USING SOIL AND GROUNDWATER DATA
TO DEVELOP DROUGHT STRATEGIES

GARY PARKIN, UNIVERSITY OF GUELPH

Published November 2015

Canadian Water Network

USING SOIL AND GROUNDWATER DATA
TO DEVELOP DROUGHT STRATEGIES

GARY PARKIN, UNIVERSITY OF GUELPH

Published November 2015

WHY DID WE DO THIS RESEARCH?

Even in a water-rich country like Canada, drought can have a serious impact on drinking water supplies, natural ecosystems and agricultural crops. In 2012, much of Southern Ontario received well below average precipitation, leading to a significant drop in crop production.[1] Extended dry conditions can cause dramatic reductions in yield (up to 75%), depending on the stage of corn development during drought.[1,2]

Drought during growing seasons can have a significant impact on crop yield and subsequent economic impacts, particularly for field crops that are not irrigated, such as forage, wheat, soybean and corn. Farmers are continually seeking better management systems to reduce the severity and variability of drought impacts.

2012 ONTARIO DRY WEATHER DAMAGE

- In May to August, 2012, most of Southern Ontario received at least 40% lower rainfall than normal.
- Hay had to be transported from western Canada to feed cattle in Ontario.
- The livestock sector received over $40 million to help deal with effects of the drought.

Source: OMAFRA[3]

One approach is to adopt a management system that conserves soil moisture during the growing season. No-tillage farming has been recommended in some regions to conserve moisture, but there is a lack of scientific data to fully support this recommendation, especially under different crop rotations.

Data from previous research which focused on measuring and modeling soil water budgets were re-examined.[4,5,6,7] The field data from these studies was used to assess soil and climatic conditions under till and no-till management systems in Southern Ontario between 2001 and 2010.

In addition to analyzing field data, a computer model called DRAINMOD was used to generate soil water budgets over 48 years.[8] Field data are frequently not available over long time periods, so models are often used to complement field data. DRAINMOD was used to examine the frequency of drought and its impact on soil moisture and corn yield in southern Ontario from 1954 to 2001.

HOW WAS THE RESEARCH CONDUCTED?

FIELD STUDY – MOISTURE STATUS OF TILLED VS. NO TILLAGE SYSTEMS

To compare the soil moisture status of no-tillage and tilled systems, sensors were installed at the University of Guelph's Elora Research Station.[7] The soil at the site is a Guelph loam characterized by 36% sand, 49% silt, 15% clay, pH of 7.5 and 4.4% organic matter. The sensors, shown schematically in Figure 1, automatically measured soil moisture content each hour over ten years between the soil surface and a depth of 1 metre. Four sensors were installed in each of four different plots. Two of the plots were converted to no-tillage in 1999 and the other two underwent annual fall ploughing and spring disking before planting crops up to 2010.

A crop rotation of soybeans, corn and winter-wheat was grown on all four plots. Red clover was planted as a cover crop after winter-wheat harvest, and nitrogen fertilizer was applied according to soil nitrogen test results to the two no-tillage plots when corn was grown. For the tilled plots, the recommended maximum amount of nitrogen was applied to corn, regardless of soil test value. These alterations were made to the no-tillage plots so that they would fit under a best management practice for nitrogen to compare against conventional practices.

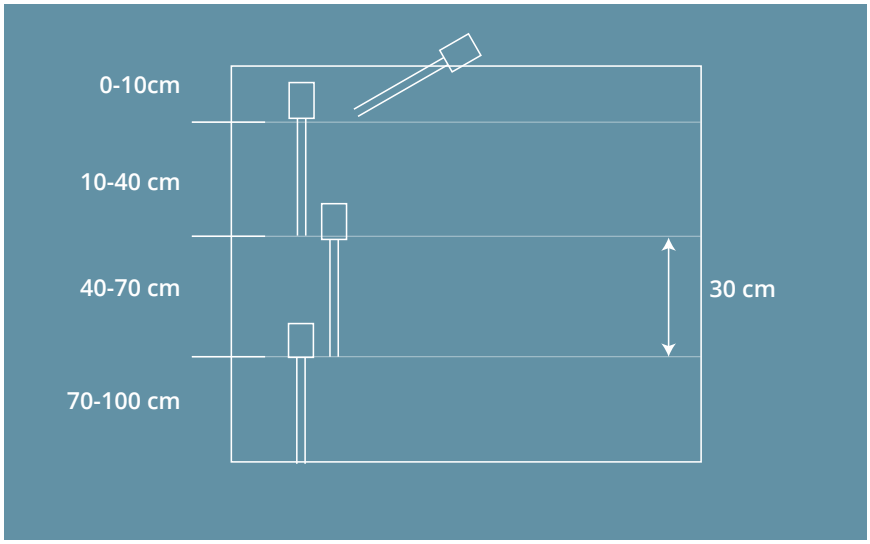

Figure 1. Schematic diagram of soil moisture sensors installed from soil surface to a depth of 100 cm.

Precipitation data were obtained from an Environment Canada weather station located on the Elora Research Station and used to help interpret the soil moisture measurements.

MODELLING STUDY – LONG TERM IMPACTS OF DROUGHT ON CORN YIELD

DRAINMOD is a sophisticated soil water budget and nitrogen partitioning model incorporating the effects of tile drainage and soil freezing and thawing, both of which are common in Ontario farm fields. This model was applied to estimate corn yield and soil moisture status between 1954 and 2001[8] for the Guelph region. A corn crop was simulated each year in DRAINMOD, along with the predominant local soil conditions, Guelph loam and Pontypool sand soil. These two soil profiles were run separately with the same weather and crop conditions to assess the effects of soil texture on drought occurrence and corn yield impact (see Figure 2).

Daily values of precipitation, as well as maximum and minimum air temperature were obtained from the Environment Canada's weather station at the Elora Research Station. DRAINMOD calculates a crop yield reduction factor based on the number of dry days that occur during the growing season.

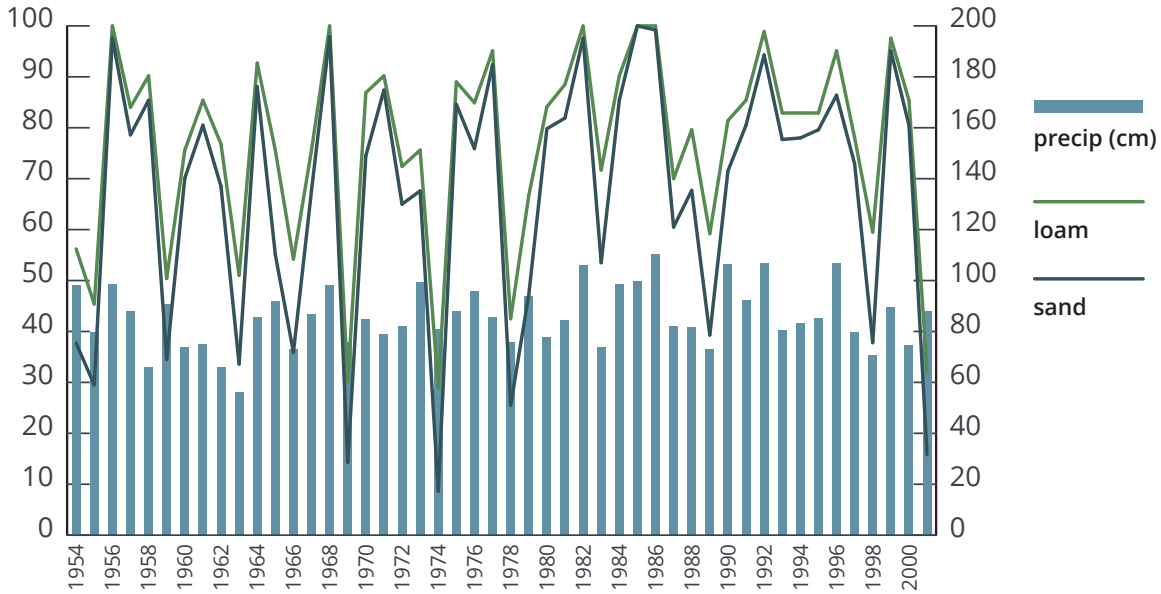

Figure 2. A comparison of DRAINMOD-estimated relative corn yield under loam and sandy soils in Guelph region from 1954 to 2001.

WHAT WERE THE RESULTS?

FIELD STUDY – MOISTURE STATUS OF TILLED VS. NO TILLAGE SYSTEMS

On average over the ten-year period, the no-tillage plots contained more soil moisture than the tilled plots (Figure 3). During the summer, the no-tillage system showed a greater average storage (21 mm) than the tilled soil in each depth layer, except from 40 cm to 70 cm. In the 40 to 70 cm depth layer, storage in the tilled soil was about 8 mm greater than the no-till.

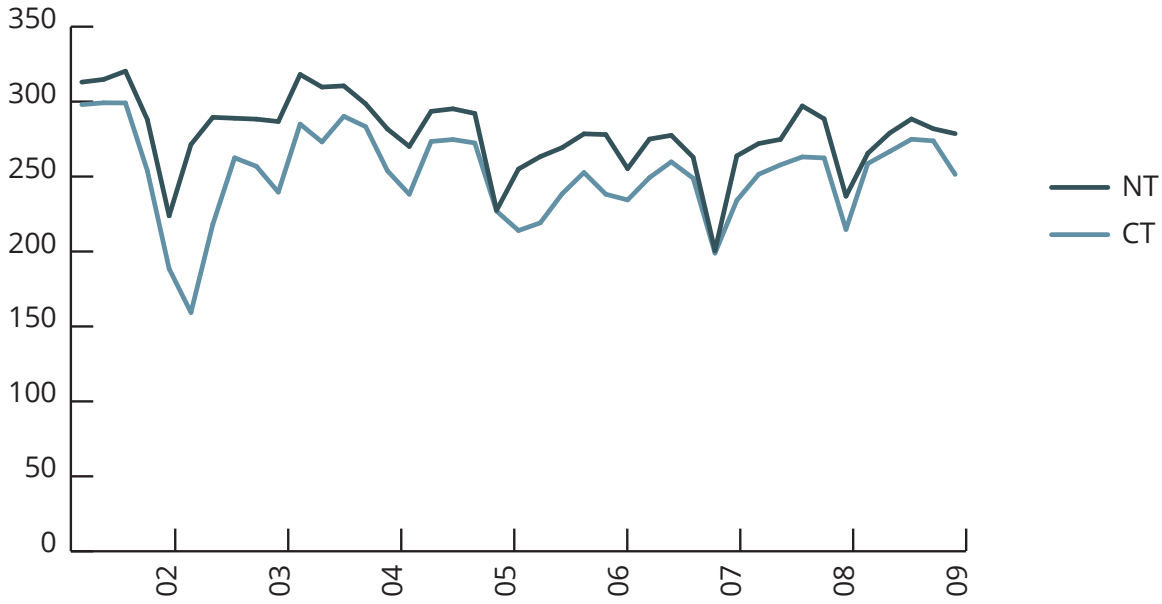

Figure 3. A comparison of soil moisture storage in no-tillage (NT) and conventionally-tilled (CT) plots over the growing seasons of 2002 (February) to 2009 (September).

The ability of a no-tillage system to conserve moisture is thought to be related to the excess amount of crop residue left on the soil surface and the lack of soil disturbance. Disturbing the soil through tillage creates a more porous and open system, allowing for more evaporation. It may be that in the 40 to 70 cm depth range, a large number of stable earthworm burrows in the no-tillage system is causing increased water drainage, leading to a lower amount of water storage.

Drought conditions occurred during most of the growing season (June – September) of 2007, with 193 mm of recorded rainfall at the Elora Research Station, vs. the long-term normal of 261 mm. Soil moisture levels remained greater in the no-tillage plots during this growing season, which may have enhanced plant development in comparison to the tilled plots.

MODELLING STUDY – LONG TERM IMPACTS OF DROUGHT ON CORN YIELD

The DRAINMOD model estimated that corn yield was reduced in drought conditions in both soil types. However, the impact of drought is consistently greater in sandy soil, since it is better drained and would experience drier soil conditions. Over the 48-year period, there was an average corn yield reduction of 24% for the loam and 33% for the sandy soils. The maximum impact of drought on model-estimated corn yield occurred in 1974. In that year, the combined rainfall for July and August was only 43 mm, compared to the long-term value of about 150 mm for these two months in the Guelph region.

WHAT ARE THE IMPLICATIONS FOR FARMERS?

The impacts of drought on soil moisture and crop yield are of interest to all members of the farming community, including farmers, farming organizations, professional agronomists and agriculture ministry personnel. Our findings indicate that a no-tillage system overall conserves more soil moisture than a tilled system. However, a layer of soil within the root zone of many crops may actually be slightly drier under no-tillage conditions.

The question of whether conservation of moisture always results in greater crop yield during a drought is not easy to answer and requires further research. The original experimental design was not intended to be a straightforward comparison of no-tillage versus tillage practices, and other differences between the two systems related to cover cropping and nitrogen inputs may have also affected crop yield. Further research should assess how a whole system of tillage, crop rotations, cover crops and fertilizer rates play a role in soil water conservation.

The application of DRAINMOD to assessing the impact of drought pointed to several findings of interest to the farming community. The model demonstrated that in 48 years of corn yield estimates, 90% or higher potential corn yield was only achieved in 13 years (when planted in loam soils) and 8 years (when planted in sandy soils) due to drought. **The majority of years were impacted by drought to some degree**, pointing to a need for soil moisture conservation and other drought adaptation strategies. The development of best management practices for conserving soil moisture may be even more important in the future, as increasing temperatures due to climate change may increase evaporation and decrease soil moisture further.

TO CONTACT THE RESEARCHER, EMAIL RESEARCHSPOTLIGHT@CWN-RCE.CA.
VISIT OUR REPORT LIBRARY AT WWW.CWN-RCE.CA

RESEARCH TEAM

GARY PARKIN, University of Guelph
DAVID RUDOLPH, University of Waterloo
GLORIA SUAREZ, University of Waterloo
PETER VON BERTOLDI, University of Guelph
BRONWYNNE WILTON, University of Guelph

PARTNERS

ONTARIO SOIL AND CROP IMPROVEMENT ASSOCIATION
ONTARIO MINISTRY OF AGRICULTURE, FOOD AND RURAL AFFAIRS

REFERENCES

1 HASHAM, ALYSHAH. "Ontario's corn crop withers under drought." Toronto Star 20 July 2012: Web.

2 ONTARIO MINISTRY OF AGRICULTURE, FOOD AND RURAL AFFAIRS. "Potential Impacts of Dry Conditions on Corn." 13 July 2012. Web. 3 June 2015.

3 ONTARIO MINISTRY OF AGRICULTURE, FOOD AND RURAL AFFAIRS. "2012 Ontario Dry Weather Damage: Summary of AgriRecovery Assessment" n.d. Web. 3 June 2015.

4 TO LEARN MORE ABOUT SOIL WATER BALANCE, visit: https://dspace.lib.uoguelph.ca/xmlui/handle/10214/2180

5 PARKIN, G.W., C. WAGNER-RIDDLE, D.J. FALLOW, AND D.M. BROWN. 1999. Estimated Seasonal and Annual Water Surplus in Ontario. Canadian Water Resources Journal, 24: 277-292.

6 FALLOW, D.J., D.M. BROWN, J.D. LAUZON, AND G. PARKIN. 2007. Variation in risk of environmental contamination of manure/nutrient application during winter conditions across Ontario. Journal of Environmental Quality 36: 31-43.

7 MCCOY, A.J., G. PARKIN, C. WAGNER-RIDDLE, WARLAND, J. LAUZON, P. VON BERTOLDI, D. FALLOW, AND S. JAYASUNDARA. 2006. Using automated soil water content and temperature measurement systems to estimate soil water budgets. Canadian Journal of Soil Science, 86(1), pp. 47-56.

8 D. MURRAY BROWN, HUMAIRA DADFAR, DAVID J. FALLOW, ROBERT J. GORDON, JOHN D. LAUZON, AND GARY W. PARKIN, "Temporal and Spatial Variability of Water Surplus in Ontario, Canada," ISRN Soil Science, vol. 2013, Article ID 362895, 7 pages, 2013. http://www.hindawi.com/journals/isrn/2013/362895/abs/