Effect of tillage system on pesticide leaching to drains

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BACKGROUND

Significant areas of arable land are managed using either reduced tillage or zero tillage systems. These provide benefits in terms of improving soil structure, increasing soil organic matter content, and reducing vulnerability of land to overland flow. However, where subsurface drains are installed, there is a possibility that reduced or zero tillage practices could exacerbate transport of pesticides to drains. Here, we present a review of empirical evidence for effects of tillage systems on pesticide transport to drains. The MACRO model[1] is then evaluated against two field drainage experiments as a first step towards predicting vulnerable situations.

LITERATURE REVIEW

- Ten field experiments have compared pesticide concentrations and/or losses in drainflow under no-till (NT) or reduced tillage (RT) vs. conventional tillage (CT). Studies are all from North America, relatively old, and dominated by atrazine, alachlor and metolachlor.
- The overall tendency is towards greater pesticide losses and concentrations in drainflow under NT vs CT, especially in longer-term studies. Five studies showed a moderate effect, two a weak effect, and three no effect; none showed smaller losses/concentrations under NT vs CT.
- No obvious correlations were observed between strength of effect and soil texture, organic carbon content, or pesticide properties.

Location	Duration	Dates	Topsoil texture	Topsoil %OC	Pesticides	Grading of effect	Description of effects seen
Saskatchewan[2]	1.5 years	1992-1993	Loam	n/a	Seven relatively mobile herbicides	Moderate negative	Overall greater concentrations and losses from NT than CT
Ontario[3]	4 years	1990-1994	Loam over silty clay	2.2	Atrazine (plus DEA metabolite), metolachlor	Moderate negative	Greater leaching through NT than CT
Iowa[4]	5 years	1988-1992	Loam/silty loam	1.7-2.3	Atrazine, alachlor, cyanazine and metribuzin	Moderate negative	Greater losses from NT and ridge till than chisel plough and CT for all four herbicides in 1990-92
Georgia[5]	10 years	1999-2009	Loamy sand/sandy loam	n/a	Fluometuron (plus DMF metabolite)	Moderate negative	Losses from strip tillage ca. 2.5 times larger than from CT across whole study
Minnesota[6]	7 years	1985-1991	Clay loam	3.7 *	Atrazine, alachlor	Moderate negative	Statistically greater concentrations from NT vs CT across study period (and in 2 of 7 individual years)
Ontario[7]	4 years	1987-1990	Clay loam	2.5	Atrazine (plus DEA metabolite), metolachlor	Weak negative	Greater concentrations in drainflow from NT and ridge till compared to CT, but less consistent effect on total losses in drainflow
New York[8]	1 year	1994	Sandy loam	n/a	Atrazine	Weak negative	Greater concentrations in drainflow overall from NT than from CT
Ontario[9]	3 years	1984-1986	Clay loam	2.5	Atrazine (plus DEA metabolite), alachlor	No effect	No effect NT vs ridge till vs CT
Ohio[10]	2 years	1987-1988	Silty clay loam	n/a	Atrazine, alachlor, metolachlor, metribuzin	No effect	No consistent effect of NT vs CT
Quebec[11]	2 years	1998-1999	n/a	1.5-2.4	Atrazine, metolachlor	No effect	No statistical effect of RT (chisel plough) vs CT)

Modelling of long-term studies with the preferential flow model MACRO

Ontario, CA (Weak negative effect)

- Brookston series (clay loam) with tile drains at 95 cm.
- NT vs CT (12.2 x 82.5 m plots) under continuous corn, 1987-1990.
- Pre-emergence applications of atrazine (Koc ca.100 L/kg, (1.1-1.8 kg/ha) and metolachlor (Koc ca. 120 L/kg, 1.7-2.6 kg/ha).

Iowa, US (Moderate negative effect)

- Floyd/Kenyon/Readlyn association (loam /silty loam/ loam) with tile drains at 120 cm.
- NT vs CT (36 plots, 58 x 67 m) under continuous corn, 1990-1992.
- Pre-emergence applications of atrazine (2.8 kg/ha) and alachlor (Koc ca. 335 L/kg, 2.2 kg/ha).

Table 1: MACRO parameters for topsoil under CT and NT at the Ontario and Iowa sites

	Ontario CT	Ontario NT	Iowa CT	Iowa NT
Organic matter content (%)	2.02	2.40	2.00	2.14
Bulk density (g/cm^3)	1.47	1.45	1.45	1.50
Total porosity (% by volume)	43.2	43.7	44.2	43.2
Boundary water content (% vol)	40.0	40.5	39.5	39.0
Wilting point (% by volume)	18.7	22.7	14.5	14.5
Saturated conductivity (mm/h)	4.6	219.6	36.0	72.0
Van Genuchten's n (-)	1.098	1.094	1.176	1.171
Van Genuchten's alpha (1/cm)	0.0228	0.0217	0.0307	0.0271
Fraction of macropores (-)	0.01	0.01	0.01	0.02
Macropore tortuosity factor (-)	2.5	2	4	3

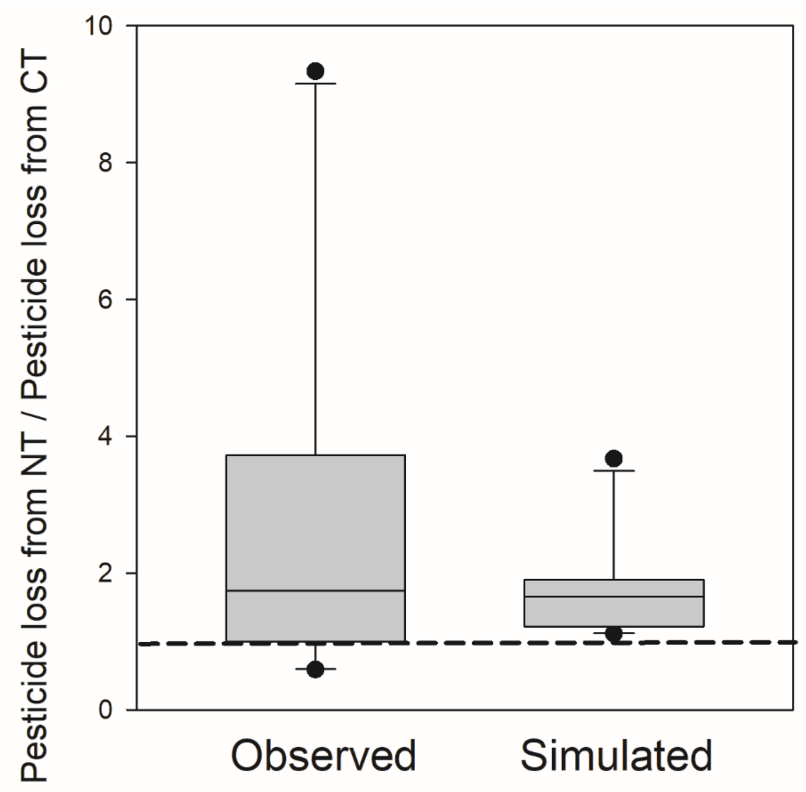

Figure 1: Box plot showing distribution in the ratio of pesticide losses from NT vs. CT (values above dashed line have NT loss > CT loss)

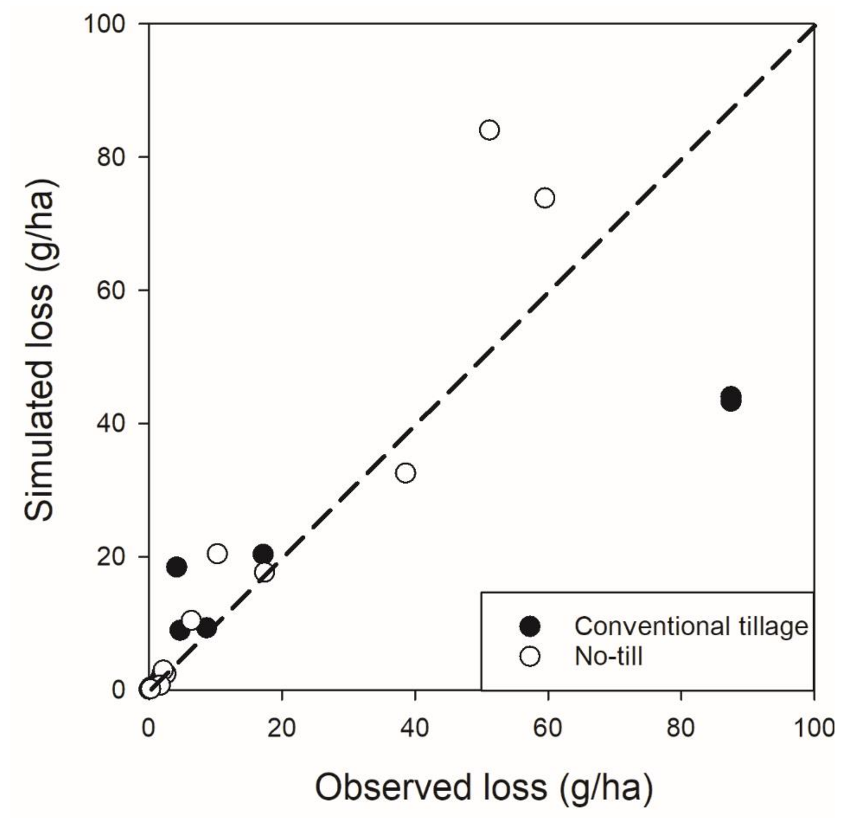

Figure 2: Observed vs. simulated losses of pesticides in drainflow (Ontario and Iowa datasets combined)

Main results

- Observed losses from NT were greater than from CT for three out of four years at Ontario and across the three years at Iowa. MACRO simulated greater losses from NT for all pesticide/year combinations.
- Figure 1 shows that MACRO gave a good prediction of the median ratio between loss under NT : loss under CT (observed 1.74, simulated 1.65), but under-estimated the range in that ratio across the dataset.
- MACRO gave a good simulation of annual losses to drains with a slight tendency to over-estimate the observed loss (Figure 2).

CONCLUSION

The literature indicates an overall tendency for greater transport of pesticides to drains under no-tillage compared to conventional tillage. However, there is variability across available studies, and it often takes several years for this effect to become significant. MACRO performed well in simulating the effect of tillage on pesticide transport for two field studies. The model could be useful in identifying situations where greater transport may occur under NT. Further research is recommended to identify vulnerable situations so that we can balance the wider benefits of reduced/zero tillage with potential impacts in some situations on pesticide transport to drains.

[1]Jarvis N, Larsbo M (2012) Trans Asabe 55:1413-23 [2]Elliott JA et al. (2000). J Environ Qual 29:1650-6. [3]Masse L et al. (1998). J Environ Qual 27:877-83. [4]Kanwar RS et al. (1997). J Prod Agric 10:227-34. [5]Potter TL et al. (2015). Sci Total Environ 530: 357-66. [6]Buhler DD et al. (1993). J Environ Qual 22:583-8. [7]Gaynor JD et al. (1995). J Environ Qual 24:246-56. [8]Rothstein E et al. (1996). Agric Water Man 31:195-203. [9]Gaynor JD et al. (1992). Arch Environ Contam Toxicol 23:240-5. [10]Logan TJ et al. (1994). Soil Till Res 30:75-103. [11]Fortin J et al. (2002). J Environ Qual 31:1940-52.