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Soil cover governs soil loss on United States claypan soils

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Abstract. Soil surveys before 1936 showed that midwestern farmers had lost about 17.5 cm (about one-half) of the original topsoil from the sloping claypan soils in about 70 years of clean-till farming. Production declined rapidly with continued removal of nutrients and topsoil in runoff.

Early research showed that the use of adequate fertilizer and good residue management practices were helpful in reducing soil loss. However, these were inadequate during extremely wet seasons. Soil loss in 1969 from areas sown with corn continuously and grown with previously 'acceptable practices' was 143 tonnes/ha. Most of the soil loss occurred when the soil cover was inadequate.

Research (1954–1973) showed that leaving about 50 per cent of the previous crop's residue on the soil surface at planting reduced soil loss to less than one-half that from conventional (clean-tilled) seedbeds. The average annual loss for the 20-year period was 2.69 and 6.05 tonnes/ha, respectively.

Research (1970–1973) showed that no-till planting techniques in which corn is planted directly through the previous crop's residue, or in a cover crop, reduced soil loss to about one-eighth that of conventionally tilled corn. The average annual losses were 1.28 and 9.75 tonnes/ha, respectively. Corn yields were nearly equal from all treatments.

Le couvert végétal régie la perte en terre des sols argileux aux Etats-Unis

Résumé. Des études sur le terrain faites avant 1936 ont montré que les fermiers du Middle West ont perdu à peu près 17.5 cm, soit près de la moitié de l'horizon supérieur originel des terres argileuses en pente, en à peu près 70 ans d'exploitation agricole utilisant des moyens réguliers de culture. La production agricole s'est rapidement abaissée avec l'enlèvement continu des substances nutritives et de la partie supérieure du sol par le ruissellement.

Les premières études ont montré que l'emploi rationnel d'engrais et de bonnes pratiques d'utilisation des résidus de culture aidaient à réduire la perte en terre. Cependant, ces mesures se sont révélées insuffisantes pendant les saisons humides. La perte en terre, en 1969, sous culture continue du maïs avec 'de bonnes pratiques' fut de 143 tonnes métriques par hectare. La plupart des pertes en terre sont survenues quand la couverture végétale du terrain était insuffisante.

Des études (1954–1973) ont montré que laisser environ 50 pour cent des résidus de récolte de l'année précédente à la surface du sol lors de la plantation réduisait de plus de moitié la perte en terre par rapport à celle qui se produit lors de semis conventionnels. Les pertes moyennes annuelles pour cette période de 20 ans furent respectivement de 2.69 et 6.05 tonnes métriques par hectare.

Des études (1970–1973) ont montré que la plantation du maïs sans travail du sol, faite directement à travers les résidus de la récolte de l'année précédente ou sur une plante de couverture, réduit la perte en terre au huitième de celle engendrée par une culture du maïs par labour conventionnel. Les pertes moyennes annuelles ont été respectivement de 1.28 et 9.75 tonnes métriques par hectare. Les rendements en maïs sont restés à peu près égaux pour tous les traitements.

INTRODUCTION

The degree of cover on the soil surface largely governs the erosion of claypan soils (soils with a significant argillic horizon or clay accumulation) in the United States. Keeping soil covered with a crop residue mulch or a living crop is important on all soils because a good cover dissipates the kinetic energy of the falling rain. This is a primary detaching force inducing erosion. Vegetative cover also reduces surface sealing and sustains higher water infiltration rates for longer periods of time and reduces runoff rates. Such a cover is especially important on claypan soils with a limited

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water storage capacity above a horizon with a low hydraulic conductivity, since excess water can cause erosion.

Whitaker *et al.* (1961) characterized the claypan soils of the Midwest United States as having gently rolling topography, low fertility, and a clay subsoil layer (containing over 55 per cent of less than 2-micron clay) of low permeability. The clay subsoil layer, which usually occurs below the 40 to 50-cm depth (depending on previous erosion), restricts air and water movement and retards the development of plant roots. The A horizon (usually a silt loam above the claypan) and the claypan are frequently quite acid (pH less than 5). Jamison *et al.* (1968) and Scrivner *et al.* (1966) further describe and characterize these claypan soils. The total area of claypan soils is approximately 4.05×10^6 ha, principally in Missouri, Illinois, and Kansas. Less extensive areas are in Nebraska, Oklahoma, and Iowa.

Conservation of the topsoil is very important with such a shallow, erodible surface soil. Field crops rely on the soil above the claypan horizon for most nutrients. With continued fertilization, however, plants grown on these soils respond significantly and root densities increase in deeper zones. Early research (Smith, 1946) showed that each additional centimetre of topsoil, to a depth of 25–30 cm, increased corn yields about 100 kg/ha.

Smith and Whitt (1948), in their research on the maintenance of high crop yields, concluded that losses from sloping claypans should not exceed 6.7 tonnes/ha per year. Higher losses caused productivity and soil tilth to decline because of the depletion of nutrients and organic matter.

CLAYPAN SOIL LOSS HISTORY AND PREVIOUS RESEARCH

The need for improved farming methods on the large areas of Midwest claypen soils became very apparent during the period of low farm incomes, 1930–1936. Soil surveys completed by 1936 showed that the farmers in Missouri and other midwestern states had lost about 17.5 cm (or about one-half) of the original topsoil from the sloping claypan soils in about 70 years (Jamison *et al.*,1968). In an effort to increase farm income, additional areas of these native prairie-covered soils were ploughed and planted with small grains and intertilled crops usually without adding fertilizer and without regard to slope gradient or row direction. Production continued to decline sharply because of continued removal of nutrients and topsoil by crops and runoff. Jamison *et al.* (1968) showed that corn yields in a corn–oats rotation with no fertilizer application averaged 1781 kg/ha for 1940–1946 and only 1273 kg/ha for 1947–1951 on small plots at the Claypan Experiment Station east of Columbia, Missouri. Later data showed that the average yield for 1952–1969 was even less, 1129 kg/ha. During 5 of these 18 years, yields were less than 627 kg/ha. Soil losses from these plots were excessive.

Adequate fertilizer, which induces early and extensive plant growth, and good residue management are the prime contributors to good soil cover. Research on improved soil fertility and crop rotations to provide more soil cover and to increase yields began in 1940 at the Claypan Experiment Station. By today's (1974) standards, however, the fertilizer applications were very light and did not include nitrogen. Nevertheless, the improved crop response resulted in significant reductions in runoff and soil loss. For example, during the 9 months from seeding to harvesting (10 October to 28 June 1941–1946), runoff was reduced 11 per cent and soil loss 23 per cent by the additional cover that resulted from a 91 kg/ha per year application of 0–20–10 (N, P_2O_5, K_2O) fertilizer on wheat plots in rotation and an initial application of 6700 kg/ha of lime. During the grain crop year of the rotations, 1947–1951, soil fertility treatments raised the P, K, and Ca to computed sufficiency levels and commercial nitrogen fertilizer was added. The applications were based on chemical so tests.

The experiments were revised in the fall of 1953: (1) to test the effect on runoff and erosion of several fertility levels on continuous corn and on corn in a rotation that included 2 years of meadow and (2) to determine the effect on runoff and erosion in a seedbed prepared for continuous corn by using a field tiller or cultivator (no-plough method) which left 50 to 60 per cent of the crop residue on or near the surface, compared with that of a ploughed seedbed (no cover). Full treatment was a basic application of phosphate, potash, and lime on the soil surface before ploughing to raise the P_2O_5 level (Bray's P_2 test) to 224 kg/ha, K to 2.4 per cent of the exchange capacity, and Ca to 80 per cent of the exchange capacity. In addition, 224 kg/ha of 33–0–0 was applied before ploughing, 224 kg/ha of 5–20–20 was applied at planting, and 224 kg/ha of 33–0–0 was used as sidedressing when the corn plants were about 25 cm tall. In the continuous corn system, an additional 112 kg/ha of 33–0–0 was applied before ploughing.

The research begun in 1954 on the effects of soil cover (obtained through the use of fertilizer and good residue management) on soil loss and corn yield was continued through 1973. The 20-year results presented in Fig.1 (A) show that the average soil loss for corn with conventional tillage was below, but near, the maximum limit of 6.7 tonnes/ha above which production declines. The soil loss from no-plough plots was less than one half that from conventionally tilled seedbeds. The precipitation averaged 146 mm below normal during the first 12 years of this 20-year comparison, followed by 4 years during which a uniform amount of water was applied immediately before some rainstorms during the growing season to increase the occurrence of runoff from all treatments, and then 4 years during which water was applied at selected stages of plant growth to obtain runoff from all treatments. However, because of low rainfall intensities following the applications of water during the first 4-year period and low application rates during the last 4-year period, soil losses were not increased significantly. Figure 1 (B) shows that, during the two wet years (1969–1970), soil loss from the conventionally tilled corn plots was about 79.4 tonnes/ha (about six times the acceptable maximum), including much organic material and nutrients. The high erosion rates always occurred when soils were bare, or cover was inadequate to

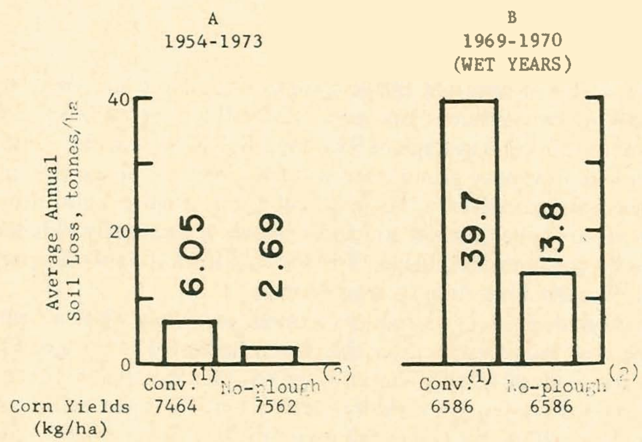

FIGURE 1. Effect of cover on soil loss and corn yields, long-term and two wet years.
(1) Conventional tillage (plough, disc, and plant); mechanical cultivation.
(2) No-plough (field cultivate once and plant); mechanical cultivation.
(3) No-till (plant directly through crop or residues without prior tillage); chemical weed control.

dissipate the rainfall energy. During these two wet years, corn yields were below the 20-year average, undoubtedly due to retarded early plant growth and poor soil aeration.

On adjacent plots, in a study of continuous corn grown for silage with soil tillage practices that were previously considered adequate, the soil loss in 1969 was 143 tonnes/ha. This is equivalent to more than 1.3 cm of topsoil from the surface area, a loss that could not be tolerated.

RECENT RESEARCH

Research results for the 4 years (1970–1973, Fig.2), 1 wet year and 3 years of near-average rainfall during the growing season, showed that a no-till system of corn production reduced erosion more than other seedbed and tillage systems previously studied. This no-till system consisted of planting corn directly through the previous crop residue or through a rye cover crop killed with a contact herbicide at planting time. Weeds were controlled with chemicals. With the no-till system, soil loss was about one-third of that with the no-plough system and about one-eighth of that with conventional tillage. Under the conventional tillage system, the soil loss again exceeded the acceptable loss limit of 6.7 tonnes/ha per year.

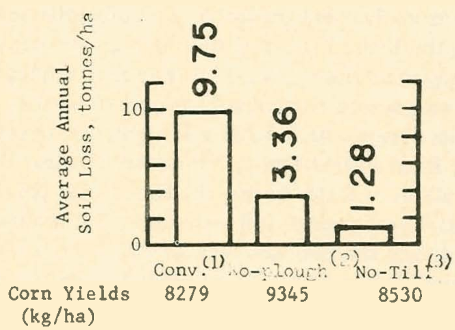

FIGURE 2. Effect of cover on soil loss and corn yields, 1970–1973. (See caption to Fig.1 for meaning of (1),(2),(3).)

Figure 3 shows the effects of different tillage systems on soil loss and yields for the first year of corn following two different land uses. Rainfall during 1970 was 246 mm higher than the long-term (83-year) average of 943 mm. Soil loss from the conventionally tilled plots which had previously grown corn was five times the acceptable maximum. The soil loss was also excessive on the no-plough plots. Figure 3 also shows that the conservation value of the meadow sod and its cover is drastically reduced when ploughed under by conventional tillage. The soil loss from the no-till system was well within the acceptable limit in both crop systems.

The no-till system of grain production reduces erosion, especially when a winter cover crop of rye is planted immediately after the corn is harvested for silage. (The same erosion control was noticed when a winter cover was planted after soybeans. In this case to obtain a good winter cover, the rye seed is broadcast just before the leaves of the soybean drop. When the leaves fall they provide a cover for the seed.) During some storms, especially those following soil tillage, runoff from conventionally farmed plots contained a high sediment concentration; however, the runoff from no-till farmed plots contained only an organic stain.

Keeping a cover on the soil surface is the key to reducing soil loss. The no-till system of grain production controls erosion but necessitates adequate fertilization to

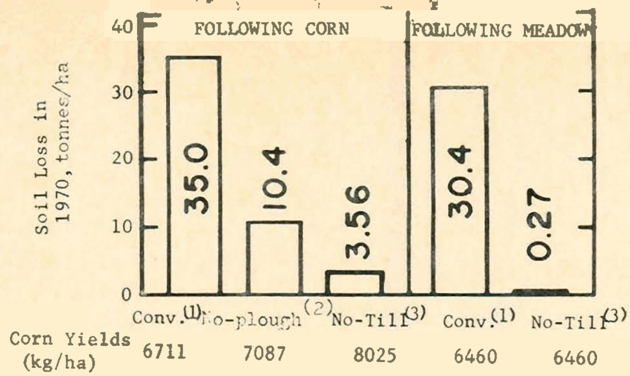

FIGURE 3. Effect of cover on soil loss and corn yields, 1970. (See caption to Fig.1 for meaning of (1),(2),(3).

promote the current cover growth. Effective residue management from the previous crop is also required.

An incidental but important side benefit is that during energy crises, the no-till system drastically reduces power and machine fuel requirements in the cultural operations of crop production.

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