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**Final Report**

**PROJECT TITLE:** Maximizing Soil Warming and Health under Different Tillage Practices in a Corn-Soybean Rotation

**PROJECT NUMBER:** 4110-14SP

**REPORTING PERIOD:** April 2014 to April 2017

**PRINCIPAL INVESTIGATOR(S):** Jodi DeJong-Hughes, Aaron Daigh, Abbey Wick

**ORGANIZATION:** University of Minnesota Regents, North Dakota State University Extension

**PHONE NUMBER:** 320-235-0726 x 2006

**EMAIL:** [dejon003@umn.edu](mailto:dejon003@umn.edu)

**INTRODUCTION**

Advantages to a reduction in tillage can include improved aggregation and water infiltration, reduced soil loss, and increased organic matter content and biological populations and diversity in the soil. However, concern about yield reductions due to cool and wet soil conditions may limit adoption of reduced-tillage systems for corn-soybean rotations on the poorly-drained soils that dominate much of North Dakota and Minnesota.

Soil tillage benefits crop production by decreasing soil density and aerating the soil. Both of which benefit germination and root development. However, different tillage practices vary in how aggressive they disturb the soil and where the disturbance occurs. Therefore, different tillage practices differ in how they accomplishes this decrease in soil density and enhanced aeration. Ultimately, this translates into how a soil warms up and dries down in the spring months during and after soil thaw.

Tillage practices allow an increased rate of soil warming due to: (1) lowering soil moisture content and reducing solid-soil particle contact points, which otherwise would conduct greater quantities of heat deep into the soil profile away from the seedbed and (2) decreasing soil residue cover allowing mineral soil to absorb greater quantities of solar radiation. Since tillage type varies in how they decrease soil density, the rate of soil warming is expected to vary with tillage type.

Therefore, we started a multi-state effort in late 2014, involving North Dakota and Minnesota, to address the following producer questions:

1. What are the benefits of using chisel plow, vertical tillage, strip till with shank, and strip till with coulters on clayey, loamy, and sandy soils when I have concerns about warm up and dry out in the spring?
2. How do I manage residue in each type of tillage system?
3. Can I achieve the same yields under all these tillage options?
4. Are there differences in yields for these tillage strategies on subsurface drained soils compared to naturally drained soils?
5. How do different tillage practices influence soil health in Red River Valley soils?
6. How does my choice in tillage practice affect the bottom line of my farming operation?

We currently have limited information pertaining to these important questions that are key to understanding how to build soil health and what tillage management practices to recommend for the different soil types.

**OBJECTIVE AND GOAL STATEMENTS**

The ultimate goal of this project is to improve yields while at the same time building soil health. We evaluate which tillage approach (chisel plow, vertical tillage, strip till with shank, and strip till with coulters) maximizes early-season soil warming and crop yields while at the same time improving soil health on subsurface drained and naturally drained soils in the Red River Valley where growing degree units are a primary consideration for soil management selection.

The objectives of this research are to:

* Monitor soil warming and water contents under chisel plow, vertical tillage, strip till with shank, and strip till with coulters on various soil series with a range in texture
* Evaluate soil health parameters and crop emergence and yields, and
* Transfer the information to producers in several formats, including but not limited to, inclusion in field days, winter programming, videos and circulars.

**MATERIALS AND METHODS**

Four on-farm locations are included in the ongoing study. Each site is under a corn-soybean rotation and rotates each year. At each site, the chisel plow, vertical tillage, strip till with shank, and strip till with coulter systems are demonstrated in a replicated design (three replicates at each on-farm location). Due to time limitation in the fall at one field site, the strip tillage with coulter was implemented in the spring. Therefore, these plots were representative of no till practices until the spring tillage operations.

Soil monitoring for temperature, moisture, thermal properties, penetration resistance (a measure of soil compaction), crop residue cover, and chemical properties (macro- and micro-nutrients, organic matter, carbon concentrations) were performed, whereas plant monitoring included population counts, plant height, and grain yields. All plots were planted to either soybean or corn each year.

All tillage operations were completed using full-sized equipment in plots of 40 or 66 feet wide by 1800 feet long. This allows us to get an accurate representation of these tillage practices so that producers will be able to visualize the implementation of each practice on their own farm.

The four on-farm locations have the following soil series: Fargo silty clay, Lakepark clay loam, Barnes-Buse loams, Delamere fine sandy loam, and Wyndmere fine sandy loam. These soil series cover over 67 million acres of prime farmland in the Northern Great Plains regions (Table 1).

*Table 1. Soil series among the on-farm locations, their taxonomy, and geographical extent in the Northern Great Plains region (NRCS Web Soil Survey data).*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Soil Series** | **Taxonomy** | **Texture** | **Geographical extent (acres)** | **Counties Present** |
| Fargo Clay | Fine, Smectitic, Frigid Typic Epiaquerts | Silty Clay | 9,469,740 | 36 |
| Lakepark | Fine-loamy, mixed, superactive, frigid Cumulic Endoaquolls | Clay Loam | 415,940 | 7 |
| Barnes | Fine-loamy, mixed, superactive, frigid Calcic Hapludolls | Loam | 37,596,920 | 60 |
| Buse | Fine-loamy, mixed, superactive, frigid Typic Calciudolls | Loam | 16,830,560 | 57 |
| Wyndmere | Coarse-loamy, mixed, superactive, frigid Aeric Calciaquolls | Fine Sandy Loam | 2,500,410 | 32 |
| Delamere | Coarse-loamy, mixed, superactive, frigid Typic Endoaquolls | Fine Sandy Loam | 505,940 | 22 |
| Total |  |  | 67,319,510 |  |

**RESULTS AND DISCUSSION**

*2015 Growing Season*

During the spring of 2016, soil temperatures, water contents, and thermal properties did differed among tillage practices as expected based on difference in the amount of crop residue cover on the soil surface and close-to-normal amount of spring precipitation (Table 2).

The chisel plow and within-plant-row zones of both strip-tills had the driest and warmest soil conditions followed by the between-plant-row zones of the strip-tills and then the vertical till had the wettest and coolest soil conditions. No differences were observed in corn or soybean’s population counts and plant heights. Grain yields did not differ among tillage treatments in the fine sandy loam soils near Barney, ND (Table 3). Similarly, grain yields did not differ among chisel plow, strip till with coulter, and vertical tillage in the loam and clay loams soils near Fergus Falls, MN; except strip till with shank yielded significantly lower (i.e., 6 bu/ac less) which was likely due to the somewhat wet soil conditions during tillage and the potential for soil smearing.

We conclude that tillage induced yield differences are more a function of not smearing the tilled soil depth rather than a function of springtime soil warming and drying.

*Table 2. Soil temperature, water content, and thermal properties among tillage practices.*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Tillage Operation** | **Temp. (F)** | **Water Content (m3 m-3)** | **Thermal Diffusivity (mm2 s-1)** | **Heat Capacity**  **(MJ m-3 K-1)** | **Thermal Conductivity**  **(W m-1 K-1)** |
|  |  |  |  |  |  |
| Chisel Plow | 49.8 c | 0.19 d | 0.220 d | 1.17 c | 0.26 c |
| Strip Tillage with Shank |  |  |  |  |  |
| * In the tillage strips | 50.9 a | 0.18 d | 0.214 d | 1.23 c | 0.28 c |
| * Between the tillage strips | 44.1 f | 0.27 b | 0.369 a | 1.70 a | 0.63 a |
| Strip Tillage with Coulter |  |  |  |  |  |
| * In the tillage strips | 50.4 b | 0.23 c | 0.259 c | 1.21 c | 0.33 bc |
| * Between the tillage strips | 45.0 e | 0.31 a | 0.369 a | 1.71 a | 0.65 a |
| Vertical Tillage | 47.3 d | 0.25 c | 0.253 c | 1.43 b | 0.38 b |
| No Tillage | 42.1 g | 0.32 a | 0.337 b | 1.72 a | 0.62 a |
|  |  |  |  |  |  |

*§ Different letters in a column are significantly different*

*Table 3. Crop Responses among Tillage Operations. Fergus Falls, MN – a spot-drained Lakepark Clay Loam and Barnes/Buse Complex Loam; Barney, ND – a undrained Delamere and Wyndmere Fine Sandy Loam*

|  |  |  |
| --- | --- | --- |
| **Tillage Operation** | **2015 Corn Yields (bu/ac)** | |
|  | Fergus Falls, MN | Barney, ND |
| Chisel Plow | 199.9 a | 155.2 a |
| Strip Tillage with Shank | 193.8 b | 154.7 a |
| Strip Tillage with Coulter | 199.4 a | 149.5 a |
| Vertical Tillage | 200.7 a | 154.4 a |
|  |  |  |

*§ Different letters in a column are significantly different*

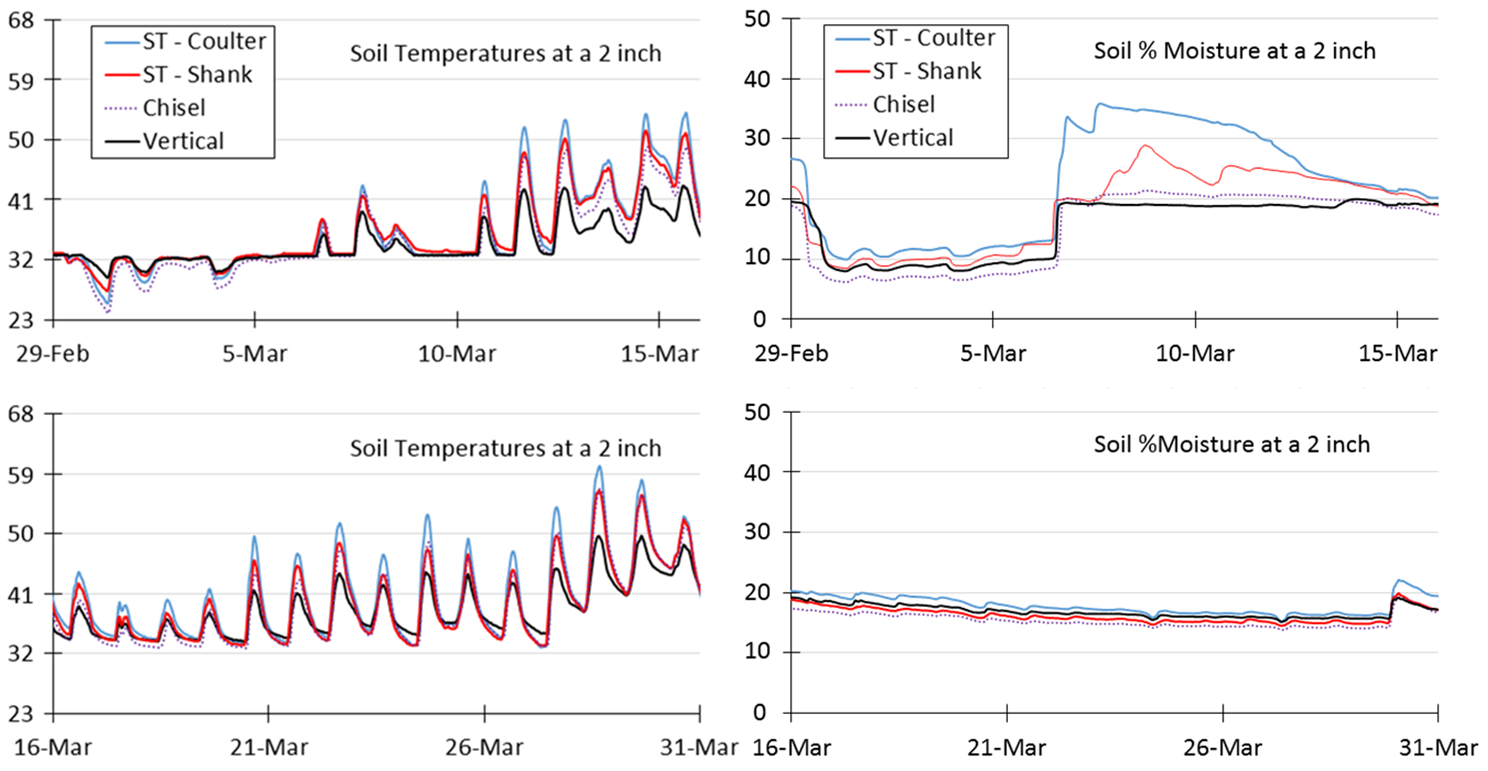
*2016 Growing Season*

During the spring of 2016, soil temperatures and water contents did not tend to differ among tillage practices except for a brief period of approximately 7 to 10 days immediately following soil thaw in early March (Figure 1). This was primarily due to the dry spring conditions and relatively low soil water contents. These differences would likely persist for longer periods as spring precipitation increases; however, observations during wet springs are needed to confirm this hypothesis.

During the summer and fall months of 2016, the chisel plow and within-plant-row zones of both strip-tills had the driest and warmest soil conditions followed by the between-plant-row zones of the strip-tills and then the vertical till had the wettest and coolest soil conditions. No differences were observed in soybean’s population counts, plant heights, or yields (Table 4). No differences were observed in corn’s population counts and plant heights. However, yields tended to be significantly lower in the vertical tillage treatments (Table 5) (i.e., average of bu/ac less than chisel plow or strip tillage) which was not due to spring soil temperatures and moistures, but instead due to the broadcasted nitrogen not being adequately incorporated into the top portions of the soil surface.

We observed yellowing of corn plants in each replicate due to this in the vertical tillage plots that were not observed in any other plot and well as significant differences in soil nitrogen concentrations. We conclude that tillage induced yield differences are more a function of getting the proper nutrient management correct rather than a function of springtime soil warming and drying.

*Figure 1 Soil temperature and moisture content at a 2” depth for four tillage systems.*



*Table 4. Crop Responses among Tillage Operations. Fergus Falls, MN – a spot-drained Lakepark Clay Loam and Barnes/Buse Complex Loam; Barney, ND – a undrained Delamere and Wyndmere Fine Sandy Loam*

|  |  |  |
| --- | --- | --- |
| **Tillage Operation** | **2016 Soybean Yields (bu/ac)** | |
|  | Fergus Falls, MN | Barney, ND |
| Chisel Plow | 48.6 a | 53.4 a |
| Strip Tillage with Shank | 49.6 a | 53.3 a |
| Strip Tillage with Coulter | 48.7 a | 54.0 a |
| Vertical Tillage | 51.8 a | 48.9 a |
|  |  |  |

*§ Different letters in a column are significantly different*

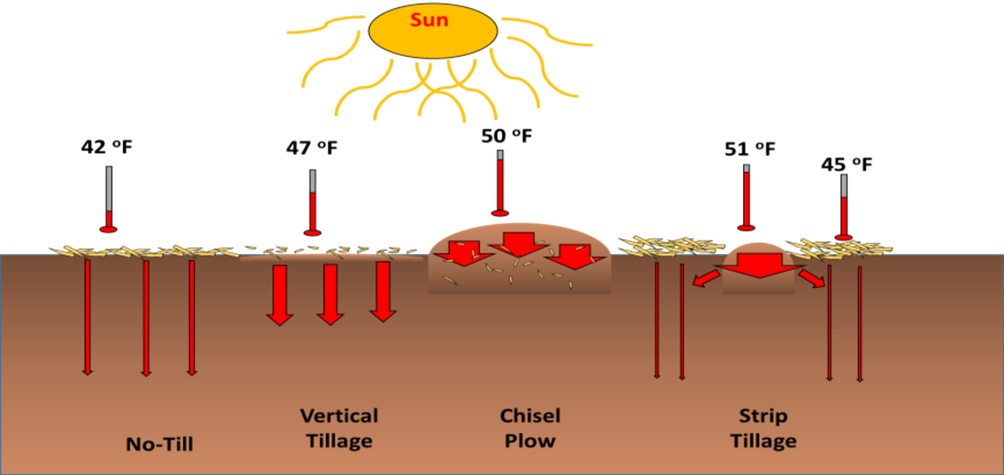
*Table 5. Crop Responses among Tillage Operations. Wyndmere, ND – a various combinations of tile drained, naturally drained, saline, and non-saline Fargo Silty Clay*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Tillage Operation** | **2016 Corn Yields (bu/ac)** | | | |
|  | Saline  & Tiled | Non-saline & Tiled | Saline | Non-saline |
| Chisel Plow | 176.0 a | 183.3 ab | 194.3 b | 202.0 a |
| Strip Tillage with Shank | 176.6 a | 188.9 ab | 196.5 ab | 204.4 a |
| Strip Tillage with Coulter | 188.1 a | 195.7 a | 204.9 a | 216.7 a |
| Vertical Tillage | 167.9 a | 175.8 b | 189.8 b | 191.3 b |
|  |  |  |  |  |

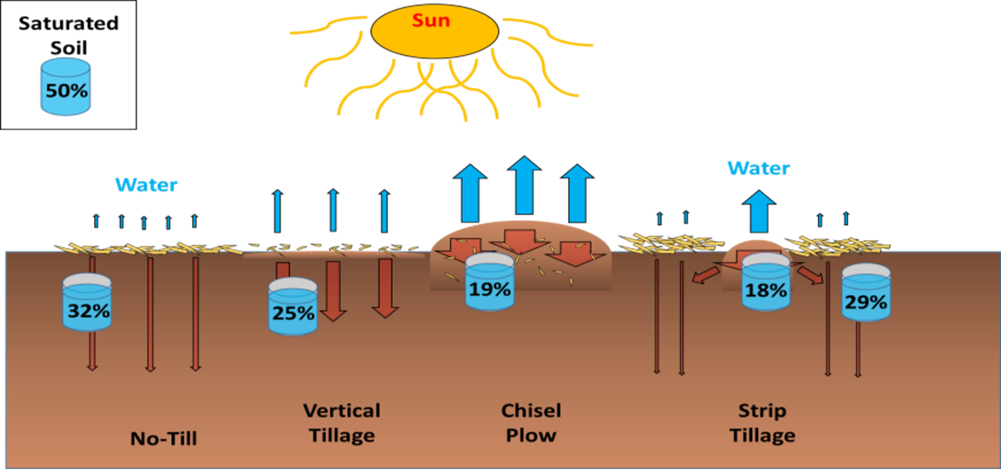
*§ Different letters in a column are significantly different*

During March through June, the strip till with either a shank or a coulter provided a comparable or slightly better alternative to the chisel plow for spring time soil warming and drying (Figure 2). Strip till was as warm in the berm as chisel plow and warmer in between the rows than no-till. Additionally, they conserved mild quantities of water in the areas between tillage strips that would be beneficial in years with little snowmelt or spring rains prior to seedling growth (Figure 3). The vertical tillage also conserved mild quantities of water but allowed the soil to dry much more than the no tillage system while also providing a mild temperature increase. Over all, strip till was as dry in the berm as chisel plow and maintained moisture in between the rows similar to no-till. The complete analysis is attached with this update.

*Figure 2. Soil temperature and thermal conductivity with four tillage systems***.**

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*Figure 3. Soil water percent and conductivity with four tillage systems.*

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**Continuing Work**

* Soil temperatures and water contents will continue to be monitored near-continuously (every 30 minutes) throughout the winter months and into the 2017 crop.
* Soil penetration resistance will continue to be measured at planting, crop canopy closure, and then again at harvest to quantify soil compaction and any evidence of natural alleviation due to wetting/drying or freezing/thawing processes.
* Soil residue cover, crop population counts, plant heights, and grain yields will continue to be measured in 2017.
* We will be expanding the soil analyses to include measures of the soil microbial community and their activities in order to evaluate effects on the below ground biology of these tillage plots. These analyses will provide us insights to shifts and temporal dynamics of arbuscular mycorrhizae fungi, total fungi, anaerobes, eukaryotes, gram positive bacteria, gram negative bacteria, and actinomycetes as well as the ratios of fungi:bacteria, protozoa:bacteria, gram+:gram- bacterial, saturated:unsaturated fatty acids, and cyclopropanes (indicator of stressful conditions for microbial populations).

**EDUCATION, OUTREACH, AND PUBLICATIONS**

**Over 29 Presentations at Winter Meetings and Summer Field Days with >1,800 participants:**

* The Conservation Technology Information Center (CTIC) hosted 8th national tour in SE MN (2015)
* MN Ag Expo (2015)
* BWSR Annual Training Conference in Brainerd, MN (2015)
* MN Association of Professional Soil Scientists annual mtg in St. Cloud (2015)
* Barriers to Bushels at 5 locations in MN (Flom, TRF, FF, Willmar, Madison)
* NRCS Soil Health Field Tour in Stearns Co., MN (2015)
* Soil Health Field Tour near Foley, MN (2015)
* Soil Health and Research Update Field Day in Barney, ND (2015)
* MN Ag Services small group mtg in Granite Falls, MN (2015)
* UMN Tillage, Technology, and Residue Field Day, Madison, MN (2015)
* Soil Health Field Day at SWROC Lamberton, MN (2015)
* State of Water Conference Alexandria, MN (2016)
* Prairie Grains Conference, Grand Forks, ND (2016)
* Conservation Tillage Conference, Fargo and Willmar (2015 and 2016)
* Cavalier Co. Tillage Workshop ND (2016)
* NDSU UMN Soil Health Bus Tour, Wahpeton, ND (2016)
* Soil Health Tour and Tillage Expo, Landgon, ND (2016)
* ETS Strip Till Field Day, Buffalo Lake, MN (2016)
* Lake Wilson Field Day, MN (2016)
* 2016 Certified Crop Adviser Update, Paynesville, MN (2016)
* Soil Science Society of America (2016), Phoenix, AZ
* Coteau des Prairies Annual Meeting, ND (2016)
* Ridgewater Community College Willmar, MN. Two classes of Corn/Soybean Production. (2016)
* MVTL Soil Lab Annual Mtg. New Ulm, MN (2016)

**Articles:**

* On-farm comparison of conservation systems for corn and soybean rotation. Mar 5, 2015 Ag Professional by Jodi DeJong-Hughes and Jeffrey Vetsch. <http://www.agprofessional.com/strip-tillage/equipment/farm-comparison-conservation-tillage-systems-corn-following-soybeans>
* Slash Tillage: Reducing the amount of tillage you do can cut costs, boost yields, and benefit the environment. March 23, 2016. Successful Farming by Jessie Scott. <http://www.agriculture.com/content/slash-tillage>
* Consider ways to reduce tillage this fall to save money and soil. August 2016. The Farmer by Van Larson (Liz Morrison).
* Tillage or No-Tillage: High yields or soil health. April/May issue of Farm Equipment magazine (pgs 18-29) by Dave Kanicki. <http://www.farm-equipment.com/articles/11545-tillage-or-no-tillage-high-yields-or-soil-health>
* Farmers Foster Soil Health to Reduce Wind Erosion. September 13, 2016. Leader Update by Jonathan Eisenthal. <http://www.mncorn.org/2016/10/13/farmers-foster-soil-health-to-fight-wind-erosion/>
* Strip Till Sweet Spot. November 22, 2016. The Farmer by Liz Morrison. <http://www.the-farmer.com/story-strip-tillage-sweet-spot-9-149732>
* Conservation tillage alters Midwest environment. Dec 2015 The Land by Dick Hagen. <http://www.thelandonline.com/news/conservation-tillage-alters-midwest-environment/article_e2476a7a-b496-11e5-b164-4be5b2b13e16.html>
* Conservation Tillage Conference a Platform for Tillage Practice Discussion. MN Soybean Growers <https://mnsoybean.org/blog-msrpc/5996/>
* Conservation tillage tales shared at conference. Lisa Young, AgriNews Jan 7, 2016. <http://www.agrinews.com/news/minnesota_news/four-conservation-tillage-tales/article_e6d75313-b608-5c7a-bbe8-ffd4e709dbad.html>
* Study points out benefits of strip tilling fields. Andrea Johnson, Tri-State Neighbor February 5, 2016. <http://www.tristateneighbor.com/news/crop/study-points-out-benefits-of-strip-tilling-fields/article_bdcbad60-c9ee-11e5-b8d1-2f16bd7c327d.html>
* Strip till best of both worlds. Aug 26, 2015 Agrinews by Lisa Young. <http://www.agrinews.com/news/minnesota_news/strip-till-best-of-both-worlds/article_ca81ea74-557f-5a75-9205-98d86b1cbacb.html>
* Reducing tillage builds soil structure, saves fuel. May 29, 2015 The Land by Dick Hagen.
* Bust that myth: Strip till practices. April 5, 2015 Strip Till Farmer by MN Soybean Growers. <http://www.striptillfarmer.com/keywords/626-jodi-dejong-hughes>
* 5 tillage myths: We challenge your thinking on no-till, strip-till, vertical, chisel and neighbors. Feb 17, 2015 Corn and Soybean Digest by Liz Morrison. <http://cornandsoybeandigest.com/tillage/5-tillage-myths>

**Radio:**

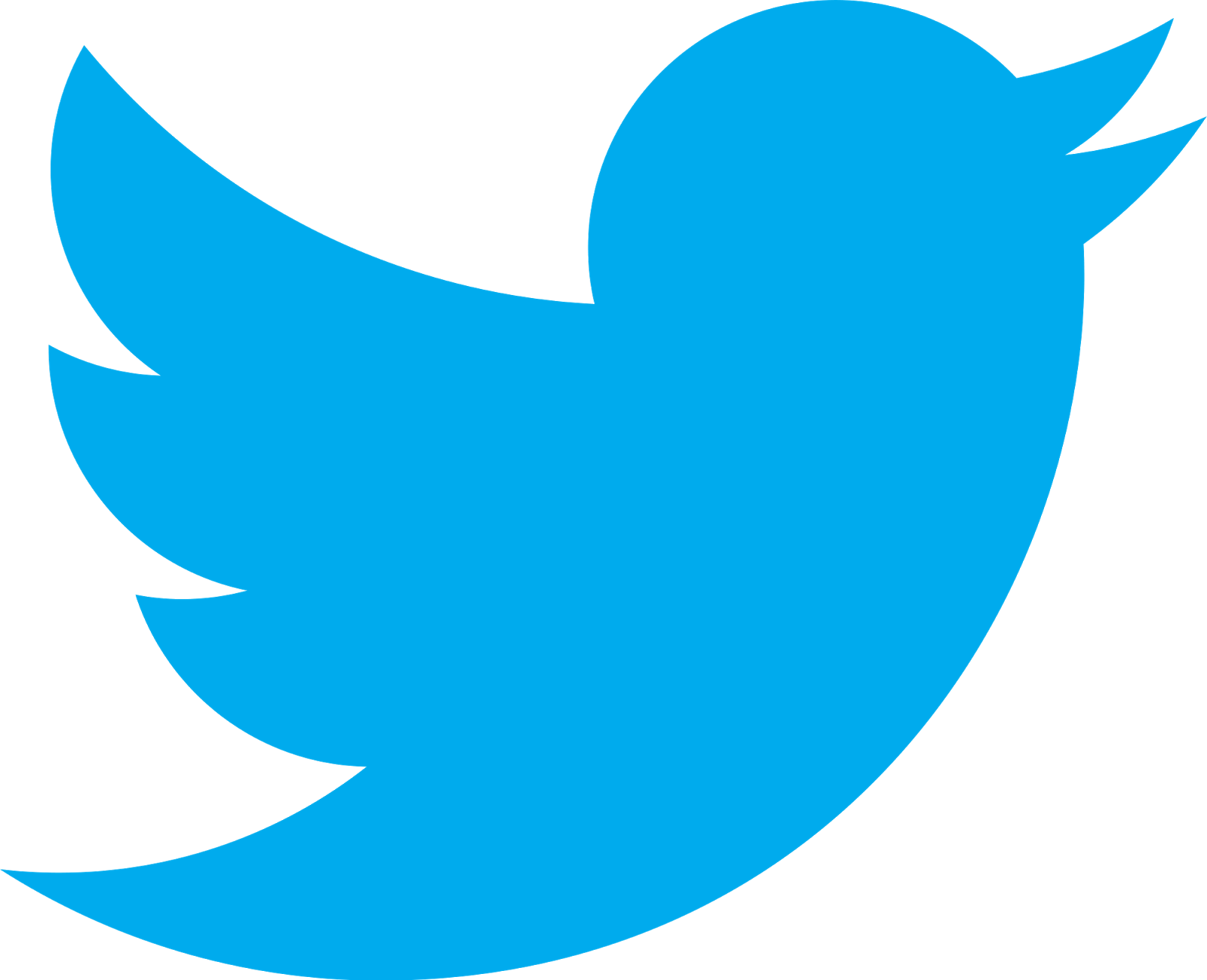
Radio interviews about tillage topics for AgNews 890, RRFN, Successful Farming syndicated radio, Linder Farm Network, KLQP, Interstate Radio, and others.

**Videos:**

Four tillage videos are in production and will be completed and released by the end of 2017.

Three extension videos were made in 2015 for producers and the general public and continue to be made available on the UMN Soil Health website at [www.extension.umn.edu/agriculture/soils](http://www.extension.umn.edu/agriculture/soils) and at the NDSU Soil Health website at <https://www.youtube.com/watch?v=_-8gAfTYktg> and <https://www.youtube.com/watch?v=9XywM4AMExM> These sites have received 6,600 views from around the world.

From the Tillage and Technology Field Day we have received over 10,750 views from around the world about deep tillage <https://www.youtube.com/watch?v=SWvjsa5_k-E>

Abbey Wick and Jodi DeJong-Hughes Tweeted pictures throughout the season and have a following of over 3,500 people.