# Deep Plowing Improves Sodic Claypan Soils

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**Sodic claypan soils of western North Dakota (also called Natriboroll or Solonetzic) are improved by deep plowing. Plowing 24 to 30 inches deep crumbles the dense subsoil layer and brings up natural gypsum (calcium sulfate) from below the pan, which permits a physical-chemical change to form a better soil. Density is reduced, permeability and water holding capacity are increased, and crop production is benefited.**

Substantial increases in small grain production under dryland agriculture have been obtained by deep plowing sodic claypan soils of western North Dakota (2,3). The deep plowing was performed 24 to 30 inches deep.

About 17 million acres of these soils are found in the Northern Plains of the United States, including about 3 million acres in North Dakota. More than 12 million acres are found in the Canadian prairie provinces. These soils have a shallow, dense subsoil (B horizon), which is high in exchangeable sodium (1) — hence the term "sodic claypan" (Figure 1). Affected land presents problems in seeding and normal tillage operations. Water infiltration and normal root development is severely restricted, and the overall result is poor productivity. Immediately below the dense layer is a calcareous (high in calcium carbonate) soil zone, which also contains natural or native gypsum (calcium sulfate). The soil is classified as a "Natriboroll"; the older term "Solonetzic" is also frequently used. Affected landscapes are commonly called "scab-land", "scab-spot land", or "pan-spot land". Principal soil series in southwestern North Dakota are Rhoades and Belfield.

### Deep Plowing Studies

Field plot studies were started in North Dakota in 1962 on small 4 x 4-foot plots where the "deep plowing" was performed tediously by hand. After three years, results from these small plots showed that either commercial gypsum added as an amendment, or by mixing the upper 1.5 feet, improved permeability and increased grass yields. Soluble salts in the soil were reduced by the leaching effect of natural precipitation.

In 1965, we initiated a study near New Salem in Morton County, where 0.7-acre plots were plowed

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2 feet deep with a large moldboard-type plow, with and without added gypsum (2). The deep plowing was performed only once at the start, and thereafter all plots were treated the same. The study was terminated in 1974 after nine years of observations. Measurements made during the study included soil chemical composition, soil water content, soil density, soil crust hardness, soil fertility, and crop yields.

Since 1970, several experimental-demonstration fields were deep plowed in cooperation with farmers.

Two locations south of Belfield in Stark County were deep plowed in 1972 and are identified in Table 1 as Brinster No. 1 and No. 2 (two miles apart). Wheat yields on summer fallow were measured yearly (duplicate plots), during the next four years (1973-1976).

The soils at the three sites were classified as Rhoades and Belfield. Except for deep plowing, the plots at each individual site were fertilized with nitrogen and phosphorus and farmed alike. Because of slightly deeper depth to the native gypsum, the Brinster No. 1 site was plowed about 6 inches deeper than at the other locations.

**Benefits on a fallow-crop rotation**

At the New Salem study, barley was grown the first four years, and spring wheat afterwards. The yield increases from deep plowing during the fifth through ninth year from a fallow-wheat rotation ranged from 5 to 16 bushels and averaged 9 bushels per acre (Table 1). Deep plowing also increased barley yields. Because these soils contain native gypsum within the plowing depth, the added gypsum had no appreciable effect.

At the Brinster Site No. 1 where the sodic claypan soil problem was moderate, the check averaged 27 bushels per acre and the deep plowing 37 bushels per acre, an average gain of 10 bushels. At the Brinster Site No. 2, which represented a more severe sodic soil problem, deep plowing increased wheat yields over the four-year period an average of 13 bushels per acre.

The average long-term gain or increase in wheat production on fallow for the three experimental sites shown in Table 1 was 11 bushels per acre (about 660 pounds per acre more grain). These increases in wheat production compare favorably with yields from several other sodic claypan sites where we have deep plowed. The average wheat production on fallow for the two-year period (1974-1975) from nine SEA-farmer cooperative research plots was 20 bushels per acre on checks and 32 bushels on deep plowed plots (data not shown).

**Why Deep Plowing Works**

Deep plowing reduces soil density, especially in the 12 to 24-inch depth, which increases soil water storage capacity and facilitates plant root development (Table 2). Deep plowing increases soil water storage and leaching opportunities during fallow periods and during the cropping season when extra precipitation is received. The greater water storage, combined with increased ability of the vegetation for water extraction, represents a substantial increase in the available water supply — averaging about 2 inches more water in the upper 3-foot soil profile for deep plowing as compared with conventional plowing.

Deep plowing breaks up the dense claypan and mixes the calcium sulfate of lower depth with the sodic soil, which reduces soil density and increases permeability (2). The calcium from gypsum exchanges with soil sodium, and in time reduces the sodic-saline soil properties. The increase in water infiltration, in turn, results in more soil water available for plant use and for leaching of soluble salts, which increase crop production. The improved soil-water-plant relationships caused by deep plowing also mean less runoff and less erosion after precipitation events.

Laboratory soil analyses from two sites are

**Table 2. Soil bulk density measured at the New Salem site five years after deep plowing.**

| PLOWING TREATMENT | SOIL DEPTH, INCHES 6-12 | 12-24 | 24-36 |
|---|---|---|---|
| | Bulk density, g/cm³ | | |
| Check | 1.46 | 1.57 | 1.62 |
| Deep plowing | 1.44 | 1.40 | 1.65 |

* *Each value is the average of 16 measurements (4 cores per plot x 4 replicated plots)*

**Table 1. Deep plowing sodic claypan land in western North Dakota increased wheat yields on fallow at three locations.**

| SITE; CROP YEARS | YIELDS CHECK | DEEP PLOWING* | GAIN | |
|---|---|---|---|---|
| | Bushels/acre | | | % |
| New Salem, 5-Yr Avg. | 30 | 39 | 9 | 30 |
| Belfield (Brin. No. 1), 4-Yr Avg. | 27 | 37 | 10 | 37 |
| Belfield (Brin. No. 2), 4-Yr Avg. | 16 | 29 | 13 | 81 |
| Average for 3 sites | 24 | 35 | 11 | 46 |

* *Deep plowing performed at New Salem in 1965, and at Belfield in 1972.*

shown in Table 3. These analyses were performed on soil saturation extracts and tabulated are the electrical conductivity (EC), which evaluates general salinity; the sodium adsorption ratio (SAR), which evaluates the sodic status; and soluble sodium content. The results show that after four years the EC was reduced, and because soluble sodium was decreased, the SAR was also lowered even at depths deeper than plowed. The SAR is highly correlated with the exchangeable sodium percentage in these soils.

**Table 3. Chemical analyses* of the soil from two test sites four years after deep plowing.**

| PLOWING TREATMENT | SOIL DEPTH, INCHES 0-6 | 6-12 | 12-24 | 24-36 |
|---|---|---|---|---|
| SITE: Brinster No. 1, Stark County | | | | |
| | Elect. conductivity (EC) | | | |
| Check | 1.5 | 1.6 | 5.6 | 8.4 |
| Deep plowing | 1.4 | 1.4 | 3.3 | 4.6 |
| | Soluble sodium (Na) | | | |
| Check | 7 | 11 | 39 | 57 |
| Deep plowing | 5 | 6 | 12 | 23 |
| | Sodium Adsorption Ratio (SAR) | | | |
| Check | 4.3 | 6.8 | 9.8 | 11.4 |
| Deep plowing | 2.2 | 2.4 | 3.4 | 5.5 |
| SITE: New Salem, Morton County | | | | |
| | Elect. conductivity (EC) | | | |
| Check | 1.0 | 2.0 | 6.8 | 8.0 |
| Deep plowing | 1.0 | 1.2 | 3.6 | 6.5 |
| | Soluble sodium, (Na) | | | |
| Check | 9 | 16 | 50 | 64 |
| Deep plowing | 6 | 10 | 26 | 52 |
| | Sodium Adsorption Ratio (SAR) | | | |
| Check | 7.3 | 11.0 | 12.1 | 14.5 |
| Deep plowing | 4.5 | 7.8 | 9.8 | 13.2 |

* *Analyses of saturation extracts. Expression units are: EC in millimhos per cm at 25°C; Na in meq per liter;* $SAR = Na / \sqrt{(Ca + Mg)/2}$

The long-term production results, like those obtained after nine years, give strong evidence that the improved land capability for increased crop productivity is relatively permanent.

**Fallow vs Continuous Cropping**

A three-year yield comparison (Table 4) of continuous (or recropped) wheat with wheat produced after summer fallow at two locations, New Salem and Brinster No. 2, showed that deep plowing and summer fallow increased the average yield 11 bushels per acre, while deep plowing on continuously cropped land increased the average yield by 7 bushels. The comparison was made at the New Salem site in 1973 and 1974, and at the Brinster site in 1976. The crop rotation comparison showed that deep plowing on recropped land gave essentially the same average yields of wheat (20 bushels per acre) as did the check plowing treatment after a season of fallow. The highest yields were obtained after summer fallow on deep-plowed plots. The recropped plots were fallowed the season after deep plowing.

The importance of these results, however, is magnified by noting that a crop was produced only on half the land area under the fallow rotation as compared with the recropped land. Fallow for the first few seasons after deep plowing seems necessary. After sufficient leaching is accomplished, the need for fallow is reduced.

**Other Trade-Offs and Potentials**

Deep plowing also causes undesirable trade-offs associated with the above mentioned benefits. Some unwanted soluble salts, mostly sodium and magnesium sulfates, are frequently found mixed with the desirable native calcium sulfate. The deep plowing treatment initially results in a slight to moderately

**Table 4. Comparison of deep plowing effect on wheat yields for 3 years on fallow and continuous cropping at two locations.**

| SITE; CROP YEARS | YIELDS CHECK | DEEP PLOWING* | GAIN | |
|---|---|---|---|---|
| | Bushels/acre | | | % |
| FALLOW | | | | |
| New Salem; 1973-74 Avg. | 23 | 30 | 7 | 30 |
| Belfield (Brin. No. 2); 1976 | 17 | 32 | 15 | 88 |
| Average for 2 sites | 20 | 31 | 11 | 55 |
| CONTINUOUS CROPPING | | | | |
| New Salem; 1973-74 Avg. | 16 | 21 | 5 | 31 |
| Belfield (Brin. No. 2); 1976 | 11 | 20 | 9 | 82 |
| Average for 2 sites | 13 | 20 | 7 | 54 |

* *Deep plowing performed at New Salem in 1965 and at Belfield in 1972.*

saline surface. However, this condition is temporary and in time the salts are leached. To accelerate the leaching process, summer fallow after deep plowing is strongly recommended because when natural precipitation exceeds evapotranspiration, especially during fallow periods, leaching occurs.

A second undesirable trade-off is more permanent. Because clay content is greater in the subsoil, the deep plowing results in a finer textured surface than was present before treatment. However, based on the relatively permanently improved productivity, there is no doubt that the trade-offs greatly favor deep plowing.

The potential to increase crop production in the northern plains is considerable when we become aware of the large acreage of similarly affected land for which these studies have application. Besides increasing small grain yields, deep plowing also permits a wider latitude for crop selection. Deep-rooted crops and crops with greater moisture requirements, like alfalfa, grass, and trees, should grow better.

To avoid mistakes, deep plowing should not be performed until the soil has been checked to be one that will probably respond to treatment.

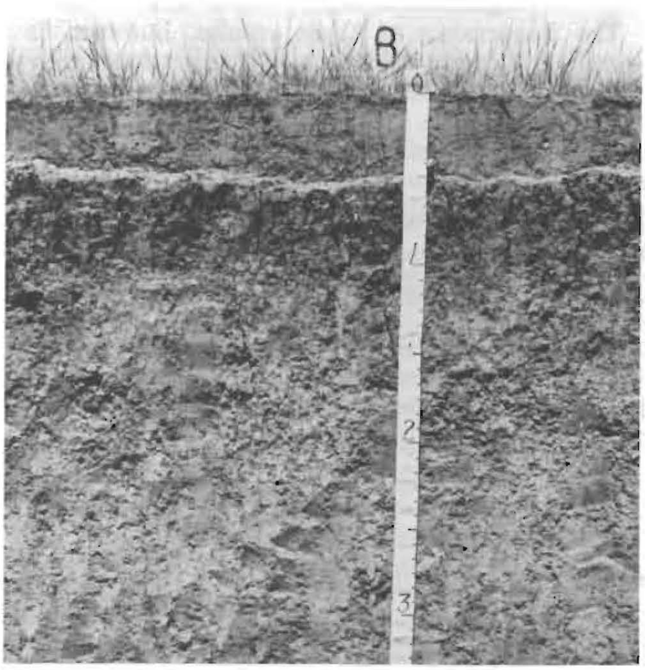

**Figure 1. Profile of the problem soil is characterized by a dense, fine-textured, slowly permeable, sodic layer (seen here between 6 and 12 inches depth). Native gypsum (calcium sulfate) is present at the lower depth — usually at 18 to 24 inches.**

### Costs and when to plow

The cost of deep plowing 24 to 30 inches depends on several things, among which are: the type of plow used, the dimensions of the field plowed, and soil properties, including moisture content, which influence power required. An approximate cost is about $30 to $40 per acre. If the farmer owns the equipment, the cost might be substantially less. We have used three kinds of large plows capable for deep plowing, which differ widely in cost and performance. Two of the plows were large moldboard-type, differing in bottom width, and we used a large disk-type plow. The different plows have both advantages and disadvantages.

We have deep plowed under a wide range of conditions and conclude that soil moisture content is important in determining the best time to plow. When the soil is too dry, the soil breaks into large and extremely hard clumps, increasing the post-plowing land preparation requirements; depth penetration is more difficult, power requirements are greater, and wear and tear on the equipment is increased. When the soil is too wet, it does not crumble and mix as desired. The best soil improvement is achieved when the soil is mixed well. Poor mixing may also result when plowing frozen soil.

It was often difficult to penetrate the dense claypan to the gypsiferous subsoil layer with the large disk-type plow, but good soil mixing was achieved to the depth plowed. The most economical plowing was probably with the narrow moldboard-type plow, designed to be pulled at faster speeds with a 4-wheel drive tractor (Fig. 2).

**Figure 2. Deep plowing 24 to 30 inches breaks up the dense subsoil layer and mixes the native gypsum. Density is reduced, improved infiltration follows, and productivity is increased.**

REFERENCES

1. Sandoval, F.M. and G.A. Reichman. 1971. **Some properties of Solonetzic (Sodic) soils in western North Dakota.** Can. J. Soil Sci. 51:143-155.

2. Sandoval, F.M., J.J. Bond, and G.A. Reichman. 1972. **Deep plowing and chemical amendment effect on a sodic claypan soil.** Trans. ASAE 15(4):681-687.

3. Sandoval, F.M., and F.C. Jacober. 1977. **Deep plowing — Cure for sodic claypan.** Crops and Soils 29(7):9-10.