

RESEARCH PROJECT TITLE: Examination of Tillage Factors, Crop Type, Soils and Non-crop Habitat upon Soil Fauna and Ground Dwelling Predators in a Small Inland PNW Watershed.

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INTERIM REPORT

PROJECT OBJECTIVES: Objectives:

1. Determine the ground dwelling predator fauna of spring wheat and pea grown under conventional-till (CT) and reduced-till, and the overlap of such fauna with that found on natural habitats.
2. Ascertain the ground dwelling predator fauna of specific natural habitats within the Palouse.
3. Determine the relationship between soil macrofauna, crop rotation, and soil fertility.
4. Examine controls over C and N distribution across a typical, direct-seeded Palouse hillslope.

KEY WORDS: spring wheat, pea, biodiversity, earthworms, nitrogen

STATEMENT OF PROBLEM:

Along with an expected increase in soil and litter dwelling predatory fauna (discussed in last year's STEEP report for this project), earthworm populations have been found to increase in conservation tillage (Cons-T) systems. Increased earthworm densities may enhance yields through improved soil aeration, infiltration and nutrient cycling. At the same time that earthworms enhance soil nutrient cycling, the presence of residue layers in cons-T may result in greater levels of nitrogen immobilization. Little is known about how earthworms influence nitrogen availability in CT and direct seed (DS) fields in the Palouse region. Cons-T management can increase C storage within agroecosystems. In addition to the direct influence of C additions to soil quality, growers may benefit financially from developing C credit trading systems. For PNW growers to fully benefit from C credit trading, the ability of cons-T practices to sequester C must be quantified under specific soil types and climates.

During the previous two STEEP reports we described the invertebrate fauna found during the 2002 growing season in conventionally tilled (CT) and cons-T commercial crops across Latah and Nez Perce counties, ID. In this report we compare the abundance and distribution patterns of the same invertebrate fauna found during 2002 with the fauna found in noncrop habitats across the aforementioned counties, but also in Whitman Co., WA. Noncrop habitats can provide important resources for many invertebrate species by providing food, refugia and overwintering habitat. Noncrop habitat has important implications for the survival of natural enemies that prey on pest species. For instance, ground beetles are known to disperse from cropland to noncrop habitat during the autumn, and then migrate back into fields during the early growing season to feed on crop pests, especially aphids. Insectivorous spiders that have relatively long life cycles benefit from the refugia provided by noncrop habitats. And finally, parasitoid wasps that help to regulate pest populations benefit from the nectar provided by flowering plants in noncrop habitats.

A complementary goal to Objectives 1 and 2 of this research is to understand how tillage systems and noncrop habitats such as Palouse Prairie and CRP influence the native and exotic

biota found in the Palouse agroecosystem. Historically, cropland and other managed habitats in fragmented ecosystems have been viewed by conservation biologists and researchers as largely hostile. However, it is now recognized that such habitats vary considerably in “structure” (i.e. size and spatial arrangement of habitats) and “quality” (i.e. kinds of habitat, including crop types, tillage systems, drainage ditch embankments, roadsides, etc.), and that organisms such as pollinators, biocontrol agents and nutrient cyclers respond differently to these variables. Clearly, some biota are incapable of persisting outside of native habitat. These species are referred to as ‘remnant-dependent’ species, and are often regarded as candidates for conservation efforts. Other species might only traverse or forage in the managed habitats, while others including many species of insects actually colonize and persist in cropland and other managed habitats. It has been shown that low disturbance tillage systems (e.g. cons-T) often enrich invertebrate communities in cropland relative to CT systems (Stinner and House 1990). A logical question we pose, then, is whether cons-T, or CRP, provide a conservation benefit for prairie-inhabiting species. If so, one would expect biological diversity and the fauna to be more similar among cons-T and prairie than among CT and prairie. As the Palouse Prairie is identified as one of the most endangered ecosystems in the United States (Noss *et al.* 1995), management practices that help to conserve prairie-inhabiting species could have important implications for regional biodiversity conservation efforts.

ZONE OF INTEREST: High rainfall, Palouse

ABSTRACT OF RESEARCH FINDINGS

Land use change within the Palouse region has resulted in a mosaic of land uses including conventional and conservation-tillage (cons-T) agricultural fields, conservation reserve program (CRP) lands, and native prairie remnants. The impact of this fragmentation on ground and soil dwelling organisms has not been adequately characterized. In this work, we compare populations of ground-dwelling beetles and earthworms in conventionally tilled and no-till fields, CRP, and native Palouse Prairie. In addition, soil properties such as total carbon, nitrogen, and plant available N are contrasted between tillage regimes. Finally, to better understand the importance of soil spatial variability to fertility management in cons-T systems, soil properties across a typical Palouse hillslope under NT management were investigated. Pitfall trapping of cropland and prairie habitat during 2002 reveals that species diversity and the fauna are more similar between prairie and conservation tillage systems than between prairie and conventional tillage systems. This suggests that conservation tillage enhances biological diversity across the landscape while conferring conservation benefits to prairie-inhabiting species. The study also reveals a rich and abundant predator fauna in Palouse cropland. Earthworm, total C and N and inorganic N data were similar to those reported in 2002. Mean earthworm density was higher under cons-T as compared to under CT. Earthworm numbers in 2003, across tillage and crop, ranged from 52 to 71 individuals m^{-2} . These numbers are similar to those measured in Palouse prairie remnants (67 individuals m^{-2}) during the same year. The number of cocoons was also greater under cons-T, suggesting greater reproduction within cons-T systems. Total C and N concentrations tended to be higher in cons-T as compared to CT fields. Overall, preliminary data analysis suggests that despite variability among fields and years, cons-T does seem to improve soil C and N content and provide a more suitable environment for earthworms. Total C and N contents varied with topographic position across the cons-T hillslope studied. Stepwise linear regression indicated that aspect and slope have a large control over C and N concentrations in the

first 30 cm of soil. Since organic matter distribution is related to soil fertility, the data indicate that defining easy-to-recognize topographic zones may be an ideal way to accomplish variable-rate nutrient management across Palouse hillslopes. Other measures of N availability and microbial activity will be analyzed and related to topographic indices and reported on next year.

METHODS

This project builds upon STEEP-funded research at the Kambitsch Research Farm. At Kambitsch, a team of researchers have been examining the effects of tillage and crop type on invertebrate fauna in replicated plots. Controlled replication is a strength of the Kambitsch experiments, but it is necessary to examine the effects of tillage on actual farms. On-farm research, among other advantages, eliminates boundary and edge effects inherent in small plots. This is a particular concern for arthropod species that readily disperse. Thus, this project extends the research being conducted at Kambitsch to large-scale fields on working farms. It will also enable us to examine a wider range of tillage systems (i.e. CT, cons-till, NT) upon the invertebrate fauna. In addition we have taken a first step towards understanding how different landscape components (agricultural fields, CRP lands, and native prairie) are used by an important group of ground-dwelling fauna.

During 2002, we surveyed the beetle fauna in cropland and prairie habitats of the Palouse. We sampled 6 cons-T and 6 CT agricultural fields, located in Latah Co. and northern Nez Perce Co., Idaho. We also sampled 5 prairie remnants located in Latah Co., and in Whitman Co., Washington (Fig. 1). The results reported here provide a general description of the beetle community found in and across these habitats. We also report on two groups of predators found in these habitats, the Carabidae (ground beetles) and Coccinellidae (lady bugs). Beetles in these families are largely predacious, and recognized as natural biological control agents of pest species. The distribution of beetles was calculated by noting presence-absence of species by habitat type (prairie, CT and consT). Beetle diversity for each habitat type was calculated using the Shannon-Wiener (H) index:

Shannon-Weiner index, $H = -\sum p_i \ln p_i$

where H= biological diversity, p_i = the observed relative abundance of species i , and \ln = natural logarithm (indices according to Southwood and Henderson 2000, p.474).

To test whether the diversity of the beetle community differed significantly among habitats, we used a randomization test. As described by Solow (1993), the prairie and each matrix data set (CT and cons-T) used to calculate H were combined into single data sets (CT-prairie, cons-T-prairie, and CT-cons-T). Each of these combined data sets was then randomly partitioned by shuffling the data (without replacement) into two subsets of size N (where N = number of individuals trapped per habitat). The Shannon-Wiener index was then calculated for each subset and the difference recorded. This procedure was repeated 10,000 times utilizing Resampling.stats (www.resample.com), and the p-value calculated as described by Manly (1991).

Faunal similarity among prairie remnants and fields was determined using the Bray-Curtis similarity index (Bray and Curtis 1957, see Southwood and Henderson 2000):

$$CN = 2N_j / (N_a + N_b)$$

where CN = faunal similarity, N_a = the total number of individuals sampled in habitat a, N_b = the same in habitat b, and N_j = the sum of the lesser values common to both habitats.

Site Selection and Sampling

Site selection for the agricultural fields sampled during 2002 have been described in our two previous STEEP reports. For ease of reading we restate our selection criteria here. Field selection was based primarily upon rainfall zone, soil type, topography, grower participation, type of crop rotation and tillage system. Operations that use moldboard plows or extensive tillage including cultipactors were classified as CT, whereas operations that used alternative tillage practices (e.g., light chiseling or harrowing) and drills to insert seed through the proceeding years crop residue were classified as cons-T (this latter method is also referred to as "Direct Seeding", Veseth and Karow 1999). In this study we sampled only spring wheat (SW) and spring pea (SP) grown in 3-yr rotations. These crops were chosen because: 1) only 2 crops could be efficiently sampled during the study; 2) they could be sampled together over the same growing season; and, 3) sampling a cereal and a legume provided a better opportunity to assess average tillage effects across crops than by sampling 2 wheat crops in the rotation. We then identified growers using CT or cons-T systems, selecting 3 fields from each crop-tillage system in the rotation (i.e. 3 CT-SP, 3 cons-T-SP, 3 CT-SW and 3 cons-T-SW), for a total of 12 fields. To capture the arthropods, pitfall traps were placed in fields 50 m apart along transects. Each field received two transects with 5 traps/transect. Traps consisted of 6-cm diameter, 9 oz. plastic drink cups (70 mm top diameter, 45 mm bottom, and a depth of 95 mm) set in plastic liners flush with the soil surface (Hatten et al. 2003). Each trap was filled weekly with 1 to 2 oz. of low-toxicity antifreeze (Sierra brand) and left open for 7 days at a time. Arthropods that fell into the traps were preserved by the antifreeze and subsequently collected. Samples were collected weekly for 8 weeks. Trap contents were then processed by transferring all specimens into 70% ethanol. Adult beetles were identified to the lowest taxonomic level, or pending identification, sorted to morphospecies (morphospecies = individuals that are very similar based upon size, shape and color).

The selection of remnant prairies was based largely upon their floral integrity (Weddell and Lichthardt 1998) and size. To capture the arthropods, we used the same sampling methods with only minor differences as those employed in the agricultural fields (Hatten et al. 2004). Prior to analysis, sample sizes among habitats were standardized by randomly deleting from the data set one sample from the cons-T data set, and 43 samples from the prairie data set, so that each habitat was described by 477 traps collected during the study.

Four small pits (approximately 20 by 30 cm) were dug along each transect (3 pits per transect in 2002 and 5 pits per transect in 2003). To minimize the influence of factors outside the scope of this study, soil was sampled on only one aspect and at the same landscape position in each field. The soil was removed and placed in sieves in the field. The sieves were gently shaken and fauna were removed. Earthworm and other macrofauna numbers were recorded. Soil samples were analyzed for total C and N by dry combustion, inorganic (plant available) N, and pH.

In order to elucidate potential relationships between topographic characteristics and soil fertility/quality indicators, a no-till hillslope was located about 30 km southeast of Moscow in northern Idaho and sampled from 11 regularly-spaced transects passing through five landscape

positions. Bulk soil samples from the 0 to 5, 5-10 and 10-20 cm depth intervals were evaluated for total soil carbon and nitrogen, activity of select enzymes, plant available nitrogen and potentially mineralizable nitrogen. Differences in carbon and nitrogen between landscape positions were tested for significance using a general linear model in SAS 8.02.

Soil sampling was designed to expose topographic controls on soil properties. To accomplish this objective, over 15,000 survey points were collected on the 7.5-ha study site with a GPS receiver and were kriged to create a DEM with 10-m grid resolution using a GIS software package. Elevation data was imported into ArcGIS 9.0 in order to derive topographic attributes, which were correlated with soil carbon and nitrogen in multiple stepwise regression analyses using SAS 8.02.

RESULTS AND INTERPRETATIONS

Ground Dwelling-Beetles in Cropland and Prairie

During 2002 we captured 28,521 beetles. Sixty three percent of these individuals occurred in CT, 27% in cons-T and 10% in prairie. However, two species accounted for 70% of all individual beetles captured in CT, while in cons-T and prairie the relative abundance patterns of the beetles were more even. With respect to the number of species captured, 106 occurred in CT, 97 in cons-T and 121 in prairie. Diversity, as a function of relative abundance and the number of species found per habitat, was least in CT, greatest in prairie and intermediate in cons-T (Fig. 2). Faunal similarity, which is a function of the number and relative abundance of species shared among habitats, was least between CT and prairie, greatest between CT and cons-T, and intermediate between cons-T and prairie (Fig. 3). Given that species diversity and the fauna are more similar between cons-T and prairie than between CT and prairie, our findings suggest that cons-T does enhance biological diversity across the landscape while conferring a conservation benefit to prairie-inhabiting species in cropland.

Of the 218 species captured during the study, 20 belong to the family Carabidae (the “ground beetles”) and 9 belong to the Coccinellidae (the lady bugs). All but one species in each group are natives (excluding the unidentified morphospecies of which their origin is as yet undetermined). Species belonging to these families are primarily predacious in nature and valued as natural biocontrol agents of pest species. Although many other species of predators were captured during the study, they are not discussed in this report and are pending further analysis. Of the 29 species discussed, 5 (17%) were captured in both prairie and cropland. Of these, *Hyppodamia convergens* (Guerin-Meneville) was the most common. This species has good dispersal capabilities, emigrating from noncrop habitat to crop fields during the summer when aphid densities are high. A 2nd ladybug species of the genus *Scymnus* also occurred commonly across habitats. *Scymnus* are small beetles that feed chiefly on mites and Homoptera. The most common ground beetle captured across habitats was *Microlestes linearis* (LeConte). *Microlestes* species are small ground beetles, approximately 4mm long, good dispersers, and as is common for ground beetles they feed on a wide array of organism including many pest species.

The most striking aspect of these data, however, is the lack of overlap in the distribution of species between crop and noncrop habitat, and the fact that a number of native species were found only in crop fields. Our data may not provide, however, a complete picture of fine scale habitat use by these beetles. For this, a sampling program that assesses the occurrence of beetles in habitats directly adjacent to crop fields might be necessary. On the other hand, a wide body of

literature shows that agroecosystems sustain arthropod communities that are tolerant of the temporal disturbance patterns observed in annual cropping systems (Kromp 1999). Such species not only use cropland, they persist in cropland, finding all the resources necessary for survival. Many such species appear capable of surviving exclusively within crop fields (Kromp 1999). In this study we have found a rich and abundant predatory fauna occurring in crop fields (Table 1). Several of these species are very abundant, and most likely contribute significantly to the natural control of pest species. However, feeding trials or gut content analysis will be required to determine the biocontrol potential of these species.

Soil macrofauna and fertility

Data collected in 2002 was reported in last year's STEEP report. Analysis of 2003 samples has been completed and is presented here in preliminary form. Data from 2002 and 2003 will be combined and analyzed together, when appropriate, for presentation in next year's report.

Similar to 2002 data, there was a general trend for higher earthworm numbers in cons-T as compared to CT fields (Fig. 4). Cocoon numbers were also higher under cons-till. As in 2002 earthworm density tends to be higher within pea plots than it is under wheat. These data correspond well to that reported from the Kambitsch experiments, and probably result from the lack of residue (food) from the previous pea crop. Across crop and tillage, mean earthworm densities ranged from 52 to 71 individuals m^{-2} . Data collected in 2003 show that mean earthworm density in Palouse prairie remnants and Conservation Reserve Program sites were 67 and 107 individuals m^{-2} , respectively (Sanchez-de León and Johnson-Maynard, 2004). These data indicate that earthworm density in cons-T and CT fields is similar to that found within native prairie remnants. Conservation Reserve Program sites, however, tend to support larger earthworm populations due to greater plant productivity, microclimate or other factors.

Mean soil pH values with depth do not show as clear of a trend as data reported in 2002 (Fig. 5). The difference in results between years is likely due to the selection of new fields for 2003. Differences such as field location, soil type, years in cons-T, and fertilization practices may have altered the relationship between pH and tillage noted in 2002. Similar to 2002 data, mean total carbon values indicate that carbon is accumulating in the top 15 cm of soil under cons-T (Fig. 6). Inorganic N values will be related to fertilization practices and discussed in the final report.

Soil topographic influence on indicators of soil fertility

Across the study hillslope, significant differences were observed among average values of total soil carbon and nitrogen between landscape positions. Figures 7 and 8 illustrate maximum concentrations of carbon and nitrogen in areas of convergence and minimum values in divergent areas for both north- and south-facing sides of the hillslope.

The relationship between total soil carbon and nitrogen and topographic indices was investigated by developing a matrix of correlation coefficients. The matrix (Table 1) showed that elevation, slope and compound topographic index (CTI) were significantly correlated to soil carbon and nitrogen contents across the hillslope. Multiple linear regression (stepwise) analyses identified landscape attributes that were used to predict soil carbon and nitrogen distribution. Table 2 presents the order of entry (at the 0.15 significance level) of topographic variables, which remained in the model at the 0.05 level of significance. Although the R^2 values are somewhat low, probably due to inherent variability in soil properties, they do indicate a moderate

ability to predict C and N across the hillslope. The regression results indicate that slope and elevation are the two most important variables controlling C and N across the cons-T hillslope, within each aspect. The relationship between total carbon and nitrogen and landform positions demonstrated significant interactions, suggesting that landforms may be relevant management zones on NT, Palouse hillslopes. Other fertility measurements including inorganic N, potentially mineralizable N, and enzyme assays have been completed on the same samples. These data are currently being statistically analyzed and will be related to topographic variables using spatial modeling. The results will be presented in the final report.

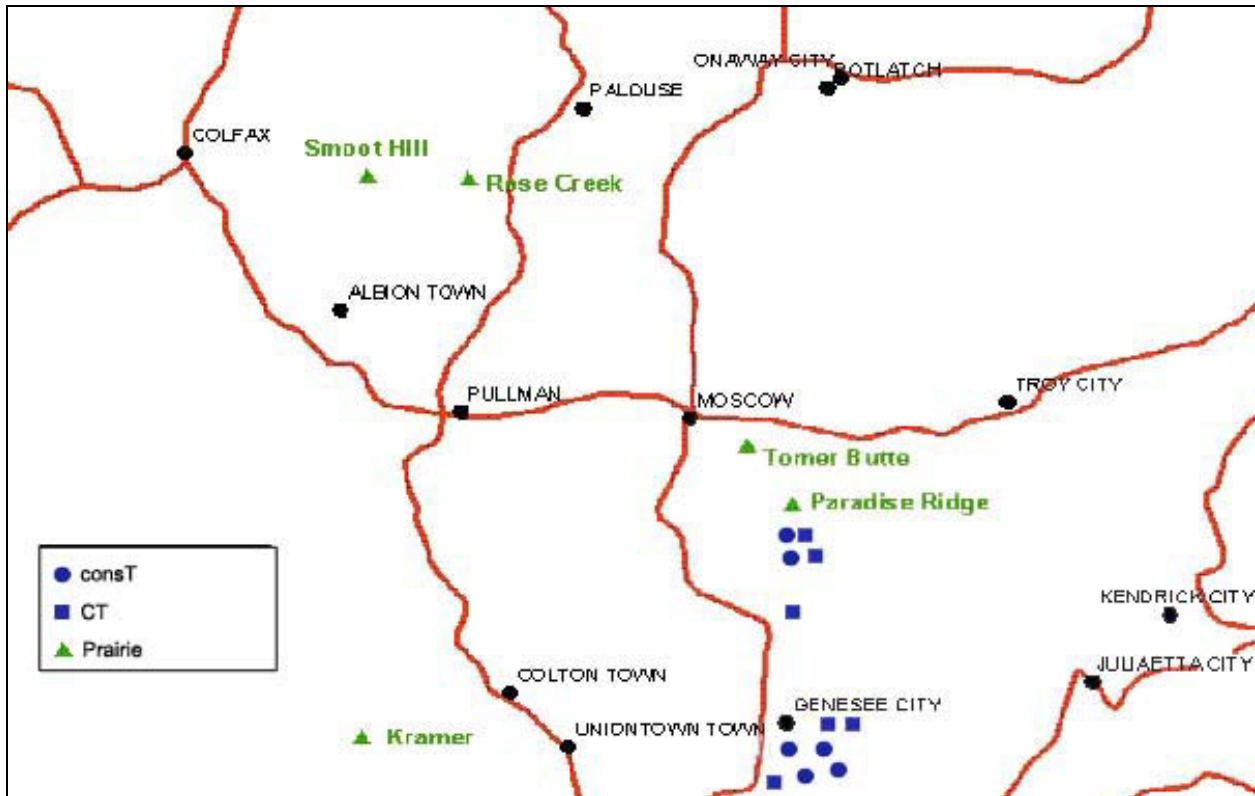


Fig. 1. Location of prairie and farm sites sampled during 2002 across the Palouse in NW Idaho and SE Washington.

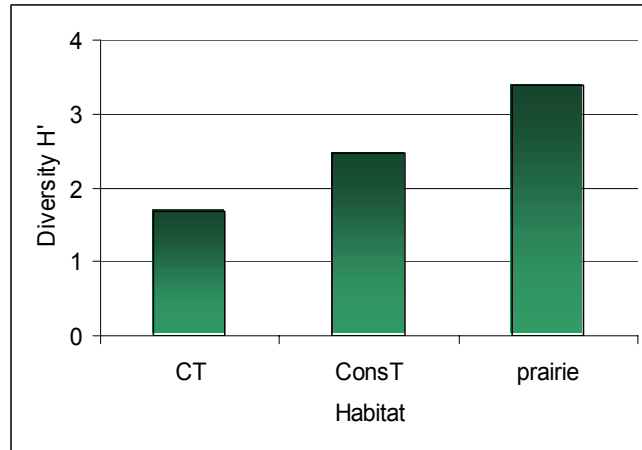


Fig. 2. Diversity (H') of beetles in prairie and cropland [conventional-tillage (CT) and conservation-tillage (Const) fields] during 2002 across the Palouse, NW Idaho and SE Washington. The Shannon-Weiner index of biological diversity $H' = -\sum p_i \ln p_i$, where p_i = the observed relative abundance of species i , and \ln = natural logarithm (see Southwood and Henderson 2000, p.474). A randomization test indicates that differences in diversity observed among these habitats are highly significant ($P < 0.001$).

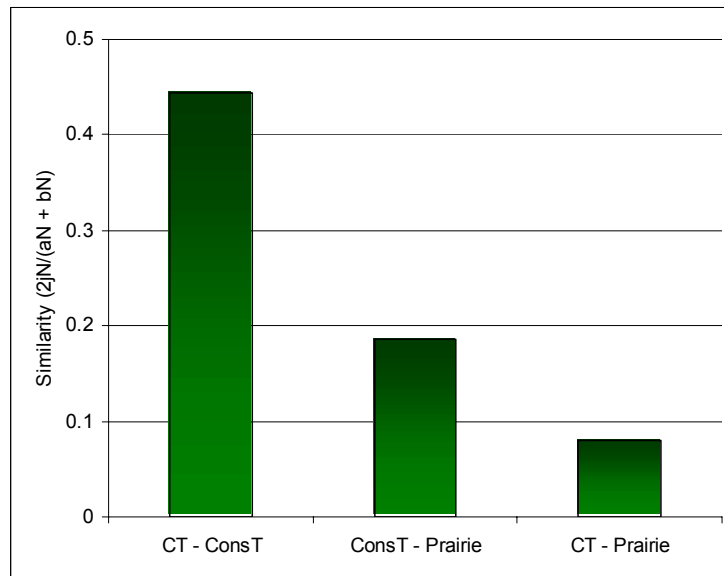


Fig. 3. Similarity of the beetle fauna among prairie and cropland [conventional-tillage (CT) and conservation-tillage (Const-T) fields] during 2002 across the Palouse, NW Idaho and SE Washington. Similarity was measured with the Bray-Curtis index $C_N = 2jN/(aN + bN)$, where C_N = faunal similarity, aN = the total number of individuals sampled in habitat a , bN = the same in habitat b , and jN = the sum of the lesser values common to both habitats (see Southwood and Henderson 2000, p.486).

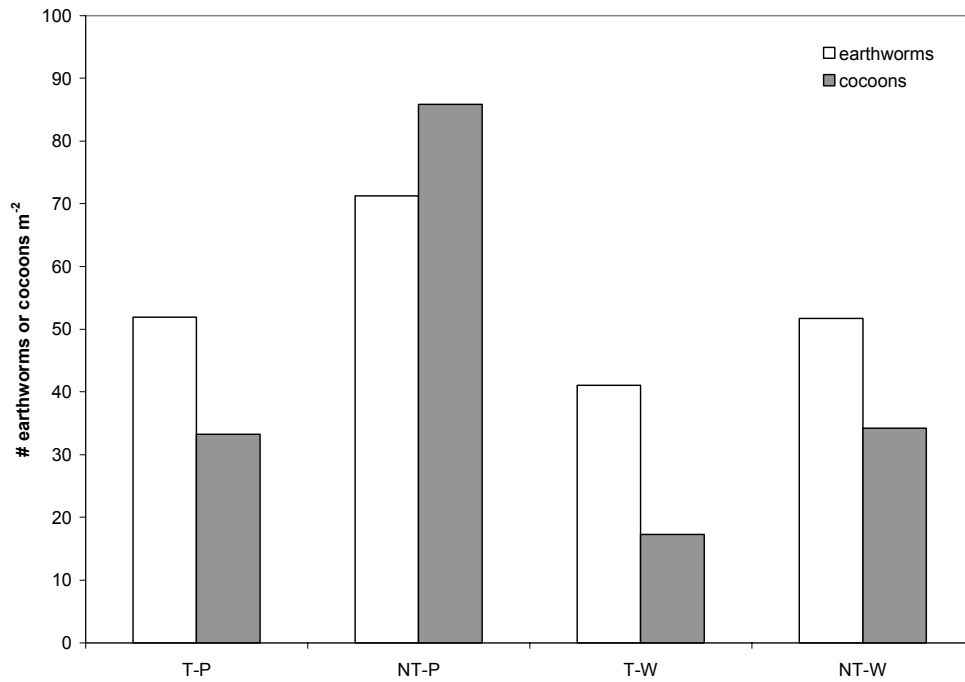


Figure 4. Earthworm and cocoons per unit area in conventionally tilled (T) and no-till (NT) fields planted to either pea (P) or wheat (W) in 2003.

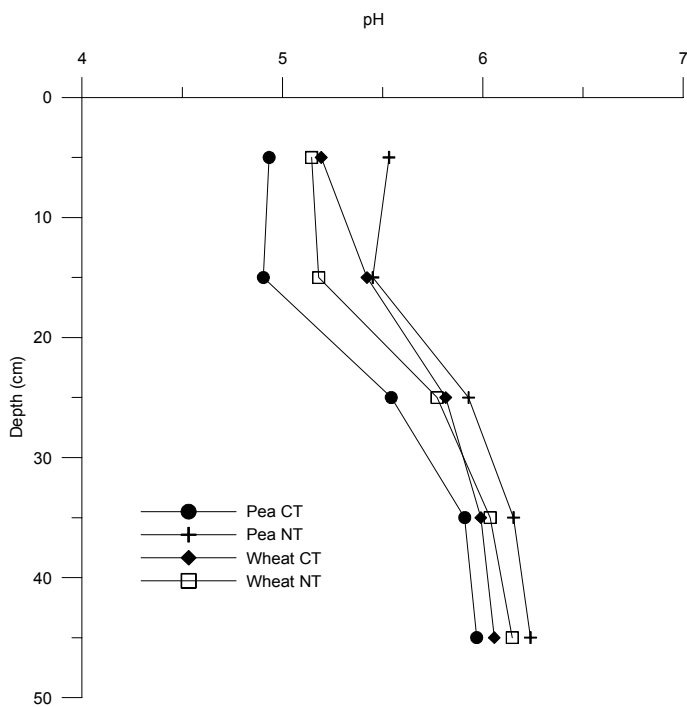


Figure 5. Mean pH with depth for conventionally tilled (CT) and no-till peas and wheat for samples collected in 2003.

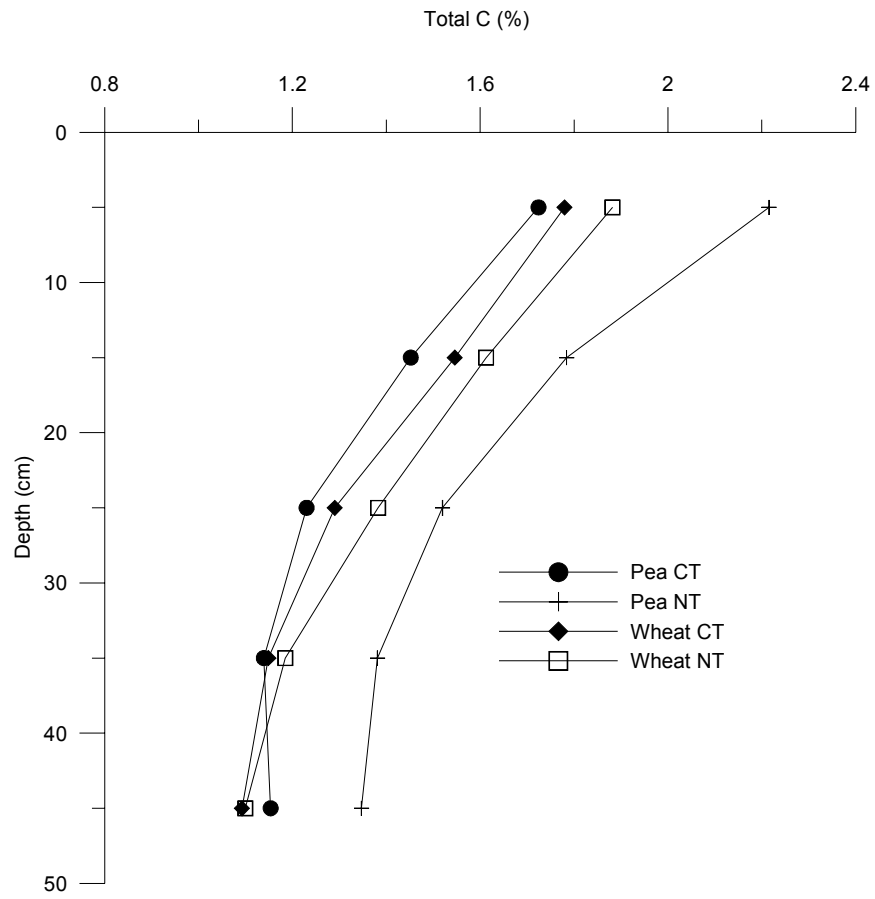


Figure 6. Total C with depth in convention and cons-till fields sampled in 2003.

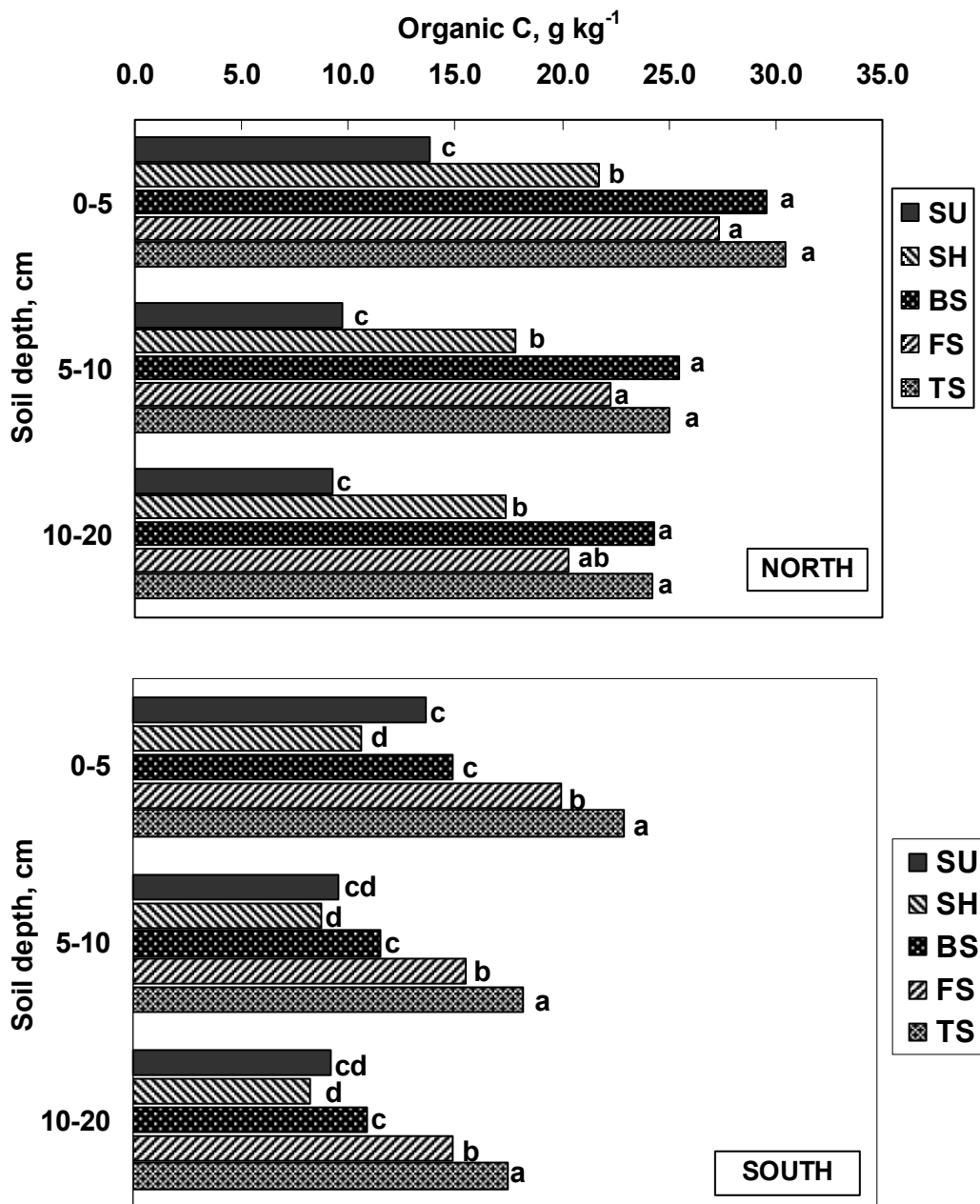


Figure 7. The distribution of total soil C averaged by landscape position for each aspect separately. Letters of significance between landscape positions for each depth increment are different at the P = 0.05 level.

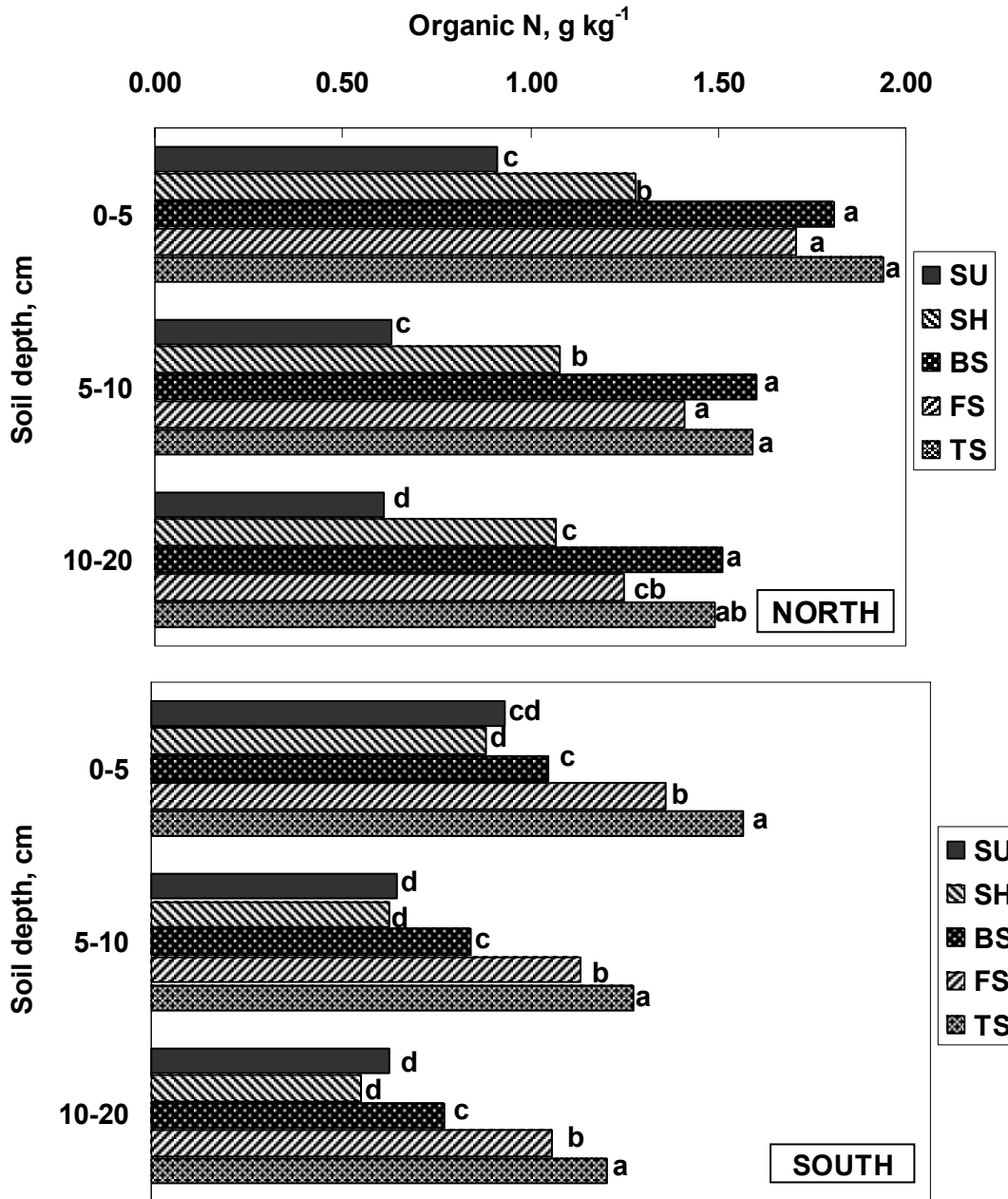


Figure 8. The distribution of total soil N averaged by landscape position for each aspect separately. Letters of significance between landscape positions for each depth increment are different at the P = 0.05 level.

Table 1. Correlation matrix of soil attributes and topographic indices.

<i>n</i> = 99	Elevation	Slope	CTI [†]
Total carbon	- 0.36 [‡]	- 0.44	0.42
Total nitrogen	- 0.35	- 0.42	0.38

[†] CTI = compound topographic index.

[‡] Significant at the 0.05 probability level.

Table 2. Stepwise regression analysis for total carbon and nitrogen.

Variable Entered	Model	R ²	Pr > F
Y = Total carbon			
Slope	Y = 2.71 - 4.46Slope	0.19	0.0001
Elevation	Y = 35.54 - 0.04Elev - 3.64Slope	0.24	0.0001
Y = Total nitrogen			
Slope	Y = 0.17 - 0.25Slope	0.18	0.0001
Elevation	Y = 1.99 - 0.0021Elev - 0.21Slope	0.23	0.0001

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