LONG-TERM EFFECTS OF AN OIL PIPELINE INSTALLATION ON SOIL PRODUCTIVITY

Crop yields and heights and soil chemical properties on and immediately adjacent to an oil pipeline right-of-way (ROW) were monitored over a 10-yr period. Effects of soil mixing on chemical properties were still apparent despite good crop management. With the exception of alfalfa, field crop yields on the ROW were reduced by an average of 28% 10 yr after installation.

Key words: Soil mixing, degradation, crop heights

[Effets à long terme de l'installation d'un oléoduc sur la productivité du sol.]
Titre abrégé: Effets de l'installation d'un oléoduc sur les rendements de cultures.
Les rendements et les hauteurs de cultures, ainsi que les propriétés chimiques du sol d'une emprise d'oléoduc ou de la zone adjacente immédiate, ont été suivis de près pendant 10 ans. Les effets du mélange des couches de sol sur les propriétés chimiques sont encore apparents malgré l'utilisation de bonnes pratiques de conduite des cultures. À l'exception de la luzerne, l'installation de l'oléoduc réduit en moyenne de 28% les rendements des grandes cultures sur l'emprise 10 ans après l'installation.

Mots clés: Mélange des couches de sol, dégradation, hauteurs des cultures

Construction of the Sarnia-Montreal oil pipeline was undertaken in the autumn and winter of 1975-1976 under generally unfavorable weather conditions. Previous publications (Culley et al. 1981, 1982) have documented construction conditions, soil disturbance, and subsequent soil productivity. During the initial 5-yr period, yields improved with time; in the 5th year (Y_5) after construction, yields of corn (*Zea mays* L.) and soybeans (*Glycine max* L.) on the right-of-way (ROW) were still significantly lower than those on undisturbed adjacent cropland at all locations. Limited data indicated that alfalfa (*Medicago sativa* L.) was not adversely affected by pipeline-installation disturbance. These pipeline ROW soils had lower organic matter levels, higher pH values, densities and penetration resistances, and lower hydraulic conductivities. The data suggest considerable mixing of surface and subsurface layers not only over the trench, but also in the work (stringing) area. The purpose of this report is to document the effect of pipeline installation on crop yields and soil chemical properties in the ROW over the subsequent 5-yr period (Y_6 - Y_{10}).

Can. J. Soil Sci. 68: 177–181 (Feb. 1988)

Crop yields and heights were determined using previously published methods (Culley et al. 1982). Preliminary statistical analysis of Y_6 through Y_{10} yield data indicated that data segregation by soil series, at the monitored sites did not significantly reduce error variances. For each year, data from all locations were combined. Yields (Y_{ijkl}) were analyzed according to the model:

$$Y_{ijkl} = \mu + C_i + S_{j/i} + Z_k + ZS_{k(j/i)} + CZ_{ik} + \epsilon_1 \quad (1)$$

where μ is the overall mean and C_i, $S_{j/i}$, Z_k, $ZS_{k(j/i)}$, CZ_{ik}, and ϵ_1 are the effects due to crop, sites-nested-within-crop, construction zone, the interaction of zone and sites-nested-within-crop, the zone by crop interaction, and experimental error, respectively. The GLM procedure (Statistical Analysis System Institute, Inc. 1985) was used to produce the AOV tables.

Following crop sampling in Y_{10}, soil samples were collected from the 0.00- to 0.15-m and 0.15- to 0.30-m layers at six spread one yield measurement locations. Soil chemical properties and particle size distributions were determined using standard procedures (Sheldrick 1984); pH was measured in 0.01 M $CaCl_2$ (method 84-001), ammonium acetate exchangeable Ca, Mg, and K by method 84-005. Total soil carbon and nitrogen were determined by combustion analysis (Sheldrick 1986). Plot location (site), depth, construction zone (zone) and the zone by depth interaction were included as sources of variation.

Soil chemical properties in Y_{10} (Table 1) were similar to those in Y_2 (Culley et al. 1982). Surface soils (0.0-0.3 m) in the ROW 10 yr after installation were significantly more calcareous and contained less total nitrogen (organic matter) than adjacent fields, indicating that soil mixing effects were still apparent. Despite the lower organic matter content, cation exchange capacities, as measured by the sum of exchangeable bases, were greater on the ROW. Some of this increase may be attributable to an increased clay-size fraction of the ROW soils; at least some of "exchangeable" Ca^{2+} may actually have derived from dissolving $CaCO_3$. Exchangeable K increased from 0.3 to 0.5 cmol (+) kg^{-1} between Y_1 and Y_{10} indicating that good soil management practices were employed at the yield-monitoring sites.

The sources of variation accounted for a minimum of 95% (in Y_8) and a maximum of 98% (Y_6) of the total yield variation. Crop and zone main effects were consistently significant at $P<0.01$. The site-within-crop effect was consistently significant ($P<0.05$)

Table 1. Selected properties of the 0.0- to 0.15-m and 0.15- to 0.30-m layers of Huron association soils at six Lambton Co., Ontario locations on and adjacent to an oil pipeline installed 10 yr previously

Soil property	Units	Depth	Construction zone: Trench	Work area	Undisturbed field
pH	—	0.0-0.15	7.5	7.5	7.0
		0.15-0.30	7.6	7.5	7.1
			LSD = 0.6†		
Total carbon	mg g^{-1}	0.0-0.15	31.3	25.3	20.2
		0.15-0.30	31.7	24.6	20.2
			LSD = 5.1		
Total nitrogen	mg g^{-1}	0.0-0.15	1.7	1.9	2.3
		0.15-0.30	1.6	1.8	2.3
			LSD = 0.8		
Exchangeable Ca^{2+}	mol(+) kg^{-1}	0.0-0.15	20.2	21.0	13.3
		0.15-0.30	21.0	21.0	13.4
			LSD = 5.5		
Exchangeable Mg^{2+}	mol(+) kg^{-1}	0.0-0.15	1.9	2.2	2.5
		0.15-0.30	2.2	2.3	2.7
			LSD = 1.1		
Exchangeable K^{+}	mol(+) kg^{-1}	0.0-0.15	0.5	0.5	0.4
		0.15-0.30	0.4	0.4	0.4
			LSD = 0.2		
Sum of exchangeable cations	mol(+) kg^{-1}	0.0-0.15	22.6	23.5	16.2
		0.15-0.30	23.5	23.6	16.5
			LSD = 6.3		
Clay	% by wt	0.0-0.15	33.3	29.9	24.6
		0.15-0.30	35.0	30.7	26.6
			LSD = 7.0		

† Any two treatment means which differ by more than the least significant difference (LSD) are significantly different at $P<0.05$.

Table 2. Crop yields (dry wt basis) on and adjacent to an oil pipeline right-of-way 6-10 year after installation

		Zone			
Years since construction	Crops†	Trench	Work area	Undisturbed field	LSD‡ ($P<0.01$)
		t ha^{-1}			
6	Alfalfa (2), grain corn (2), cereals (2), soybeans (1), silage corn (1)	4.41	4.23	5.70	0.42
7	Alfalfa (2), soybeans (3), cereals (2), silage corn (1)	2.70	3.34	4.24	0.44
8	Grain corn (2), soybeans (2), cereals (1), alfalfa (1)	4.22	3.82	5.31	0.46
9	Grain corn (2), soybeans (1), alfalfa (1)	4.94	5.29	6.23	0.87
10	Grain corn (2), soybeans (2), cereals (2), alfalfa (1)	3.85	3.68	5.22	0.37
6-10	Grain corn (8)	6.52	6.38	8.47	—
6-10	Soybeans (9)	1.79	1.81	2.65	—
6-10	Cereals (7)	3.03	3.08	4.20	—
6-10	Alfalfa (7)	2.52	2.44	2.49	

† Figures in parentheses refer to the number of locations at which crop yields in construction zones were determined.
‡ Means within each row which differ by more than the least significant difference (LSD) are significantly different at $P<0.01$.

while an equivalently significant interaction between zone and sites-within-crop was noted in Y_9 only. A significant ($P<0.01$) crop by zone interaction was observed in all but one year (Y_9), when only four sites were sampled for yield determinations. Overall, trench and work-area yields differed by less than 0.05 t ha^{-1} (Table 2), and work-area yields averaged 77% of those in adjacent undisturbed-fields. There was no trend in the ratio of work-area-to-adjacent-field yields with time, indicating no significant improvement in soil productivity over the monitoring period. Average 5-yr undisturbed-field yields of corn and soybeans exceeded Lambton county estimates (Ontario Ministry of Agriculture and Food 1986) by 25 and 16%, respectively, indicating that co-operative farmers practiced superior crop management.

The crop by zone interaction for alfalfa was different than that for corn, soybeans and cereals. There was no alfalfa yield decrease on the ROW, while cultivated crops all exhibited a similar depression on the ROW. This substantiates earlier results obtained from Y_1 through Y_5.

Work-area to adjacent-field yield ratios were well correlated (r = 0.72**) to mid-season (early June for forages and cereals, and late July for corn and soybeans) crop height ratios. Elimination of the alfalfa data reduced the r to 0.49, which was still significant at $P<0.01$. For corn and soybeans, the relationship between yield and height was also significant (r = 0.55**). Cereal, corn and soybean height ratios were also related to the time from installation (Fig. 1). An exponential equation accounted for 37.4% of the variation at the yield sites (n=41) and for 17.8% of the variation at height-monitoring locations which were much more numerous (n=334). Thus, it appears that the rate of improvement in ROW soil productivity during the first 5-yr period was not sustained in the subsequent 5 yr at those sites not seeded to alfalfa. ROW yields in Y_{10} amounted to roughly 72% of those on adjacent undisturbed land.

In conclusion, ROW yields of corn, soybeans and cereals were depressed for up to 10 yr after the installation of an oil pipeline under adverse weather conditions. Organic matter dilution, resulting in lower N supply capacities from mineralized organic matter, together with more highly compacted surface soil layers may be responsible for reduced yields of annual crops. However, alfalfa yields were not detrimentally affected by pipelining. The atypical response of alfalfa cannot be attributed to the greater ROW soil pH as the pH values of the adjacent fields were within the range considered optimum for this crop (Mclean and Brown 1984).

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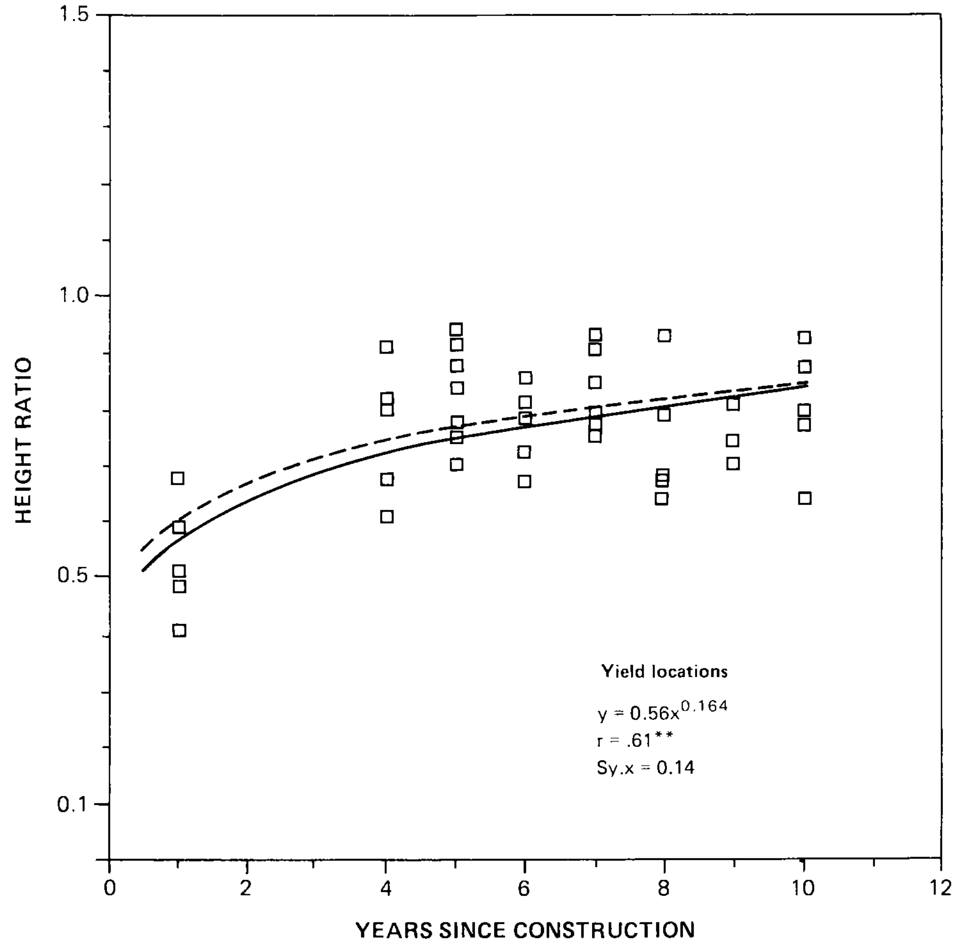

Fig. 1. Work-area to adjacent-field crop height ratios at yield-monitoring locations as a function of time from construction and best-fit exponential regression (solid curve). The best-fit exponential equation for all height monitored locations (dotted curve) is included.

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Contribution no. 86-98, received 6 Jan. 1987, accepted 6 Oct. 1987.