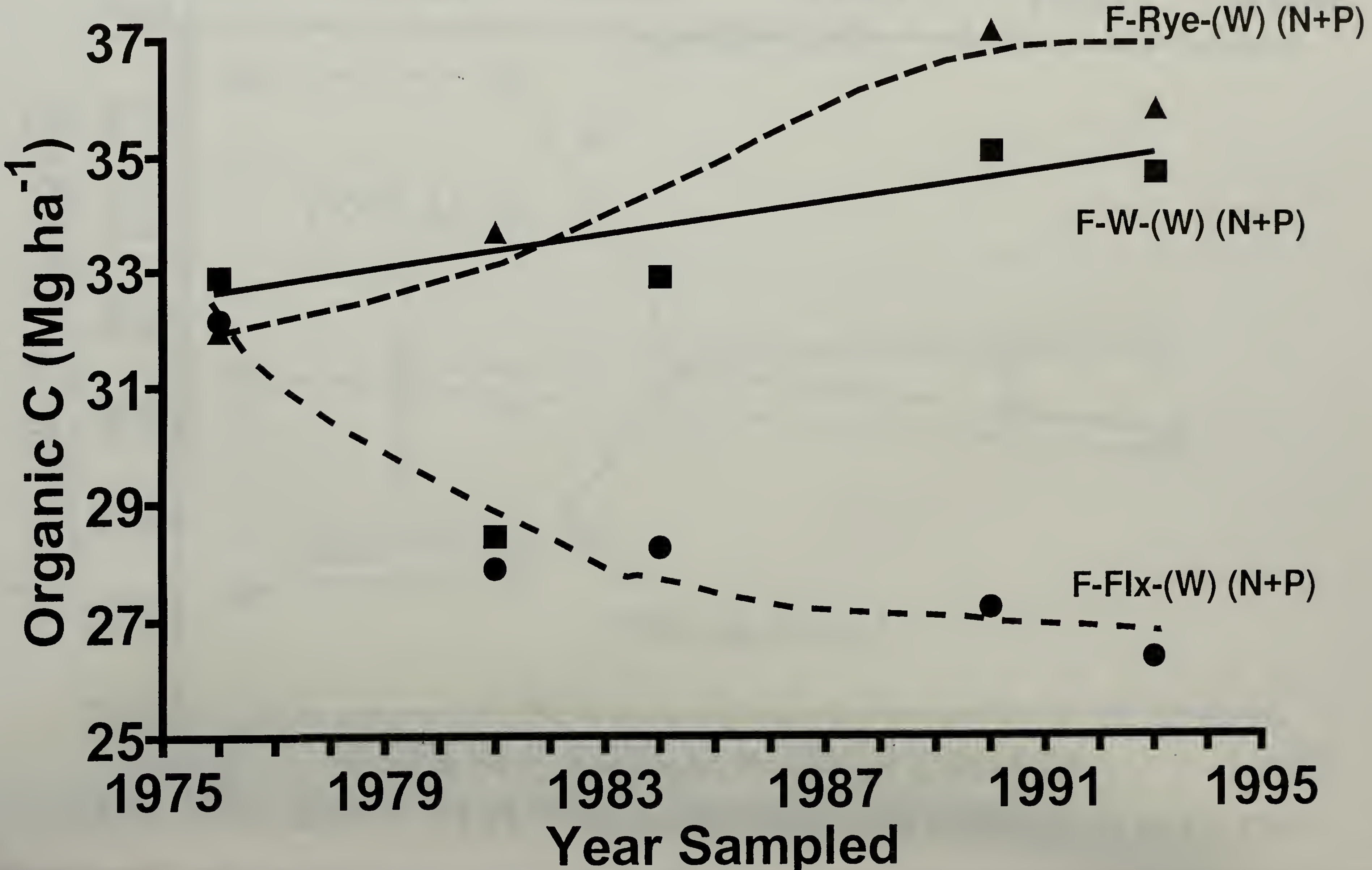


Fig 3(b). Effect of fall-seeded cereal and oilseed on total N in 0-15 cm depth of a fallow-crop-crop rotation at Swift Current

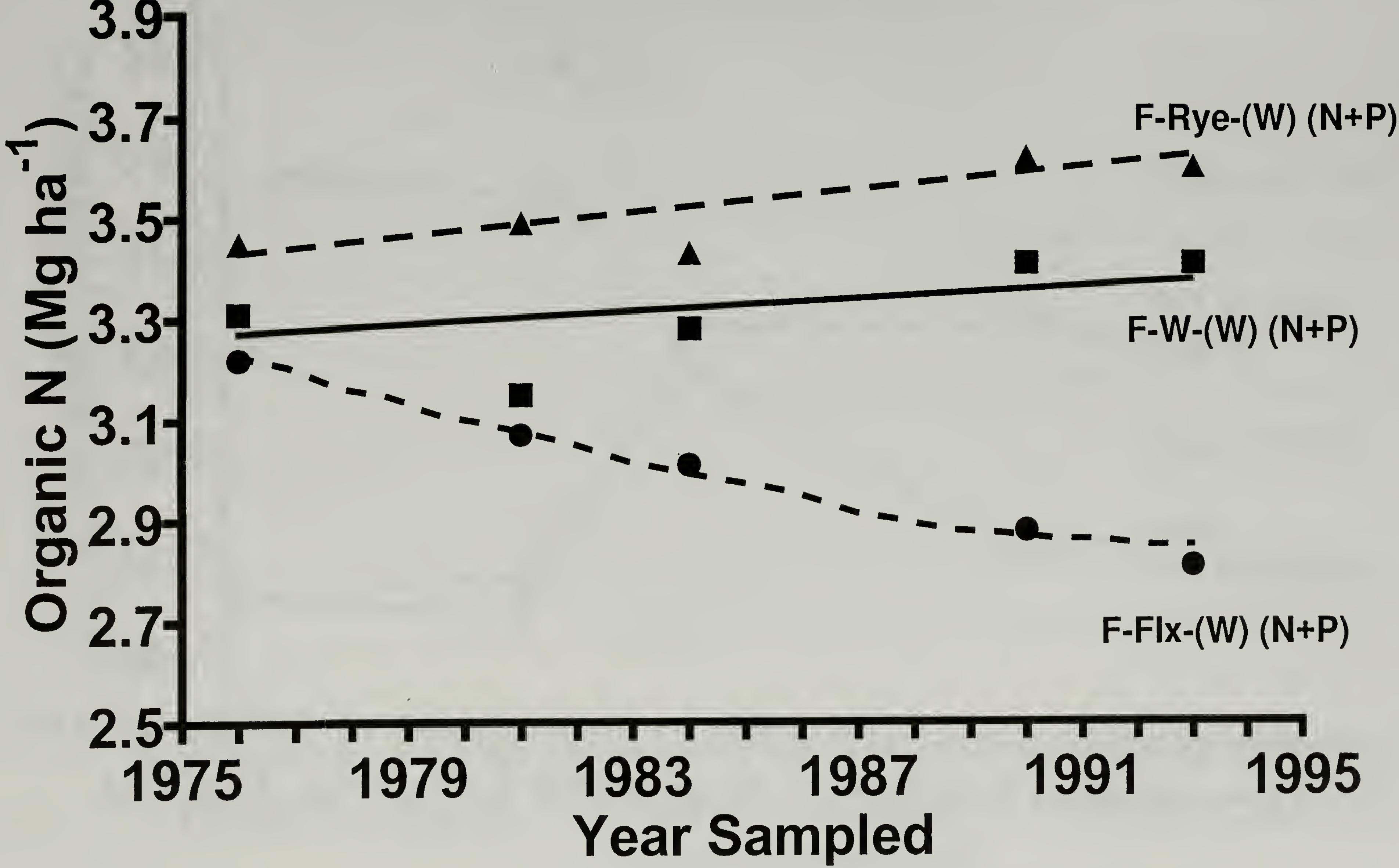


Fig 3(c). Effect of a pulse crop in building organic C in 0-15 cm depth in continuous cropping rotation at Swift Current

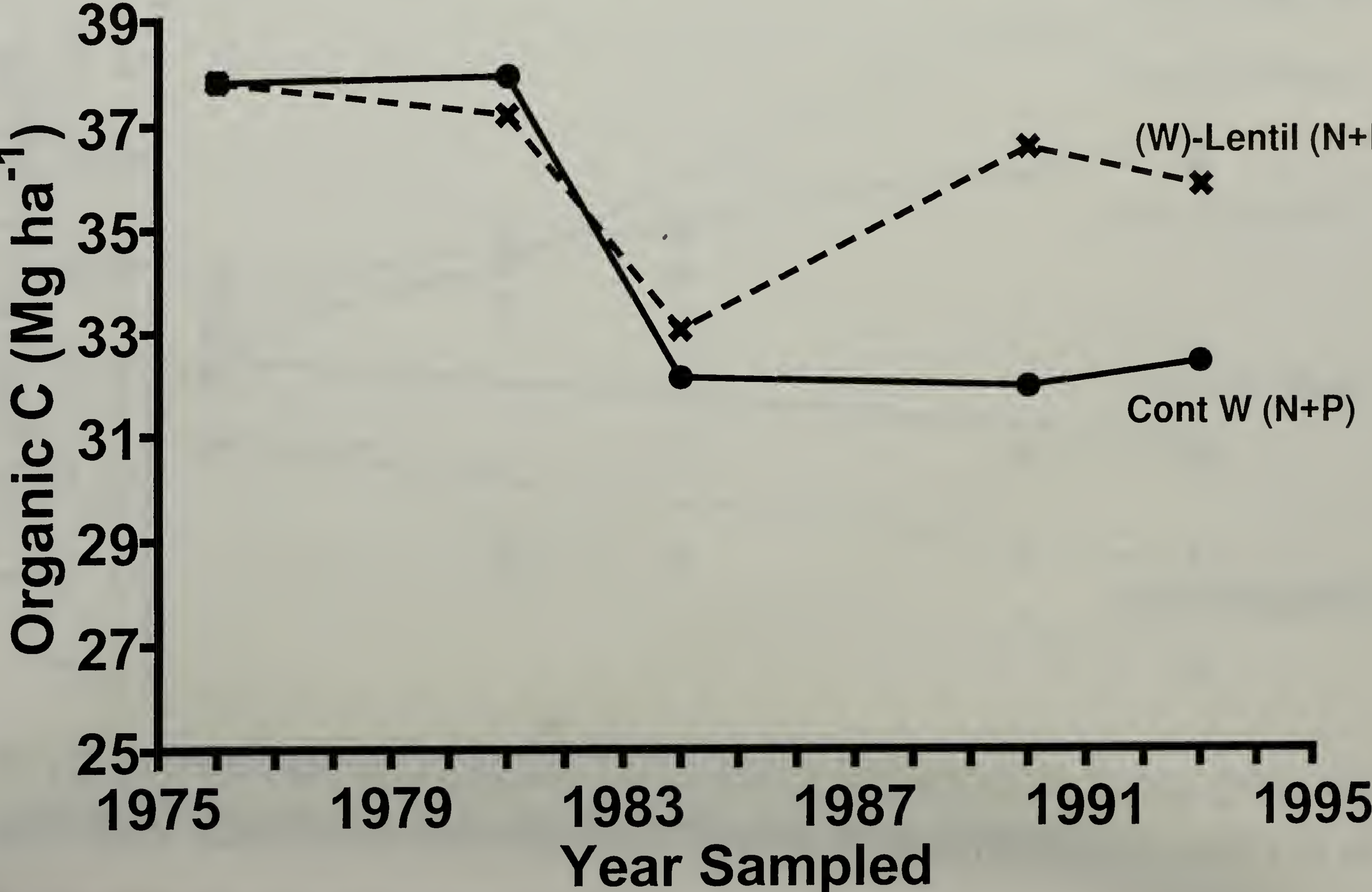


Fig 3(d). Effect of a pulse crop in building total N in 0-15 cm depth in continuous cropping rotation at Swift Current

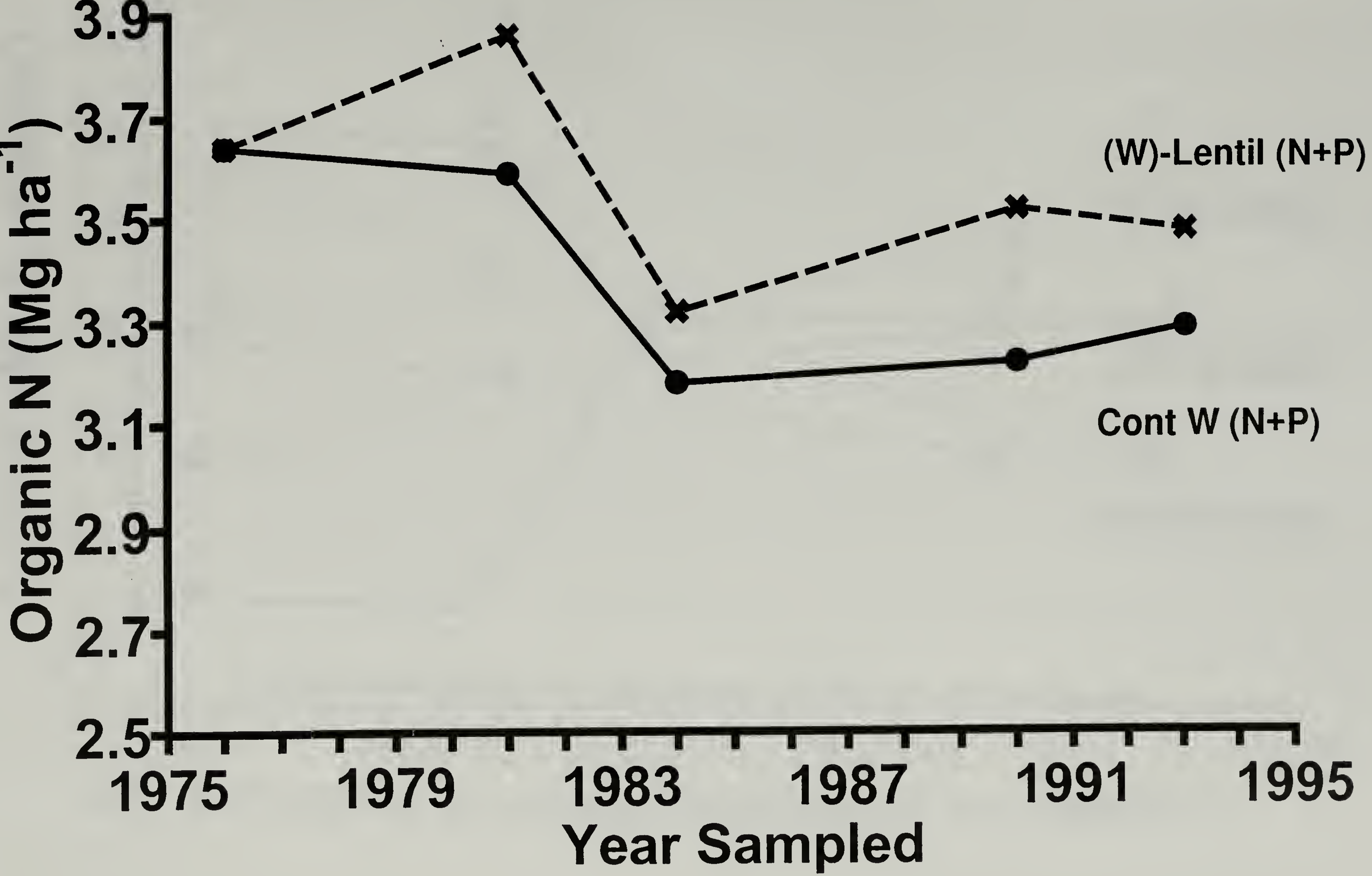


Fig 4(a). Effect of cropping frequency on organic C in 0-15 cm at Swift Current

(Regression lines are Campbell's intuitive estimations)

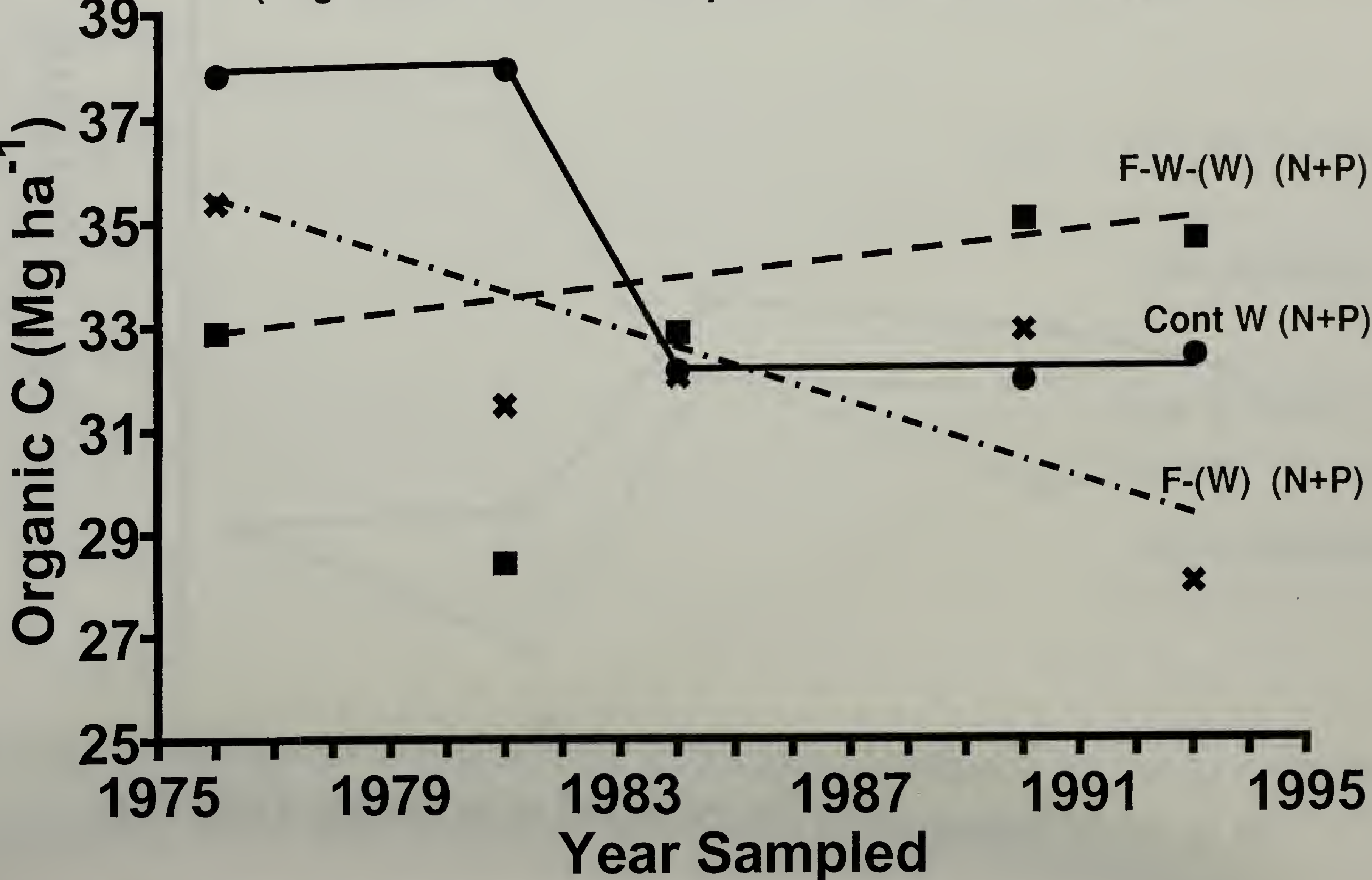
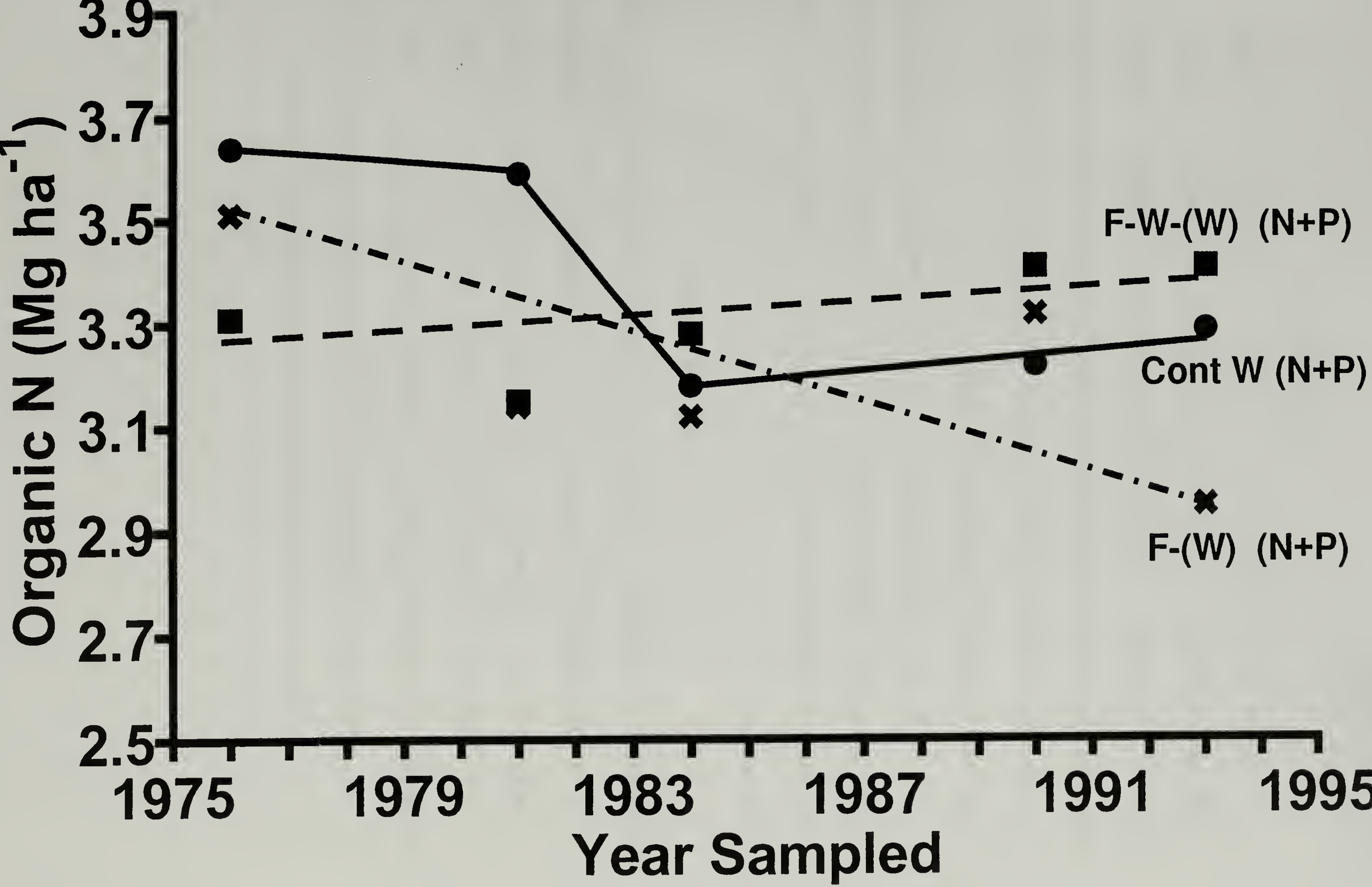


Fig 4(b). Effect of cropping frequency on total N in 0-15 cm at Swift Current



CONCLUSIONS

These results provide convincing evidence that systems that are frequently fallowed, inadequately fertilized, or that contain flax in the crop mix, may eventually reduce soil organic C and total N. Conversely, continuous cropping with proper fertilization, and particularly when legumes(including pulses) are included in the rotation, is likely to enhance soil organic C and total N. Including fall-seeded crops, such as fall rye, in the rotation will positively influence soil organic C and total N compared to growing spring cereals.

Finally, these results emphasize how variable (in time) organic C and total N can be, even in apparently uniform-looking land. Thus, if we are to assess treatment effects with any degree of confidence, it is imperative that soil organic C and N be monitored over time in preference to one-time samplings.

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