Agricultural Practices and Policies for Carbon Sequestration in Soil

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CHAPTER 7

Climatic Influences on Soil Organic Carbon Storage with No Tillage

A. J. Franzluebbers and J. L. Steiner

CONTENTS

ABSTRACT

No-tillage crop production has become an accepted practice throughout the U.S. The Kyoto Protocol on climate change has prompted great interest in conservation tillage as a management strategy to help sequester CO_2 from the atmosphere into soil organic matter. Numerous reports published in recent years indicate a large variation in the amount of potential soil organic carbon (SOC) storage with no tillage (NT) compared with conventional tillage (CT). Environmental controls (i.e., macroclimatic variables of temperature and precipitation) may limit the potential of NT to store SOC. We synthesized available data on SOC storage with NT compared with CT from published reports representing 111 comparisons from 39 locations in 19 states and provinces across the U.S. and Canada. These sites provided a climatic continuum of mean annual temperature and precipitation, which was used to identify potential SOC storage limitations with NT. Soil

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organic C storage potential under NT was greatest (~0.050 kg · m^{-2} · yr^{-1}) in subhumid regions of North America with mean annual precipitation-to-potential evapotranspiration ratios of 1.1 to 1.4 mm · mm^{-1}. Although NT is important for water conservation, aggregation, and protection of the soil surface from wind and water erosion in all climates, potential SOC storage with NT compared with CT was lowest in cold and dry climates, perhaps due to prevailing cropping systems that relied on low-intensity cropping, which limited C fixation. Published data indicate that increasing cropping intensity to utilize a greater fraction of available water in cold and dry climates can increase potential SOC storage with NT. These analyses indicate greatest potential SOC storage with NT would be most likely in the relatively mild climatic regions rather than extreme environments.

INTRODUCTION

Conservation-tillage crop production has become an accepted practice throughout the U.S. and Canada. Thirty-seven percent of the cropland in the U.S. is now managed with some form of conservation tillage (i.e., no tillage, ridge tillage, and mulch tillage) (CTIC, 1998). The Kyoto Protocol on climate change has prompted the agricultural sector to promote more seriously various forms of conservation tillage as practices to help sequester CO_2 from the atmosphere into soil organic matter.

Numerous reports have been published in recent years concerning the effect of no-tillage crop production (NT) compared with conventional tillage (CT) on potential soil organic carbon (SOC) storage. However, these reports indicate a large variation in the amount of potential SOC storage with NT. For example, SOC in the Ap horizon (0 to 20-cm depth) of a Dark Brown Chernozemic clay loam in Alberta increased at only 0.17 to 0.20 mg · g^{-1} soil · yr^{-1} compared with shallow CT in two studies conducted 9 and 19 years under NT (Dormaar and Lindwall, 1989). In contrast, SOC at a depth of 0 to 7.5 cm during 4 years under NT compared with plowed CT increased at 0.69 mg · g^{-1} soil · yr^{-1} on a Waukegon silt loam in Minnesota (Hansmeyer et al., 1997) and at ~1.15 mg · g^{-1} soil · yr^{-1} on a Kamouraska clay in Quebec (Angers et al., 1993). Incorporation of residues below 7.5 cm with plowing would likely reduce this effect when considering the entire plow depth.

Soil organic C accumulation rates between these extremes have also been observed. At a depth of 0 to 5 cm, SOC increased at 0.42 mg · g^{-1} soil · yr^{-1} during 14 years under NT compared with multiple-disk CT on a Norfolk loamy sand in the South Carolina coastal plain (Hunt et al., 1996) and at 0.28 to 0.42 mg · g^{-1} soil · yr^{-1} during more than 20 years under NT compared with plowed CT on a Bertie silt loam in the Maryland coastal plain (McCarty and Meisinger, 1997). On a Hoytville silty clay loam in Ohio, SOC of the 0- to 10-cm depth increased at 0.66 mg · g^{-1} soil · yr^{-1} during 12 years under NT compared with plowed CT (Lal et al., 1990). The large range of changes in SOC with NT compared with CT among the aforementioned studies may be related to differences in cropping system, fertilization, depth of tillage tool, numerous soil characteristics, climatic conditions, and depth of sampling.

When comparing management effects on SOC storage, soil sampling depth is an important consideration. Depth distribution of SOC is altered with NT compared with CT. For example, SOC under NT was 40 ± 22% greater than under CT at a depth of 0 to 7.5 cm, similar at a depth of 7.5 to 15 cm, and 7 ± 11% less at a depth of 15 to 30 cm, resulting in a net change of only 9 ± 7% greater SOC under NT (Doran, 1987). Changes in depth distribution of SOC with tillage systems suggest the need to standardize sampling protocols to collect soil to at least the depth of deepest tillage tool in order to make fair comparisons.

A growing database has accumulated reporting differences in SOC between CT and NT crop management. Recently, efforts have been made to synthesize results from long-term studies on SOC within regions (Paustian et al., 1998). However, efforts to isolate particular regions of North

America with the greatest potential to store SOC with adoption of NT have only begun. Although models have been developed to predict such regional differences in SOC accumulation potential (Smith et al., 1998), long-term observational data could provide verification of such predictions if enough cross-regional data were collected and synthesized. It was hypothesized that macroclimatic conditions would have an influence on the potential of NT to sequester SOC compared with CT. Objectives were to (1) summarize published data from the U.S. and Canada and (2) test whether soil type, cropping intensity, N fertilization, and macroclimatic regime affected the difference in standing stock of soil organic C due to adoption of NT compared with CT.

MATERIALS AND METHODS

Data were obtained from the literature in which SOC was reported for NT crop management compared with some form of CT (Table 7.1; Figure 7.1). Only reports that contained SOC information on an area basis were used in order to avoid misleading interpretations due to management-induced changes in bulk density (Ellert and Bettany, 1995). Differences in standing stock of SOC between NT and CT were standardized to an annual basis. Net annualized change in SOC with NT compared with CT was expected to decline with time, but this did not occur in the available data from three locations (Figure 7.2). Length of time in all comparisons was 10.7 ± 6.1 years, with 85% of comparisons >5 years in length.

"Decomposition potential" of each location was evaluated using several different indices based on climate. Long-term mean monthly precipitation and temperature data from the closest weather station to each of the evaluated locations (i.e., within 30 km) were obtained (Global Historical Climatology Network, 1999). Monthly potential evapotranspiration (PET) was calculated from long-term mean monthly temperatures and latitude using the Thornthwaite equation (Thornthwaite et al., 1957).

Index 1 was calculated as the sum of each monthly precipitation-to-potential evapotranspiration ratio divided by 12. Monthly precipitation exceeding PET was assigned a value of 1, because those locations with subzero mean monthly temperature were calculated to have no PET using the Thornthwaite equation.

Index 2 was calculated as mean annual precipitation divided by mean annual PET (derived from the sum of monthly values). Index 2 was allowed to exceed 1.

Index 3 was calculated as the sum of products from temperature and precipitation coefficients on a monthly basis divided by 12. The temperature coefficient was calculated from a nonlinear function that assumed a doubling of microbial activity for every 10°C change in temperature [$2((°C-30)/10)$] (Kucera and Kirkham, 1971), with 30°C assumed as an optimum (Figure 7.3a). None of the locations had mean monthly temperatures exceeding 30°C. The mean monthly precipitation coefficient was expressed as mean monthly precipitation (mm) divided by 100. It was assumed that 100 mm of precipitation per month would be adequate for maximum decomposition at any temperature. Months with precipitation exceeding 100 mm were assigned coefficients of 1 (Figure 7.3b).

Index 4 was calculated as the product of temperature and precipitation coefficients on an annual basis. The mean annual precipitation coefficient was calculated as mean annual precipitation (mm) divided by 1200. When annual precipitation exceeded 1200 mm, the precipitation coefficient was allowed to exceed 1.

Index 5 was calculated as the sum of the most limiting monthly coefficient (i.e., lowest temperature or precipitation coefficient for each month) divided by 12.

Index 6 was calculated as the most limiting annual temperature or precipitation coefficient.

Because of unequal representation of geographical regions, soil orders, soil textural classes, and fertilization regimes, individual univariate analyses on the net annualized change in SOC with NT compared with CT were conducted for each of these variables separately, using the general linear model procedure (SAS Institute Inc., 1990). Polynomial regressions (i.e., linear plus quadratic

Table 7.1 Characteristics of Locations

Location	Soil Texture	Soil Classification	Years	Crop Intensity	Soil Depth	MAT	MAP	PET	Source
AB Beaverlodge	CL	Cryoboralf	4	0.5	20	2.0	447	489	1
AB Breton	L	Cryoboralf	11	0.5	15	2.0	495	504	2
AB Ellerslie	L	Cryoboroll	11	0.5	15	2.3	483	504	2
AB Lethbridge	SiL	Haploboroll	12 ± 4	0.4 ± 0.1	15 ± 1	5.5	415	556	3, 4
AB Rycroft	C	Natriboralf	6	0.4	20	0.6	369	489	1
BC Dawson Creek	SiL	Cryoboralf	16	0.5	20	1.4	466	489	1
BC Rolla	L	Cryoboralf	7	0.5	20	0.6	466	484	1
CO Akron	SiL	Paleustoll	15	0.25	20	9.4	404	641	5
GA Athens	SL	Kanhapludult	12 ± 3	1.0	20 ± 3	16.5	1230	874	6, 7
GA Griffin	SL	Kanhapludult	10 ± 5	1.0	30	16.5	1230	874	6
GA Watkinsville	SL	Kanhapludult	4	1	15	16.5	1230	874	8
IL DeKalb	SiCL	Haplaquoll	10.5	0.5	30	9.4	874	678	9
IL Elwood	SiL	Ochraqualf	6	0.5	30	9.2	892	660	10
IL Monmouth	SiL	Hapludoll	10.5	0.5	30	10.6	912	716	9
IL Perry	SiL	Argiudoll	10.5	0.5	30	10.6	912	716	9
KY Lexington	SiL	Paleudalf	12 ± 8	0.5	30	12.9	1129	765	10, 11, 12
MD Beltsville	SiL	Hapludult	2 ± 1	0.5	20	12.9	1076	770	13
MI East Lansing	L	Ochraqualf	9 ± 3	0.5	20	8.3	785	617	14
MN Waseca	CL	Haplaquoll	9 ± 3	0.5	23 ± 11	7.2	767	642	10
MT Culbertson	SL	Argiboroll	10	0.5	21	5.6	337	602	15
ND Mandan	SiL	Argiboroll	6	0.4 ± 0.1	30	5.2	402	588	16
NE Lincoln	SiCL	Argiudoll	9 ± 4	0.5	30	10.3	782	712	10, 17
NE Sidney	L	Haplustoll	14 ± 4	0.25	28 ± 5	8.4	468	606	10, 18, 19
OH Wooster	SiL	Fragiudalf	29 ± 1	0.7 ± 0.3	23 ± 8	10.9	1028	695	20, 21

ON Delhi	SL	Psamment	4	0.5	60	7.9	950	598	22
ON Harrow	CL	Haplaquoll	11	0.5	60	9.0	831	641	22
ON Ottawa	SL	Eutrochrept	5	0.5	60	5.6	879	587	22
PE Harrington	fSL	Haplorthod	8	0.5	60	5.5	1074	531	22
QC La Pocatiere	C	Humaquept	5 ± 1	0.5	38 ± 32	4.1	944	520	22
QC Normandin	SiC	Humaquept	3	0.5	60	2.2	887	502	22
SK Melfort	CL	Boroll	12	0.25	20	0.8	401	510	3
SK Scott	L	Boroll	2	0.5	10	1.1	356	508	3
SK Swift Current	fSL	Haploboroll	12	0.25	15	3.6	380	545	23
SK Swift Current	SiL	Boroll	12	0.4 ± 0.1	15	3.6	380	545	24
SK Watrous	CL	Boroll	4	0.5	10	0.8	420	505	3
TX Bushland	CL	Paleustoll	9 ± 2	0.4 ± 0.1	17 ± 3	14.0	516	796	25, 26, 27
TX College Station	SiCL	Ustochrept	9 ± 1	0.7 ± 0.2	20	20.2	1027	991	28, 29, 30
TX Corpus Christi	SCL	Ochraqualf	15 ± 1	0.5	20	22.7	713	1033	26, 27, 31
TX Temple	C	Pellustert	10	0.5	20	19.2	871	971	26, 27
WI Lancaster	SiL	Hapludalf	12	0.5	25	8.0	833	634	32

Note: AB = Alberta, BC = British Columbia, CO = Colorado, GA = Georgia, IL = Illinois, KY = Kentucky, MD = Maryland, MI = Michigan, MN = Minnesota, MT = Montana, ND = North Dakota, NE = Nebraska, OH = Ohio, ON = Ontario, PE = Prince Edward Island, QC = Quebec, SK = Saskatchewan, TX = Texas, and WI = Wisconsin. Textures are: C = clay; CL = clay loam; L = loam; SCL = sandy clay loam; SL = sandy loam; SiC = silty clay; SiCL = silty clay loam; SiL = silt loam; fSL = fine sandy loam; MAT = mean annual temperature (°C); MAP = mean annual precipitation (mm); and PET = mean annual potential evapotranspiration (mm). *Sources*: 1 = Franzluebbers and Arshad (1996); 2 = Nyborg et al. (1995); 3 = Carter and Rennie (1982); 4 = Larney et al. (1997); 5 = Halvorson et al. (1997); 6 = Hendrix et al. (1998); 7 = Beare et al. (1994); 8 = Franzluebbers et al. (1999); 9 = Wander et al. (1998); 10 = Mielke et al. (1986); 11 = Blevins et al. (1977); 12 = Ismail et al. (1994); 13 = McCarty et al. (1998); 14 = Pierce et al. (1994); 15 = Pikul and Aase (1995); 16 = Black and Tanaka (1997); 17 = Eghball et al. (1994); 18 = Lamb et al. (1985); 19 = Cambardella and Elliott (1992); 20 = Lal et al. (1994); 21 = Dick et al. (1998); 22 = Angers et al. (1997); 23 = Campbell et al. (1996); 24 = Campbell et al. (1995); 25 = Peterson et al. (1998); 26 = Potter et al. (1997); 27 = Potter et al. (1998); 28 = Franzluebbers et al. (1994); 29 = Franzluebbers et al. (1995); 30 = Franzluebbers et al. (1998); 31 = Salinas-Garcia et al. (1997); 32 = Karlen et al. (1994).

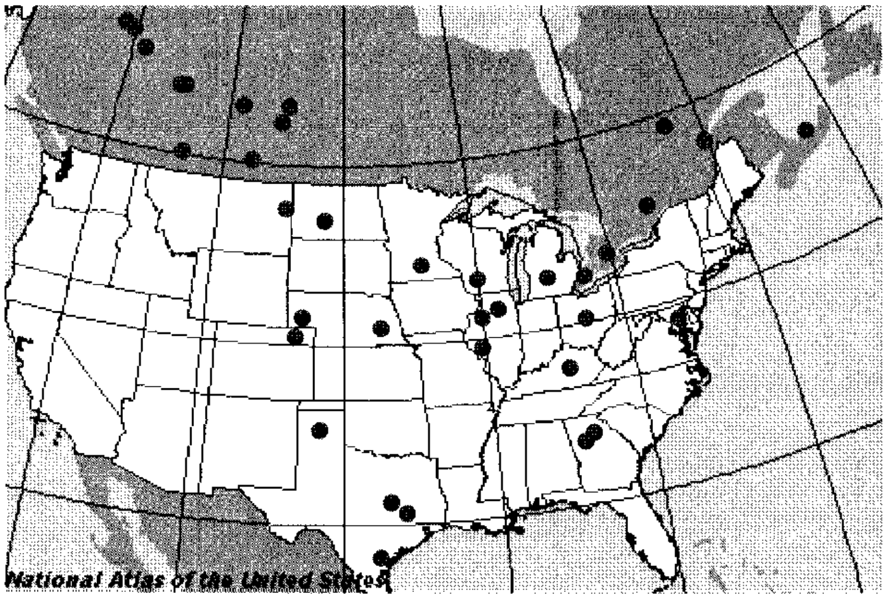

Figure 7.1 Geographical location of studies evaluated.

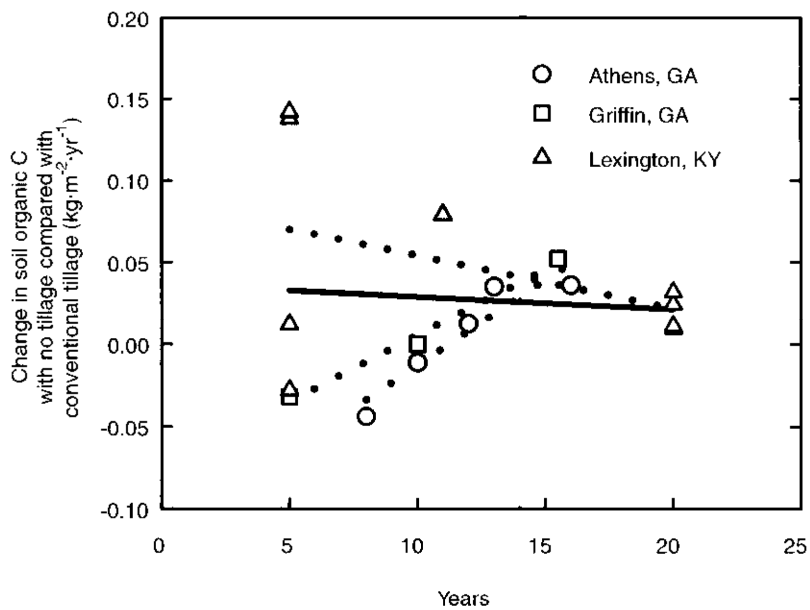

Figure 7.2 Net annualized change in soil organic C with no tillage compared with conventional tillage as affected by number of years under investigation. Data were compiled from Blevins et al. (1977), Mielke et al. (1986), Beare et al. (1994), Ismail et al. (1994), and Hendrix et al. (1998). Dotted lines are for individual locations, while solid line represents the mean of all observations.

functions using the general linear model procedure) were used to test the significance of continuous variables, including cropping intensity, temperature, precipitation, and PET. Cropping intensity was numerically expressed as the fraction of year in cropping, in which the year was divided into two halves of winter and summer cropping. For testing of univariate climatic effects (i.e., indices 1 to 6 composed of temperature, precipitation, and PET variables), mean net annualized change in SOC for each location was computed across cropping systems and N fertilization regimes.

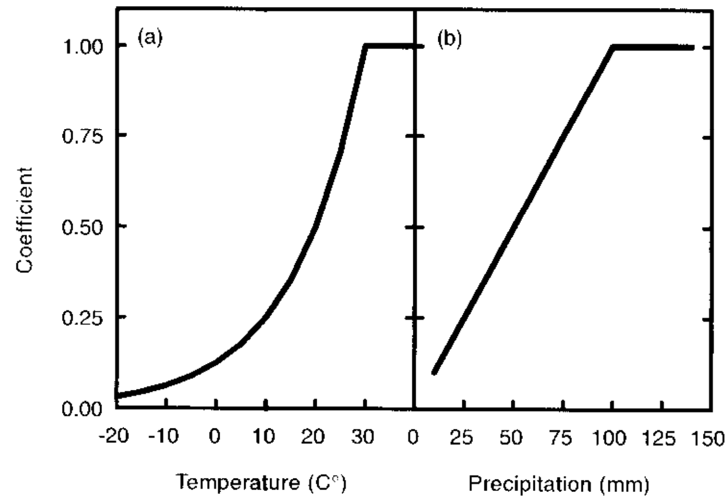

Figure 7.3 Diagrammatic representation of monthly temperature (a) and precipitation (b) coefficients used to characterize decomposition potential of locations in indices 3 and 5.

RESULTS AND DISCUSSION

General

A total of 111 comparisons between NT and CT on SOC were available from 39 locations with a wide range of temperature and precipitation coefficients (Figure 7.4). Temperature coefficients for indices 3 and 4 were highly related to latitude (Figure 7.4c), while precipitation coefficients were closely related to longitude (Figure 7.4b). Unfortunately, locations were not uniformly distributed among these gradients in order to avoid completely the confounding effects of temperature and precipitation. Locations tended to have higher precipitation at lower than at higher latitudes (Figure 7.4a) and higher temperatures at intermediate than at extreme longitudes (Figure 7.4d). To obtain a better distribution of environments in the U.S. and Canada, data from long-term studies are needed, especially from locations west of the Rocky Mountains, in southeastern U.S., and in central Canada.

Without regard to other variables, the net annualized change in SOC with NT compared with CT was normally distributed with a mean of 0.030 kg · m^{-2} · yr^{-1} ($P<0.001$ of mean = 0) (Figure 7.5). The mode and median of observations were 0.027 and 0.025 kg SOC · m^{-2} · yr^{-1}, respectively. The change in SOC with NT compared with CT was between 0.005 and 0.066 kg · m^{-2} · yr^{-1} for 50% of the observations.

Soil Type

Net annualized change in SOC with NT compared with CT was little affected by soil order (Figure 7.6). Based on a least significant difference comparison, the change in SOC was greater ($P = 0.04$) only in Inceptisols compared with Mollisols.

Net annualized change in SOC with NT compared with CT was little affected by soil textural class (Figure 7.7). Based on a least significant difference comparison, the change in SOC was greater ($P = 0.05$) only in silty clay loams compared with loams. Previous observations (Jenkinson, 1988; Amato and Ladd, 1992) and model predictions (Hassink and Whitmore, 1997) have suggested greater potential to store organic C in soils with a greater quantity of fine particles.

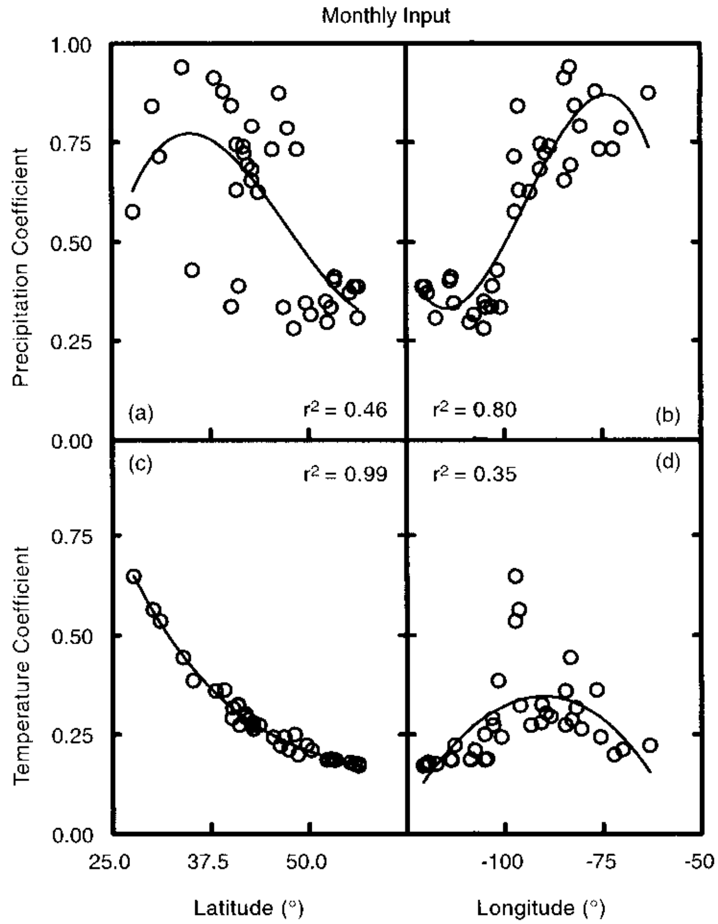

Figure 7.4 Distribution of precipitation (a) and temperature (c) coefficients along a latitudinal gradient and precipitation (b) and temperature (d) coefficients along a longitudinal gradient.

Nitrogen Fertilization

Net annualized change in SOC with NT compared with CT was unaffected by fertilizer application level. However, SOC under CT averaged 0.026 kg · m^{-2} · yr^{-1} greater ($P = 0.07$) under fertilized (102 ± 85 kg N · ha^{-1} · yr^{-1}) than unfertilized cropping. Under NT, SOC averaged 0.027 kg · m^{-2} · yr^{-1} greater ($P = 0.02$) when crops were fertilized rather than unfertilized in 15 comparisons. The additional C stored with fertilization averaged ~2.5 kg · kg^{-1} fertilizer-N applied, which is greater than the C cost of manufacturing, distributing, and applying commercial N fertilizer, estimated at 1.23 kg · kg^{-1} (Izaurralde et al., 1998).

Cropping Intensity

Net annualized change in SOC with NT compared with CT increased ($P<0.001$) with increasing cropping intensity (Figure 7.8). For example, under wheat-fallow (cropping intensity of 0.25), SOC was an average of 0.026 kg · m^{-2} · yr^{-1} less under NT than under CT. Under continuous sorghum, wheat, or corn (cropping intensity of 0.5), SOC was an average of 0.038 kg · m^{-2} · yr^{-1} greater under NT than under CT. Under double cropping (cropping intensity of 1.0), SOC was an average of 0.062 kg · m^{-2} · yr^{-1} greater under NT than under CT. More C input, and less water available to soil microorganisms by crops extracting more water with increasing cropping intensity, would likely

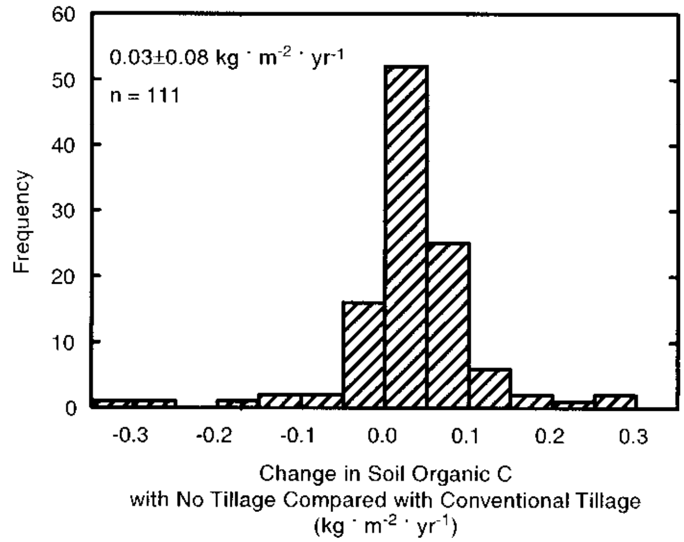

Figure 7.5 Frequency distribution of the net annualized change in soil organic C with no tillage compared with conventional tillage.

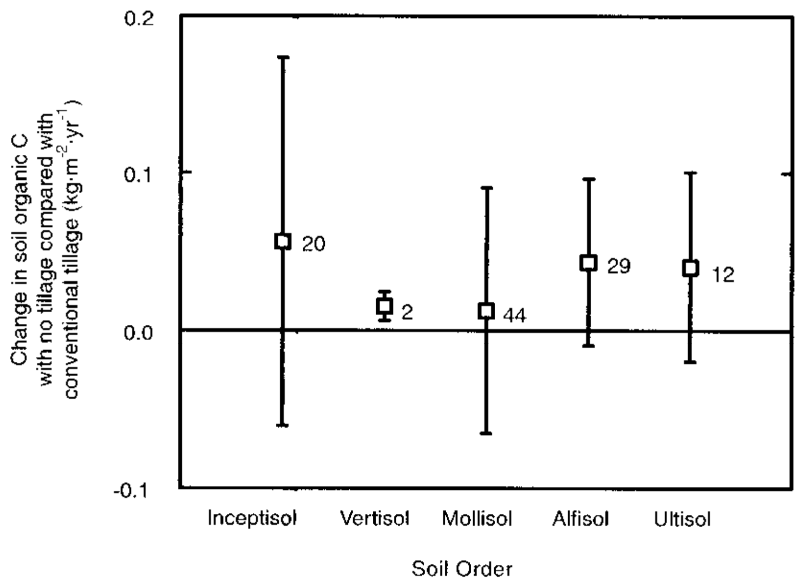

Figure 7.6 Mean and standard deviation of the net annualized change in soil organic C with no tillage compared with conventional tillage as affected by soil order. The number beside the mean is the number of observations.

leave more plant-derived C at the soil surface under conditions less ideal for decomposition than if incorporated. Increasing cropping intensity would utilize available water in winter–spring more effectively to provide more C input.

Climate Indices

Since locations varied in fertilizer rate, cropping intensity, and length of time under investigation of NT compared with CT, a mean difference in SOC storage between tillage regimes across these variables for each location was computed (n = 39). Data were also sorted by rank of each climate index and then a mean computed for each group of three locations to reduce some of the large variation in net annualized change in SOC among locations.

Index 1 (i.e., mean monthly precipitation-to-potential evapotranspiration ratio) was poorly related to net annualized change in SOC with NT compared with CT (Figure 7.9a). Index 1 values

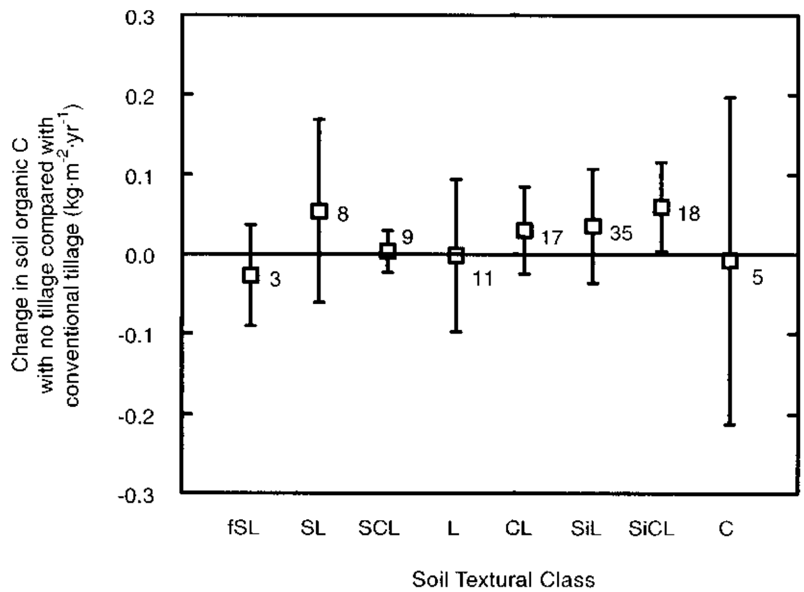

Figure 7.7 Mean and standard deviation of the net annualized change in soil organic C with no tillage compared with conventional tillage as affected by soil textural class. The number beside the mean is the number of observations. (Note: fSL is fine sandy loam, SL is sandy loam, SCL is sandy clay loam, L is loam, CL is clay loam, SiL is silt loam, SiCL is silty clay loam, and C is clay.)

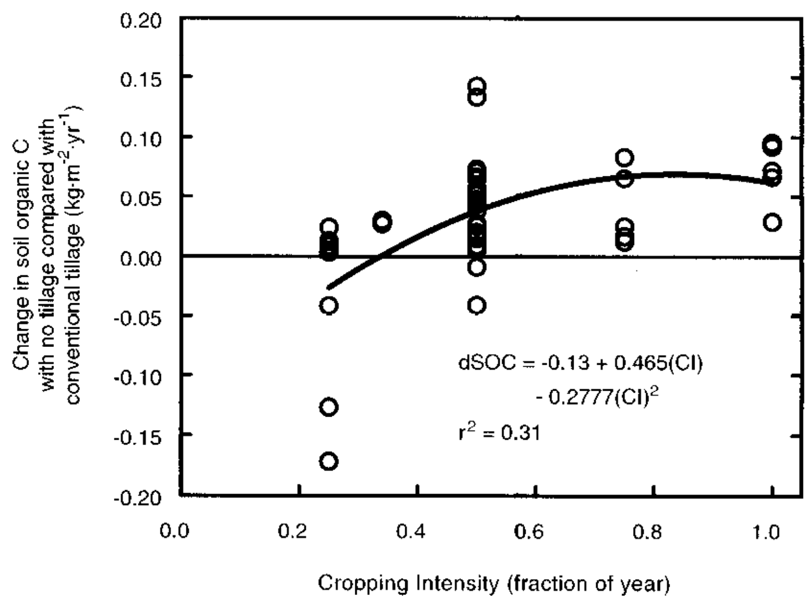

Figure 7.8 Net annualized change in soil organic C with no tillage compared with conventional tillage as affected by cropping intensity.

differed little, partly because precipitation exceeded potential evapotranspiration during winter months at most locations. Across all locations, index 1 values were assigned a value of 1 during 59 ± 13% of the months. Index 2 (i.e., mean annual precipitation-to-potential evapotranspiration ratio) indicated that maximum potential SOC storage with NT occurred at a ratio of 1.27 mm · mm^{-1} (Figure 7.9b). No benefit of NT on potential SOC storage would be expected at an index 2 level <0.75 mm · mm^{-1}, probably because low precipitation limits the potential of plants to fix C or limits decomposition under both tillage regimes, even when crop residues are mixed with soil using CT. At index 2 levels exceeding 1.75 mm · mm^{-1}, there was also little potential SOC storage with NT. Abundant precipitation would reduce potential SOC storage with NT because surface-placed residues would be moist more frequently or for a longer period of time, leading to rapid decomposition of residues under NT, similar to that under CT.

Indices 3 and 4 (i.e., combined temperature and precipitation coefficients on a monthly and annual basis, respectively) also indicated climatic controls on potential SOC storage with NT (Figure 7.10). Drier and colder locations had poor potential to store additional C with NT compared with CT, whereas mild locations (i.e., neither dry and cold nor wet and hot) had the greatest potential. Interestingly, indices 4 and 2 (i.e., on an annual basis) were better related to the change in SOC with NT compared with CT than were indices 3 and 1 (i.e., on a monthly basis). This indicates that these simple annualized climatic descriptions of locations could more effectively predict potential SOC storage with NT than seasonal descriptions. However, large variation in potential SOC storage occurred among the three locations used to obtain means, suggesting that much more work is needed to elucidate the intricacies of soil organic matter dynamics as affected by management and climate.

Indices 5 and 6 (i.e., most limiting temperature or precipitation coefficient on a monthly and annual basis, respectively) produced climatic responses similar to other indices (Figure 7.11). Most locations had monthly limitations due to temperature, although 28% had at least one month with a precipitation limitation. As an example, Akron, CO, was limited by precipitation rather than by temperature during 7 months. On an annual basis, only Corpus Christi, TX, had a precipitation limitation rather than a temperature limitation.

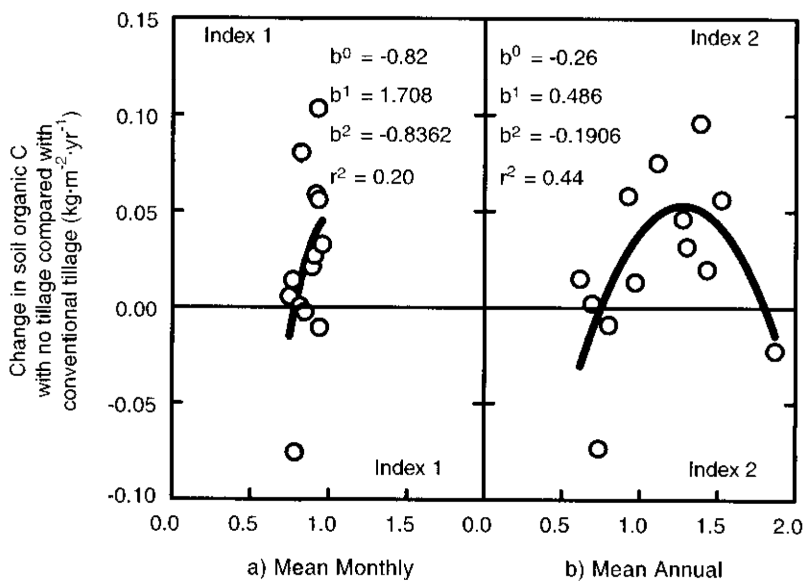

Figure 7.9 Net annualized change in soil organic C with no tillage compared with conventional tillage as affected by precipitation-to-potential evapotranspiration ratio on a mean monthly (a) and a mean annual (b) basis. Points represent the means of 3 consecutively ranked locations. Regression equations are of the form: $\Delta SOC = b_0 + b_1 \cdot (P/PET) + b_2 \cdot (P/PET)^2$.

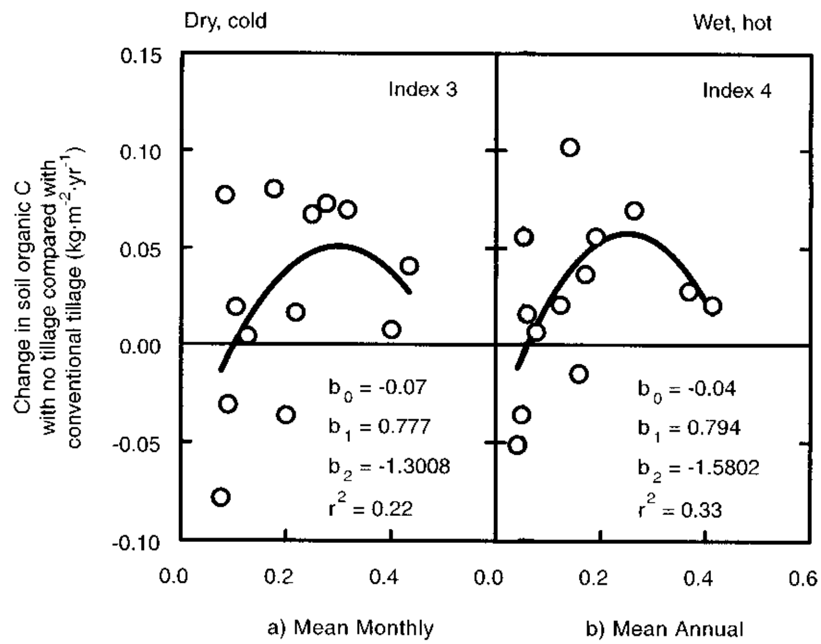

Figure 7.10 Net annualized change in soil organic C with no tillage compared with conventional tillage as affected by the product of temperature and precipitation coefficients on a mean monthly (a) and a mean annual (b) basis. Points represent the means of 3 consecutively ranked locations. Regression equations are of the form: $\Delta SOC = b_0 + b_1 \cdot (TxP) + b_2 \cdot (T \times P)^2$.

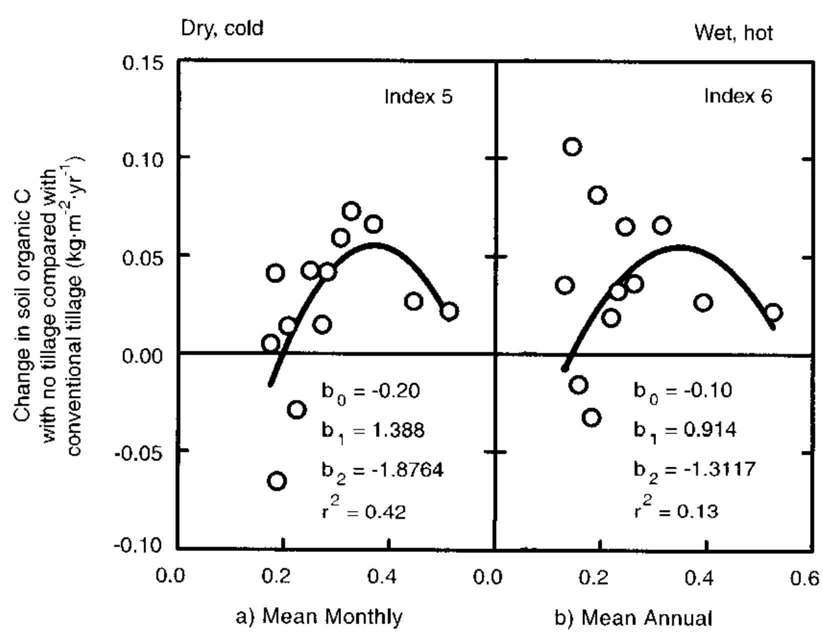

Figure 7.11 Net annualized change in soil organic C with no tillage compared with conventional tillage as affected by the most limiting climatic coefficient (i.e., temperature or precipitation) on a mean monthly (a) and a mean annual (b) basis. Points represent the means of 3 consecutively ranked locations. Regression equations are of the form: $\Delta SOC = b_0 + b_1 \cdot (MLCC) + b_2 \cdot (MLCC)^2$.

Mean annual precipitation-to-potential evapotranspiration ratio (index 2; Figure 7.9b) and mean monthly most limiting climatic coefficient (index 5; Figure 7.11a) were the best predictors of net annualized change in SOC with NT compared with CT. To achieve 90% of maximum net annualized change in SOC, regressions suggested that locations have (1) mean annual precipitation-to-potential evapotranspiration ratios of 1.11 to 1.44 mm · mm^{-1}, (2) mean monthly most limiting climatic coefficients of 0.19 to 0.31, or (3) mean annual temperature × precipitation coefficients of 0.32 to 0.42. Geographical locations in North America that meet these restrictions are in parts of Illinois, Indiana, Ohio, and Kentucky (Figure 7.12). A wider area encompassing one or more of these restrictions extends from the panhandle of Texas in the west to the coastal plain of Maryland in the east and from the piedmont region of Georgia in the south to the prairie region of Minnesota in the north (Figure 7.12). Much lower potential in SOC storage with NT compared with CT was observed in more extreme environments, including the dry Great Plains region and the cold, humid eastern provinces of Canada. However, more data are needed to validate and strengthen the confidence of these relationships.

In a multivariate analysis, none of these climatic variables interacted significantly with cropping intensity. Thus, in all regions the most intensive cropping systems (i.e., greatest C input) would produce the maximum potential SOC storage with NT compared with CT. On a practical level, this might mean shifting from (1) wheat–fallow to a wheat–sorghum–millet opportunity cropping in the central Great Plains, (2) continuous corn to a corn and wheat–soybean and vetch cover cropping system in the Midwest, or (3) continuous cotton to a cotton and clover–sorghum and wheat double cropping system in the southeastern U.S.

The analyses in this review of literature were restricted to the effect of NT compared with CT on SOC storage only and do not imply that NT is an inappropriate technology for semiarid and humid regions. NT offers many other important benefits, including reducing fossil fuel consumption and labor inputs, reducing soil erosion and water runoff, increasing soil aggregation and water infiltration, creating wildlife and soil biotic habitat, etc. These should be considered as incentives for producers to adopt this conservation management system.

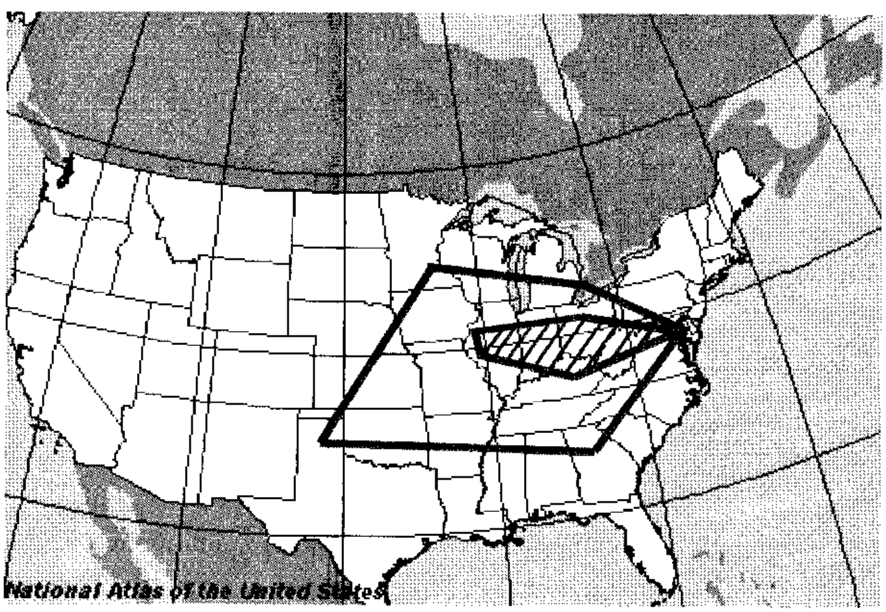

Figure 7.12 Geographical locations of maximum potential soil organic C storage with no tillage compared with conventional tillage meeting each criterion of indices 2, 4, and 5 (inner striated loop) and meeting any criterion of indices 2, 4, and 5 (outer loop).

CONCLUSIONS

It can be concluded from an analysis of available data in the literature that potential SOC storage with NT compared with CT was greatest (~0.050 kg · m^{-2} · yr^{-1}) in mesic, subhumid regions of North America with mean annual precipitation-to-potential evapotranspiration ratios of 1.1 to 1.4 mm · mm^{-1}. Much lower potential in SOC storage with NT compared with CT was observed in more extreme environments, including the dry Great Plains region and the cold, humid eastern provinces of Canada. However, more data are needed to validate and strengthen confidence in these relationships.

Soil order and soil textural class had little effect on potential SOC storage with NT. Interaction of tillage regime with other management variables on potential SOC storage occurred with cropping intensity, but not with level of fertilization. Potential SOC storage with NT compared with CT increased when cropping intensity increased, regardless of climatic conditions. Published data from North America were summarized so that policies to encourage or discourage land use for enhancing SOC storage could be developed on an objective basis.

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