

Northern Great Plains Research Laboratory



NORTHERN GREAT PLAINS

INTEGRATOR

For environmentally and economically sound agro ecosystems for the northern Great Plains.

July 2007



EVOLUTION OF THE PLOW OVER 10,000 YEARS AND THE RATIONALE FOR NO-TILL FARMING

The beginning of civilization depended on agriculture for food production - so does civilization's future. At the end of the last glaciation, humans began to take advantage of their natural landscapes in ways that their ancestors could not have imagined.

About 10,000 years ago, Sumerian and other civilizations developed simple tools to place and cover seed in the soil. Some of the earliest cultivated seeds included emmer wheat, einkorn wheat, barley, flax, chickpea, lentil, pea, and bitter vetch.

The rise of urban societies centered in impressively wealthy cities was entirely based on the food surpluses of plow-based agriculture. As fewer hands were needed to produce food for a kingdom, individuals could specialize in crafts and trades in villages.

Average settlement size grew from less than 200-300 people to cities with over a million people. Until the modern era, hunger and resulting disease has always been the limiting factor to the growth of cities. By the time the industrial revolution rolled around in the 1700s, the technologies developed throughout the agricultural revolution enabled the world's human population to soar from a mere 4 million around 8000 BC to nearly 400 million.

Greater food production required more efficient tools and techniques. Tillage was essential for improved seedbed preparation and post-emergent cultivation for weed and crop disease control. A wide variety of light tillage tools were originally designed, ranging from a simple digging stick to a paddle-shaped spade or hoe that could be pulled by humans or animals. A wooden plow, called an "ard," was probably developed in Mesopotamia about 4000 to 6000 BC.

Over time, the Ard evolved into the improved "Roman Plow" described by Virgil in the first century AD. The major advance before 1000 AD was the development of the heavy plow, which was more than the simple, light plows farmers used earlier. It had a coulter designed to cut a thin strip in the turf. The coulter was followed by a share that would slice into the soil and then the soil would ride up the moldboard and subsequently be turned over. Later, wheels were attached to this type of plow and eventually a seat was added.

This plow with an iron share was widely used in Europe about fifth century AD. The Roman plow evolved into a soil-inverting plow during eighth to tenth century AD. By turning over the soil, crop residues were incorporated and organic matter mineralized, weeds and crop diseases were limited, and it supported the overall plant growth process.

A moldboard plow used in the U.S. was designed by Thomas Jefferson in 1784, patented by Charles Newfold in 1796, and marketed in the 1830s as a cast iron plow with a steel cutting edge (to cut through the clay soils of the U.S. Heartland) by a blacksmith named John Deere.

The use of plows expanded rapidly with the introduction of the steam

horse in 1910. By 1940, there were 2 million tractors in the U.S. Introduction of tractors enhanced farm income, which rose as much as 156% between 1939 and 1944.

The number of people fed by one U.S. farmer increased exponentially during the 20th century. As new technology evolved, farmers in the U.S. were equipped with the largest equipment in the world. Use of powerful tractors and large machinery along with fertilizers and improved varieties enhanced crop yields by 300% to 500%. The ratio of civilian to agriculturally employed population increased from 10.5% in 1940 to 63% in 2000, and the number of U.S. farms decreased from 5.65 million in 1950 to 2.17 million in 2000.

Today's agricultural revolution occurred across many generations, culminating with the Green Revolution in the second half of the 20th century. This involved use of genetically improved varieties, supplemental irrigation where needed, soil fertility enhancing organic amendments and inorganic fertilizers, and plow-based seedbed preparation.

ENVIRONMENTAL IMPLICATIONS OF PLOW TILLAGE

Intensive tillage and use of heavy machinery brought mixed blessings.

Historically, the moldboard plow was an essential tool for the early pioneers in settling the prairies of central and western U.S. and Canada. It allowed the farmer to create a soil environment in which grain crops could thrive and meet the needs of the increasing population. It was the only practical method for seedbed preparation and, other than crop rotation, for weed and crop disease control.

While plowing improved soil fertility and agronomic productivity, it set in motion a long-term trend of decline in soil structure and increasing susceptibility to major erosion, crusting, and compaction.

Plowing increased aeration of the soil which increased mineralization of the soil's organic matter, unsequestering it into the atmosphere as

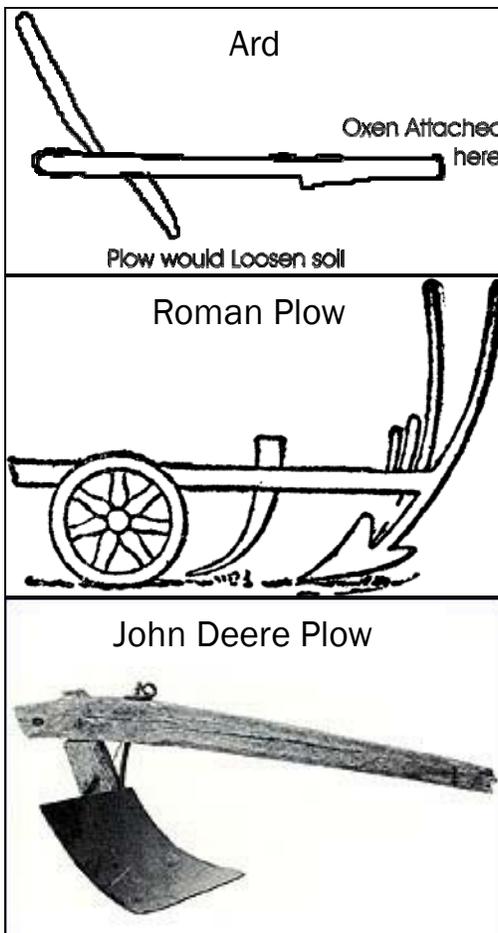
carbon dioxide. In the U.S. Corn Belt, intensive tillage has caused a soil carbon loss between 30% and 50%, leading to emission of greenhouse gases, and the attendant global warming.

This release of significant plant-available nutrients led initially to high productivity of newly 'broke' sod. Over time, as plowing decreased the soil's organic matter concentration and natural nutrients were removed and increasing amounts of inorganic nutrients were required to maintain plant growth.

With increasing demand on the limited prime soil resources and shrinking per capita arable land area in densely populated regions of the world, soil erosion has become a global issue with regard to its on-site impact on productivity and agricultural sustainability.

Intensive tillage systems leave the soil bare allowing rain to pulverize it

(continued on page 5)



THE IMPACT OF TILLAGE ON SOIL ORGANIC MATTER, AGGREGATION AND MICROBES

Preserving the soil resource is a function of managing the quality and quantity of soil organic matter. Many chemical and physical soil properties including aggregate formation and stability, porosity, nutrient cycling, water infiltration, compaction, and aeration are affected by soil organic matter, specifically organic matter quality.

Organic matter quality refers to the molecular structure of carbon compounds which impacts their chemistries and decomposition rates. Some of these compounds are higher in oxygen or nitrogen and are more easily-decomposable while others are higher in carbon and hydrogen and are more resistant to decomposition. The easily-decomposable compounds are plant leaf and root debris (particulate organic matter), and sugars from roots, bacteria, fungi, and microscopic organisms. The resistant compounds are lignin, humic acid, humin, glomalin, and wax-like compounds.

Conversion of native prairies to crop production using the plow has caused a decline in soil organic matter throughout the Great Plains. Changes in agricultural management from conventional tillage to no tillage and crop sequencing (see Integrator, Issue February 2007) can increase accumulation of soil organic matter. This increase in soil organic matter has a positive affect on the chemical and physical properties discussed above, the maintenance of the soil resource and crop productivity.

A study conducted in eastern South Dakota on silty clay loam soils examined the impacts of fall chisel and disk tillage compared to ten years of no tillage for adjacent farms with a corn-soybean rotation on soil organic matter, aggregation, and select microbial exudates.

Surface soil samples (top 50 mm) were separated into 6 aggregate size groups with a rotary sieve: <0.4 (1), 0.4-0.8 (2), 0.8-2 (3), 2-6 (4), 6-19 (5), and >19 (6) mm. Soil organic carbon, nitrogen, glomalin, and fine particulate soil organic matter (0.5 - 0.053 mm) and coarse particulate organic matter (2.0-0.5 mm) were measured on all groups. Water stable aggregation was calculated by wet-sieving groups 2-5. Wettability was quantified under 100 mm of tension on aggregates of approximately 10-mm in diameter. Humic acid, humin, and basidiomycete (another fungal group) concentrations were measured for groups 3-5. Soil organic matter quality was determined in humic acid, humin,

Conversion of native prairies to crop production using the plow has caused a decline in soil organic matter...no tillage and crop sequencing can increase accumulation of soil organic matter

The results showed that ten years of no tillage compared to conventional tillage increased soil organic matter by almost 10% and water stable aggregation by over 50%. Aggregate wettability was slower under no tillage possibly because of the presence of more wax-like compounds that resist decomposition in both soil and humin in the no-till field. Overall, glomalin was found in higher concentrations under no tillage compared to conventional tillage and was higher in particulate organic matter associated with water stable aggregates. Basidiomycete concentrations were highest in the stable aggregates from the no-till field. In addition, groups 1 and 2 (containing the smallest sized aggregates) represented over one-quarter of the total soil in the conventional tillage field but less than 10% in the no tillage field. The greater accumulation of root biomass, maintenance of hyphal

networks (fine-threads that act as a plant nutrient transportation system), and root and microbial sugars in the no-till field increased the number of large aggregates formed by binding together the smaller aggregates. The small aggregates are part of the erodible fraction of soil and typical contains some of the best quality soil because they have a high concentration of nutrient rich fine particulate organic matter.

Although this study was conducted on silty clay loam soils in eastern South Dakota, the characteristics to curb soil loss by maintaining soil conditions resistant to erosion are applicable to most soils and conditions. The types of carbon compounds stabilizing aggregates may differ depending on soil type, climate, and function, however, the principles for forming larger aggregates over smaller, highly erodible aggregates, and stabilizing these aggregates with wax-like compounds keeps the best soil (containing the fine particulate organic matter) in place.

A no-till seeding practice utilizing diverse crop sequencing (see Integrator, Issue February 2007) creates a system where the soil chemical, physical, and biological properties are all interacting to sustain the soil resource and optimize productivity.

Dr. Kris Nichols

kristine.nichols@ars.usda.gov

Based on a manuscript entitled 'Soil aggregate stability and components of organic matter affected by tillage' by Joseph L. Pikul Jr, Gabriela Chilom, James Rice, Anna Eynard, Thomas Schumacher, Kristine Nichols, Jane M. F. Johnson, Sara Wright, TheCan Caesar, and Michael Ellsbury submitted to Soil Science Society of America Journal.

GROWING AND FATTENING CATTLE ON THE NORTHERN GREAT PLAINS WITH LITTLE OR NO TIME IN A FEEDLOT

With the cost of grain and feedlot finishing up and the profitability of feeding cattle much less certain, it is reassuring to know that growing and finishing cattle in a feedlot on expensive grain rations is not a given.

Dakota cattle that fatten easily can be finished to choice by fall of their yearling year with little or no grain feeding in a feedlot.

During the dry summer of 2006, the scientists and technicians at the Northern Great Plains Research Laboratory grew and finished yearling Angus steers from western North Dakota. Grazing consisted of a combination of common perennial grasses during the summer and irrigated Proso millet from mid-August to nearly the end of September. The steers then grazed irrigated perennial grassland again until about mid-October. They were then penned and fed barley, flaxseed, and hay for only a month prior to slaughter.

The millet and fall grass was irrigated to simulate higher rainfall conditions seen some of the time in the western Dakotas and often in the eastern areas. While grazing millet and perennial grass in late

summer and fall, the steers were supplemented with 2 lbs. of flaxseed per head per day. They averaged 3.1 lbs of daily gain. This high rate of gain was possible because of the relatively high forage quality of the millet and grass. Proso millet had digestibility ranging from 62 to 70%. As its seeds matured, the digestibility increased. The digestibility of fall perennial grass was about 70%.

These steers gained about 3.9 pounds per day during the month in pens on a ration of flaxseed, barley, and hay.

Fifty percent of the steers graded low to average choice with yield grades averaging 2.8 and a final average weight of 1261 lbs. The other steers graded select with yield grades averaging 2.6 and a final average weight of 1242 lbs.

This summer the research staff is working with somewhat smaller atypical Angus steers that should weigh only about 1100 lbs. when finished to choice. They should be fattened for slaughter while grazing high quality forage with no time in a feedlot.

Dr. Scott Kronberg

scott.kronberg@ars.usda.gov



2007 FRIENDS & NEIGHBORS DAY

The staff and management at the Northern Great Plains Research Laboratory invite you and your family to join them for their annual open house, research tour, and community barbecue.

This event is hosted by the Area 4 Soil Conservation Districts Cooperative Research Farm and supported by eighty sponsors. This activity provides the lab's environmental, farmer, and rancher customers the opportunity to visit this USDA-ARS facility and learn more about the world-class research being performed.

Campus activities will run from 2-5 PM with many exhibits, a Rendezvous Tent Demonstration by Faye Kroh, and a continuous history presentation of the Northern Great Plains Research Laboratory.

Jackson Bird, Forester of the City of Bismarck will provide tours of the 90-year old trees on campus and Dr. Mohammed Iddrisu, NDSU Forest Geneticist, will focus on improved shelterbelt plantings.

Guests will be able to visit and view the ornamental grass beds on campus. Craig Stange and Mike Knudson of North Dakota NRCS will also present, "Living Landscapes and Rain Gardens in North Dakota."

The administrative and research staff will have a children's activity area for the younger guests.

The research tour will depart the main campus at 4 PM. On the tour, Dr. Eric Scholljegerdes will present, "Effects of Oilseed Supplements on Beef Cow Reproduction. Dr. Don Tanaka and Dr. Joel Ransom, NDSU Extension Agronomist, will focus on "Corn in Your Crop Sequence." Dr. Mark Liebzig will also discuss "Soils of the Area 4 SCD Cooperative Research Farm."

After the tours, all guests are invited to a free community barbecue and musical entertainment by Merrill Piepkorn, host of Prairie Public Radio's "Hear It Now" program.



Friends & Neighbors Day Research Roundup



**AREA
4
SCD**
Cooperative
Research Farm

**NORTHERN GREAT PLAINS
RESEARCH LABORATORY**
Highway 6 South, Mandan, ND



USDA
ARS

July 19th

2 PM CDT — CAMPUS ACTIVITIES & EXHIBITS
4 PM CDT — AGRICULTURE AND ENVIRONMENTAL TOURS

<http://www.mandan.ars.usda.gov> 701.667.3000

Science Supporting Agriculture

- Crops - Cattle - Carbon
- Campus Exhibits
- Managing for Drought
- Trees of the Northern Plains
- Living Landscapes & Rain Gardens in ND
- Children's Activities & Free Evening Barbecue
- Music by Merrill Piepkorn
- Host of Prairie Public Radio's "Hear It Now" Program



A dense collage of logos for various agricultural and research organizations, including BASF, TWIN CITY IMPLEMENT, PANAR, NOVARTIS, Sunflower Association, DYNAGRO, ADM, Starion, GARTNER SEED FARM, CROPLAN, MONSANTO, NEW HOLLAND, WILBURELLIS, MANDAN EQUIPMENT, INC., Farm Credit Services, Pioneer, Degelman, Syngenta, Agrium, Proseed, NDSU, and many others.

Use of product or corporation names or trademarks does not constitute official endorsement by the United States Department of Agriculture or the Agricultural Research Service of any product or service. Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at 202-720-2600 (voice and TDD). The United States Department of Agriculture prohibits discrimination in all its programs and activities based on race, color, national origin, gender, religion, age, disability, political beliefs, sexual orientation, and marital and family status. To file a complaint of discrimination, write USDA, Director, Office of Civil Rights, Room 326-W, Whitten Building, 14th and Independence, SW, Washington, DC 20250-9410 or call 202-720-5964 (voice or TDD). USDA is an equal opportunity provider and employer.

EVOLUTION OF THE PLOW OVER 10,000 YEARS AND THE RATIONALE FOR NO-TILL FARMING (continued from page 1)

excessively, creating conditions where soil and nutrients are carried away by heavy rains. Later, the surface sealing dries, resulting in crusting that may hinder or impede the germination and emergence of crop seeds. Accelerated erosion is one of the causes of soil degradation, others being soil carbon loss and nutrient depletion, soil compaction, acidification, pollution, and salinization.

Accelerated soil erosion and reduced soil productivity has plagued the earth since the dawn of settled agriculture, and has been a major issue in the rise and fall of many early civilizations. Permanent desertification of many areas of the world resulting from long exposure of unprotected soil during periodic drought cycles has occurred.

The American "Dust Bowl" was as much about tillage as it was about drought. The combination of intensive tillage and drought resulted in the catastrophe. A documentary film of the time, *"The Plow that Broke the Plains"* blamed the Dust Bowl on excessive plowing. Poor agricultural practices and years of sustained drought caused the Dust Bowl which lasted for about a decade.

When the soil is unprotected and rainfall comes, agricultural runoff removes topsoil, nutrients, pesticides, and organic materials and carries them to water bodies where they become pollutants. Sediment fills streams, rivers, reservoirs, lakes and roadside ditches, reducing their useful life.

The once-productive soil then becomes a costly maintenance problem since the sediment must be removed to provide adequate water-carrying capacity and to prevent flood damage. In addition to loss of storage capacity, the sediment fills water bodies and impairs water quality. When runoff enters a water course, the lighter soil particles remain in suspension and block sunlight vital to the growth of desirable, oxygen-producing plants living in the water. Sediment-darkened water also absorbs more heat from sunlight than clearer water, thus causing warming.

The combination of warm and muddy water leads to ecological shifts by replacing desirable fish species with less desirable types more tolerant to these conditions. Nutrients and pesticides that may be present in agricultural runoff also cause serious economic and environmental problems.

The direct effect on the producer is the economic losses connected with removing these materials from the field. In addition, nutrients derived from soil, commercial fertilizers or animal manure may cause excessive algal growths in ponds and lakes. These growths filter out and absorb sunlight, and release offensive odors and toxicants.

Pesticides are as toxic in the water as they are on the field and may affect a wide variety of aquatic organisms. If contacted or ingested in sufficient quantity, pesticides pose a health hazard to all forms of life.

Water supplies can be jeopardized by the presence of pesticide or algal growths, and purification expenses must be endured by the producer as well as other users.

As early as 1937, President Franklin D. Roosevelt stated that "A

nation that destroys its soils destroys itself." Plowing the American Heartland, called "sod-busting" or "breaking" is unsustainable.

STOPPING THE PLOW

During the 20th century, U.S. agriculture has undergone vast transformations. The number of farmers has decreased, more farmers are relying on off-farm income, agriculture's contribution to the U.S. gross domestic product has declined, and a minority of non-metro counties in the U.S. are farming dependent. Productivity per unit input of energy is the principal criteria of success today.

The development of the plow provided early farmers better seedbed preparation, weed and crop disease control and a 'mining' of the soil

for increased food productivity that led to development of civilization. Intensive use of invasive tillage technology has created environmental issues which has decimated cultures throughout history.

As modern civilization has advanced, new technologies have been developed which today have the capability of significantly reducing or eliminating use of the plow. Since the 1950s, there's been a gradual transition from the moldboard plow to various forms of "conservation tillage", ultimately to no-till production systems throughout the world.

The no-till movement began with the marketing of 2,4-D by Dow Chemical and development of paraquat by ICI in England after World War II. These products, and those that followed them, reduced weed competition and the need for mechanical weed control through tillage.

In the early 1960s, no-till agriculture was not widely supported among farmers and agriculture specialists in the U.S. The controversy between "no-till" and "plow tillage" was dubbed by Time Magazine as the "hottest farming argument since the tractor first challenged the horse."

Most tillage practices bury or remove large amounts of organic crop residue. No-till implements are specifically designed for the management of crop residue left on the soil surface to protect the soil.

Peak plow production in the U.S. occurred in the 1950s and 1960s when 75,000 to 140,000 units were shipped annually. By 1991, only 1440 units were shipped.

The primary reasons given by farmers for this transition away from the plow were efficiency, equipment width, and speed which the multiple combination tillage tools can be pulled through the soil.

Modern no-till technologies are effective in minimizing soil and crop residue disturbance, controlling soil evaporation, minimizing erosion losses, sequestering carbon in soil and reducing energy needs.

Agriculture as we know it evolved over many millennia, and is destined to undergo remarkable change during the 21st century. As future historians may someday record, plow tillage created civilization. Eliminating tillage allowed it to continue.

Dr. Jon Hanson (jon.hanson@ars.usda.gov), USDA-ARS Northern Great Plains Research Laboratory, Mandan, ND, Dr. Rattan Lal, Ohio State University; Dr. and Don Reicosky, USDA-ARS North Central Soil Conservation Laboratory, Morris, MN.

"Evolution of the plow over 10,000 years and the rationale for no-till farming" full article available at [Journal of Soil & Tillage Research](#).



The basic principles of no-till agriculture include:

- 1. Growing crops without using traditional tillage.***
- 2. Using special planting equipment that cuts through the residue mulch.***
- 3. Using seeders that require four-wheel tractors, although the seed can be dibbled in by hand (often using sticks to make the opening), or some small equipment suitable for animals or hand tractors.***
- 4. Retaining surface residue that reduces erosion, evaporation and limits weed growth.***
- 5. Sowing directly into the soil covered by residue mulch.***
- 6. Improving water infiltration capacity by ameliorating effects of residue mulch which provides bioturbation and enhances macroporosity despite some increase in bulk density.***



In The News



The Northern Great Plains Research Laboratory diverse cropping system matrix was featured on the cover of the June 2007 issue of the *Agronomy Journal*. The publication featured six papers on diverse cropping systems authored by scientists at the Northern Great Plains Research Laboratory.



Dr. Mark Liebig, Soil Scientist at the Northern Great Plains Research Laboratory, has been recognized as the "Early Career Scientist of 2007" in the USDA-ARS Northern Plains Area. This program annually recognizes the creative efforts, scientific leadership and the major research accomplishments of USDA-ARS research scientists. This honor was presented to Dr. Liebig for improving the understanding of management influences on the soil resource, and his efforts to communicate research and promote science to a broad range of clientele.



Dr. Don Tanaka, Soil Scientist at the Northern Great Plains Research Laboratory, has been recognized for his accomplishments by two prestigious organizations. The Manitoba-North Dakota Zero Tillage Farmers Association selected Dr. Tanaka as the 2007 "Zero-Till Non-Farmer of the Year" for his extensive research into management strategies to maximize soil sustainability while improving productive capacity in the Northern Great Plains. Tanaka was also selected as the first recipient of the international Soil and Water Conservation Society's "Conservation Research Award." Tanaka is being honored for extensive research and promotion of no-till production systems and specifically for his contributions as part of the Northern Great Plains Research Laboratory's interdisciplinary research team focused on diverse cropping systems. Tanaka will receive the award at their International Conference in Florida on July 23rd.



Cal Thorson, Technical Information Specialist at the Northern Great Plains Research Laboratory, was elected president of the Manitoba-North Dakota Zero Tillage Farmers Association at the annual meeting in Brandon, Manitoba in February. Thorson will lead the oldest no-till farmer's organization in North America through 2007.



NORTHERN GREAT PLAINS

INTEGRATOR

Technology Transfer Product of the
Northern Great Plains Research Laboratory
United States Department of Agriculture
Agricultural Research Service

USDA-ARS-NGPRL
1701 10th Avenue SW PO Box 459
Mandan, ND 58554-0459

Phone: 701 667-3018 Fax: 701 667-3077