Adapting Cropping Practices and Systems for Co-Existence with Energy Development In Southwestern North Dakota

Patrick M. Carr, Glenn B. Martin, and Timothy J. Winch
North Dakota State University, Dickinson Research Extension Center

RESEARCH SUMMARY

Research on long-term crop rotations, dryland corn production, and energy industry impact on crop production has been identified as high priorities among farmers across southwestern North Dakota. This project and the field studies that are described have been proposed as a response to the farmer-driven requests.

INTRODUCTION

Various forces are reshaping agricultural production systems in western North Dakota. Conservation-tillage has replaced conventional clean-tillage on many farms. Canola (*Brassica* spp.), corn (*Zea mays* L.), and cultivars of several other crops developed using genetic engineering technologies have replaced cultivars developed using traditional breeding methods on many farms. Cropping systems have intensified because of these changes, creating a need for understanding the benefits provided by diverse rotations in the region - including knowledge of why the benefits occur - to aid farmers in making decisions that optimize profit and environmental stewardship. Strategies for incorporating warm-season grasses and broadleaf crops into rotations are needed to reduce pest problems that result from the continuous small-grain systems which dominate the region. Corn is a warm-season grass which has been grown for decades as a forage crop, but much less successfully for grain in this semiarid environment. Recent improvements in corn genetics and no-tillage planting equipment suggest corn can be grown profitably for grain in southwestern North Dakota, but work is needed to integrate modern technologies into a successful grain corn production system. Overshadowing impacts of emerging crop choices and production methods on western North Dakota agriculture is the explosive growth of the energy industry, which has and will continue to transform agrarian life. Of most immediate concern to crop producers is the perceived negative effect that airborne particulates (i.e., dust) from unpaved and damaged paved roads is having on crops growing nearby. Western farmers have stressed a need to determine if dust deposited on plants from roads is impacting crop growth negatively and, if so, to what extent are crop yield and quality affected.

This project will provide farmers in southwestern North Dakota with scientific information on the benefits that can be expected when small-grain cropping systems are replaced with diverse crop rotations. In addition, practices that maximize the likelihood of growing dryland corn successfully for grain will be developed. Finally, impacts of dust deposition from unpaved roads on growth of crops growing nearby will be determined. Results of this project will generate the first modern research in western North Dakota that is published in refereed journals on: (1) benefits provided by diversifying small-grain cropping systems, (2) emerging dryland strategies for corn grain production, and (3) crop growth impacts of road dust deposits in the region.

Develop Crop Rotations that optimize the dual goals of profit and soil stewardship (Objective 1)

Benefits result when crop production systems are diversified. Existence of a rotation benefit has been known for millennia, and is widely documented in the scientific literature (e.g., Bullock, 1992; Dick, 1992). Discussion of rotation benefits is not confined to scientific journals; numerous publications targeting farmers have been produced, including some published by the North Dakota State University (NDSU) extension service (e.g., Helm, 1993). Vasey (1993) summarized results of non-peer reviewed, crop rotation research in western North Dakota. A study conducted from 1910 through 1933 at Dickinson demonstrated a yield benefit of 9% when wheat followed corn compared with wheat, but only 2% when wheat followed an unidentified green manure crop, indicating the high native fertility levels that existed during that time. Diverse multi-year (e.g., 4-yr) rotations apparently were not included in that early conventional-till study, or in subsequent studies at Dickinson which consisted of comparisons between wheat-fallow, wheat-corn, and wheat-sunflower (*Helianthus annuus* L.). Other broadleaf and warm-season grass crops were not included in these two crop comparisons.

Recent studies have compared continuous wheat monoculture to wheat following field pea (*Pisum sativum* L.) and lentil (*Lens culinaris* Medik.) at Williston, ND, and those two pulse crops plus dry bean (*Phaseolus vulgaris* L.), chickpea (*Cicer arietinum* L.), and soybean (*Glycine max* L.) at Carrington, ND (Miller et al., 2002). No rotation benefit was detected at Williston, while a wheat yield benefit ranging from 31 to 61% occurred at Carrington, depending on the preceding pulse crop. Miller et al. (2002) suggested that the lack of a rotation benefit at Williston probably was explained by the relatively dry conditions at that location, resulting in soil water deficits following the pulse crops that winter precipitation failed to overcome prior to seeding the wheat crop. However, a pea rotation benefit was demonstrated at Dickinson (Carr et al., 2006), which receives comparable amounts of annual precipitation (406 mm) compared with Williston (360 mm; HPRCC, 2012). As pointed out by Miller et al. (2002), benefits can occur when crops are rotated rather than grown each year in western North Dakota and similar regions, although complex interactions between soil water availability, nutrient supply, pests, crop choice, and other factors govern the frequency of the rotation benefit.

The most extensive study of previous crop impacts on subsequent crop performance in North Dakota was conducted by USDA-ARS scientists located at the Northern Great Plains Research Laboratory (NGPRL) at Mandan, ND, beginning in 2001. Ten crops were grown in long strips during the first year and then grown in perpendicular strips the following year, resulting in a matrix consisting of 100 different 2-yr crop sequence combinations (Tanaka et al., 2002). Results of this study provided new information on how previous crop choice impacts disease (Krupinsky et al., 2002), soil water use (Merrill et al., 2007), and grain yield (Tanaka et al., 2007) of subsequent crops, as well as offered new guidance on crop sequencing strategies (Hanson et al., 2007). The Crop Sequence Calculator, an interactive decision-making tool to aid farmers in crop sequencing choice, incorporates results of this study and can be downloaded for free by accessing the NGPRL web site address (NGPRL, 2012).

Research has been conducted and published on crop sequences in western North Dakota. However, this research was limited to short, 2-yr rotations (e.g., Carr et al., 2006; Miller et al., 2002) or, in the case of the USDA-ARS study at Mandan, to “short-term crop sequences” (Liebig et al., 2007). No comparable research has been conducted on long-term, diverse rotations. This is unfortunate since many rotation benefits are not observed immediately but only over time (Dick, 1992). The establishment of a long-term crop rotation study at Dickinson is needed to quantify not only the immediate impact of diverse rotations on profit and environmental stewardship, but also to quantify the medium- and long-term benefits that diversified rotations offer dryland farmers in western North Dakota and similar regions.

Refine dryland corn production strategies for sustained grain production in western North Dakota (Objective 2)

Corn was an important food crop of among Native Americans prior to the arrival of European settlers in North Dakota (Wilson, 1917). More recently, corn has become an important grain crop in the state, with over 6 million Mg harvested from 760,825 ha grown for grain in 2010 (USDA-NASS, 2011). A majority of this was grown in southeastern North Dakota. Still, corn was grown for grain on almost 54,000 ha in western North Dakota in 2010, with over 22,000 Mg of grain produced. The amount of corn grain produced in western portions of the state is considerably higher than 20 or 30 years ago, when almost all corn was ensiled. Improvements in corn genetics are largely responsible for increasing amounts of corn being grown for grain in western North Dakota, along with a favorable corn grain market.

Research on dryland corn production practices for grain (and forage) was conducted at Mandan by USDA-ARS scientists, beginning in the 1960s. These early studies focused on the impacts of N fertilizer, plant population, row spacing, seeding depth, and cultivar selection on dryland corn production (Alessi and Power, 1965; 1974; 1975a, b; and 1976). Several current recommendations regarding dryland corn production in western North Dakota (e.g., Ransom, 2004) reflect results of this research: (1) narrowing the inter-row spacing between adjacent corn rows – typically 76 cm – generally fails to offer a yield advantage in western North Dakota (Alessi and Power, 1974); (2) grain yield is optimized at plant populations ≤49,000 ha^{-1} (20,000 ac^{-1}; Alessi and Power, 1974; 1975b), and; (3) early rather than late maturing cultivars are preferred for grain production (Alessi and Power, 1974; 1976). However, Ransom (2004) adjusted recommendations to reflect improvements in corn production methods and changes that have occurred since the early research was completed. For example, Alessi and Power (1965) reported no grain yield benefit following fertilizer N applications, whereas N fertilizer generally is applied when corn is grown today in western North Dakota.

Ongoing research is being done to modernize fertilizer recommendations when growing corn for grain in western North Dakota (Roger Ashley and Dave Franzen, personal communication, 2011). A field study also was completed recently which reconsidered impacts of inter-row spacing and plant population on dryland corn grain production (E. Eriksmoen, personal communication, 2012), although results of the latter study will likely never be published in the scientific literature. With these two exceptions, no additional research has been done or is ongoing which refines dryland corn production practices in western North Dakota. A scientific study at Dickinson is needed which determines state-of-the-art practices for growing dryland corn for grain using modern technologies and theory.

Determine the impact of unpaved road dust on crop development and yield

Deposits of dust from roads and other sources can impact plant growth. Specifically, dust can cause physical injury, interfere with photosynthesis, disrupt transpiration, and allow the penetration of toxic gaseous substances into plants (Farmer, 1993). Dust particles can travel a considerable from unpaved roads after becoming airborne; deposition still was occurring 1 km from an unpaved road in an Alaskan study reviewed by Farmer (1993). Studies have demonstrated that deposits of dust on crop leaves can reduce growth of cucumber (*Cucumis sativus* L.) and dry bean (Hirano et al., 1995), and reduce seed yield of sunflower up to 7% (Borka, 1980). Dust deposited on leaves also has been shown to reduce the efficacy of herbicides in controlling weeds, including glyphosate (Zhou et al., 2006).

Rapid and extensive expansion in oil and gas drilling across western North Dakota has increased traffic on roads exponentially. Many of these roads are unpaved with no plans for pavement in the near- and intermediate-term; surfaces of other paved roads have been damaged severely by heavy traffic that the roads were not designed for (Hollywell, 2011). It is likely that the dust created by the heavy traffic on unpaved and damaged paved roads is impacting crops growing in adjacent fields, but no research has been conducted to quantify the impact. A study is needed to quantify the impacts of road dust on crop growth in southwestern North Dakota.

MATERIALS AND METHODS:

The NDSU Dickinson Research Extension Center (DREC) agronomy advisory board convened on 9 December, 2011, to provide input on objectives for this project. The advisory board is comprised of farmer, extension educator, and agricultural industry representatives from throughout southwestern North Dakota. A questionnaire was sent out prior to the meeting asking board members and county educators to identify and prioritize areas of agronomic research that should be undertaken; topical categories (e.g., nutrient management) were listed along with spaces for additional write-in topical areas. Twenty-two topical areas were identified; those with the highest rank were: (1) crop rotation; (2) dryland corn management; (3) crop sequences; (4) reclamation of saline soils; (5) soil management; (6) alternative or specialty crops, and; (7) effect of road dust on crops. Among survey respondents who farmed, ranking of research topics was nearly identical, except the effect of road dust on crops was considered to have the fourth highest priority rank behind areas (1) through (3). Interestingly, given the perceived current interest in cover crops, rank of cover crops among the 22 topical areas was 15 among all survey respondents, as well as the farmer sub-category of respondents.

Results of the survey were presented to agronomy advisory board members at the December meeting. Board members then were asked to identify crop rotations that should be included in a study at Dickinson after several rotations, ranging from 2- to 7-yr in length, were presented as examples. Board members also were asked to list specific areas of research that were needed to improve dryland corn success when grown for grain. Without prompting, several board members expressed a need to quantify the impact of road dust on crop plant growth. Four specific studies are included in this project as a result of suggestions provided by the DREC agronomy advisory board.

Objective 1. Develop Crop Rotations that optimize the dual goals of profit and soil stewardship.

Long-Term Study

Sixty different rotations were suggested for inclusion in a long-term study by farmer board members and county extension educators. Several iterations of the original list were done to parry the number down to a workable group size that matched equipment, land, and labor resources available at the DREC. Specific crops (e.g., field pea and lentil) sometimes were categorized more broadly (e.g., cool-season pulse crop) so that as many of the original 60 rotations as possible could be included in the final group, although frequency of a particular crop (e.g., corn) across all 60 rotations also was noted. A final list of eight different rotations (two, 2-yr and six, 4-yr) was developed and sent out to board members for reaction; the list also included wheat and corn monocultures to serve as checks. Responses indicated support for the study and the rotations and monocultures that were included.

A rotation study will be established at the DREC, beginning in 2013, that consists of 10 cropping systems. Crop rotations and continuous wheat and corn treatments [(1) and (2)] initially will be established in a randomized complete block design (RCBD) with all crop phases of each rotation represented every year, as is typical of modern, crop rotation research design (e.g., Chen et al., 2012). There will be a total of 30 crop phases in a block with treatments randomized in each of four blocks. Rotations will proceed within a plot from the crop phase that first is established (i.e., corn will be followed by cool-season pulse, then sunflower, then spring wheat, then repeated in the wheat/corn/cool-season pulse/sunflower rotation in the plot where corn is seeded when the experiment first begins).

Soil samples will be collected randomly from 0 to 90 cm (0 to 3 ft) using a hydraulic probe within micro-plots located randomly in each plot when the experiment begins, and every four years thereafter, to determine if measurable improvements in soil quality have occurred. The samples will be composited within each micro-plot, and base-line soil data (organic matter and carbon, pH, bulk density, nitrate- and ammonium- N, phosphorus, soluble salts, etc.) determined. Crop rotations and monocultures will be established and maintained using methods that reflect best management practices for no-till dryland cropping systems. Crop growth, yield, and quality data will be collected for all crops, as is described elsewhere for wheat (Carr et al., 2003a, b). Soil water content will be determined every 14 days from two weeks after seeding to approximately two weeks before harvest. Soil temperature at a 2-inch soil depth and ambient air temperature will be recorded simultaneously using temperature data loggers at 6-hr intervals, beginning at 14 days after seeding and continuing until crops are harvested. Profitability will be determined by modifying enterprise budget spread sheets developed annually for each crop (CES, 2012) to reflect actual yield and other data collected in the study when appropriate.

Crop Sequence Study

Three 2-rowed ('Conlon', 'Conrad', and 'Pinnacle') and three 6-rowed ('Lacey', 'Stellar-ND', and 'Tradition') cultivars will be seeded following canola, corn, field pea, and spring wheat in a RCBD in a split-plot pattern with previous crop comprising whole plots and barley cultivar comprising subplots. Barley cultivar and previous crop treatment combinations will be randomly allocated in each of three blocks. Crop growth, yield and quality, along with soil water content, will be determined as described under the *Long-Term Study* heading. Additional 2-yr crop sequence studies are embedded in the *Long-Term Study* and will be completed during the first four years of that study.

Objective 2. Refine dryland corn production strategies for sustained grain production in western North Dakota.

Advisory board members identified 14 different topical areas of research focused on dryland corn production, ranging from hybrid adaptation experiments to comparisons of ridge-tillage and conventional no-tillage establishment at the December meeting. Some potential areas of research were eliminated because other scientists were conducting similar ongoing research nearby (e.g., hybrid adaptation experiments are conducted annually at the NDSU Hettinger Research Extension Center), or resources presently are unavailable to conduct the research successfully (i.e., DREC crop scientists do not have access to a ridge-tillage planter). Planting rate and row arrangement (i.e., narrow, twin or paired, and standard or wide) comparisons were identified by board members as high priority areas of research in western North Dakota, even though others indicate that these are not considered to be important research topics further east in the state (Joel Ransom, personal communication, 2012), and equipment and other resources currently at the DREC are sufficient to conduct this research.

Corn will be seeded so that there are four established densities in narrow, wide (76-cm; 30 in) and twin- or paired- rows arranged in a RCBD as a 4 by 2 factorial with all density by row-spacing combinations replicated four times. Desired plant densities in each plot will be attained by over seeding and then thinning. Crop growth, yield and quality (both grain and silage), and soil water content will be determined as described under **objective 1**. Leaf-area index and light interception associated with interior corn rows in each plot will be determined on the same dates that soil moisture measurements are made.

Objective 3. Determine the impact of unpaved road dust on crop development and yield.

An existing integrated crop and livestock project (ND06259) located at the DREC Manning Ranch unit will be used to provide crop (field pea, sunflower, and wheat) plots adjacent to an unpaved road that is heavily used by oil truck traffic. Plots are arranged in a RCBD with crop treatments replicated three times; replicates are oriented at increasingly greater distances from the road. Growth stage and height of crop plants selected randomly in strips within each plot, with strips parallel to the road but at increasingly greater distances from it, will be determined every 14 d, beginning two weeks after seeding and continuing until plants reach physiological maturity. Interception of light by dust will be determined. Soil water content in each plot will be determined as already described. Yield will be determined within the entire area encompassed by each strip when crop plants reach physiological maturity.

Statistical Analyses

Data under **objectives 1 and 2** will be analyzed using an appropriate model with PROC MIXED from SAS. Presence of a relationship between distance from the road and the dependent parameters under **objective 3** will be determined using PROC REG.

LITERATURE CITED

Alessi, J., and J.F. Power. 1974. Effects of plant population, row spacing, and relative maturity on dryland corn in the Northern Plains. I. Corn forage and grain yield. Agron. J. 66:316-319.

_____________________. 1965. Influence of moisture, plant population, and nitrogen to dryland corn in the Northern Plains. 57:611-612.

_____________________. 1975a. Effect of plant spacing on phonological development of early and midseason corn hybrids in a semiarid region. Crop Sci. 15:179-182.

_____________________. 1975b. Response of an early-maturing corn hybrid to planting date and population in the Northern Plains. Agron. J. 67:762-765.

_____________________. 1976. Water use by dryland corn as affected by

maturity class and plant spacing. Agron. J. 68:547-550.
Berger, A., A. McDonald, and S. Riha. 2010. A coupled view of above and below-ground resource capture explains different weed impacts on soil water depletion and crop water productivity in maize. Field Crops Res. 119:314-321.
Borka, G. 1980. The effect of cement dust pollution on growth and metabolism of Helianthus annuus. Environ. Pollution 22:75-79.
Bullock, D.G. 1992. Crop rotation. Crit. Rev. Plant Sci. 11:309-326.
Carr, P.M., R.D. Horsley, and G.B. Martin. 2006a. Impact of tillage and crop rotation on grain yield of spring wheat I. Tillage effect. Crop Management doi:10.1094/CM-2006-1018-01-RS.
Carr, P.M., R.D. Horsley, and W.W. Poland. 2003a. Tillage and seeding rate effects on genotypes in wheat-fallow monoculture I. Grain production. Crop Sci. 43:202-209.
Carr, P.M., R.D. Horsley, and W.W. Poland. 2003b. Tillage and seeding rate effects on genotypes in wheat-fallow monoculture II. Plant growth. Crop Sci. 43:210-218.
Chen, S., P.M. Porter, C.D. Reese, and C. S. Ward. 2001. Crop sequence effects on soybean cyst nematode and soybean and corn yields. Crop Sci. 41:1843–1849.
CES. 2012. Projected crop budgets – south west North Dakota. Accessed 26 Feb., 2012 at http://www.ag.ndsu.edu/farmmanagement/crop-budget-archive.
Dick, R.P. 1992. A review: long term effects of agricultural systems on soil biochemical and microbial parameters. Agric. Ecosyst. and Environ. 40:25-36.
Farmer, A.M. 1993. The effects of dust on vegetation – a review. Environ. Pollution 79:63-75.
Hanson, J.D., M.A. Liebig, S.D. Merrill, D.L. Tanaka, J.M. Krupinsky, and D.E. Stott. 2007. Dynamic cropping systems: increasing adaptability amid an uncertain future. Agron. J. 99:939-943.
Helm, J.L. 1993. Crop rotations for profit in North Dakota. Ext. Serv. pub. A-1059, Fargo. 7 p.
Hirano, T., M. Kiyota, and I. Aiga. 1995. Physical effects of dust on leaf physiology of cucumber and kidney bean plants. Environ. Pollution 89:255-261.
Hollywell, R. 2011. North Dakota's oil bloom is a blessing and a curse. Accessed on 26 Feb., 2012, at http://www.governing.com/topics/energy-env/north-dakotas-oil-boom-blessing-curse.html.
HPRCC. 2012. Historical climate data summaries – North Dakota. Accessed 23 Feb. at http://www.hprcc.unl.edu/data/historical/index.php?state=nd&action=select_state&submit=Select+State.
Krupinsky, J.M., D.L. Tanaka, S.D. Merrill, M.A. Liebig, M.T. Lares, and J.D. Hanson. 2007. Crop sequence effects on leaf spot diseases of no-till spring wheat. Agron. J. 99:912-920.
Liebig, M.A., D.L. Tanaka, J.M. Krupinsky, S.D Merrill, and J.D. Hanson. 2007. Dynamic cropping systems: contributions to improve agroecosystem sustainability. Agron. J. 99:899-903.
Miller, P.R., B.G. McConkey, G.W. Clayton, S.A. Brandt, J.A. Staricka, A.M. Johnston, G.P. Lafond, B.G. Schatz, D.D. Baltensperger, and K.E. Neill. 2002. Pulse crop adaptation in the northern Great Plains. Agron. J. 94:261-272.
NGPRL. 2012. Northern Great Plains Research Laboratory web page. Accessed 23 Feb. at

http://www.ars.usda.gov/Main/docs.htm?docid=17646.
Ransom, J. 2004. Basics of corn production in North Dakota. Ext. Serv. Pub. A-834 (rev.), Fargo. 20 p.
Tanaka, D.L., J.M. Krupinsky, M.A. Liebig, S.D. Merrill, R.E. Ries, J.R. Hendrickson, H.A. Johnson, and J.D. Hanson. 2002. Dynamic cropping systems: an adaptable approach to crop production in the Great Plains. Agron. J. 94:957-961.
Tanaka, D.L., J.M. Krupinsky, S.D. Merrill, M.A. Liebig, and J.D. Hanson. 2007. Dynamic cropping systems for sustainable crop production in the northern Great Plains. Agron. J. 99:904-911.
Vasey, E. 1993. Profitable cropping systems for western North Dakota. Extension Bull. No. 59, Fargo. 20 p.
USDA-NASS. 2011. North Dakota. Annual summary bulletin. Accessed 23 Feb., 2012, at http://www.nass.usda.gov/Statistics_by_State/North_Dakota/Publications/Annual_Statistical_Bulletin/index.asp.
Wilson, G.L. Agriculture of the Hidatsa Indians: An Indian Interpretation" Ph. D. Thesis, Univ. Minnesota. Accessed on 23 Feb., 2012, at ttp://digital.library.upenn.edu/women/buffalo/ garden/garden.html.
Zhou, J., B. Tao, and C.G. Messersmith. Soil dust reduces glyphosate efficacy. Weed Sci. 54:1132-1136.

IMPORTANCE TO THE STATE OF NORTH DAKOTA

Almost 60% of spring wheat was grown following spring wheat in southwestern North Dakota during 2010, and 6% following barley. Diversifying small-grain cropping systems could increase grain yield up to 40% in some years, based on limited previous research. Even a modest rotation benefit of 5% would have translated into an additional 1 million bushels of wheat being produced in the region during 2010, generating an additional $6.7 million in revenue. Results of this project will provide farmers with science-based information on how diverse rotations can impact yield and quality of spring wheat and many crops grown in the region, and on rotation benefits to soil quality and profit. This project will enhance corn production in the region, not only because corn is featured prominently in many of the rotations that will be studied, but because practices will be developed specifically for optimizing corn production for grain in the region. This project will generate the first scientific data on the impact of airborne dust on crop performance that has resulted from the tremendous increase in heavy traffic on roads in western North Dakota.