# PREDICTING THE AMOUNT OF NITRATE-NITROGEN AND WATER IN THE SOIL PROFILE

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***Abstract.*** Four simulation models were used to predict the amount and distribution of nitrate-N and water in soil from long-term spring wheat (*Triticum aestivum* L.) rotations at the end of the 1990 growing season at Melfort, Saskatchewan. There were significant differences between models in accurately simulating the nitrate-N and water status of the soil profile.

## INTRODUCTION

Determining the amount and distribution of nitrate-N and water in the soil profile is important from an agronomic and environmental standpoint. This information can form the basis of more accurate fertilizer N recommendations and can influence future cropping decisions, as well as indicate the potential for nitrate-N leaching losses below the crop rooting zone. Amount and distribution of nitrate-N in soil primarily depends on amount and distribution of precipitation over the growing season, the availability of soil nitrate-N, and soil texture (Campbell et al. 1983). Nitrate-N availability, in turn, is significantly influenced by agronomic practices such as N fertilization and frequency of fallow in the crop rotation (Campbell et al. 1984). Fallow soils typically have higher soil mineral N and water in the rooting zone compared with continuously cropped soils.

Four models for simulating biophysical processes in agroecosystems are CERES-Wheat (Crop Estimation through Resource and Environment Synthesis), EPIC (Erosion/Productivity Impact Calculator), NLEAP (Nitrogen Leaching and Economic Analysis Package), and NTRM (Nitrogen, Tillage, and Residue Management). They simulate soil-crop-climate interactions. The CERES, EPIC, NLEAP, and NTRM models are described by Ritchie and Otter (1985) and Godwin et al. (1990); Williams et al. (1983, 1990); Shaffer et al. (1991); and Shaffer and Larson (1987), respectively. Accurately simulating nitrogen and hydrological processes in soil are primary requirements of these models. However, they have not been evaluated for predicting amount and distribution of nitrate-N and water in soil in western Canada. Both EPIC and CERES previously were evaluated for predicting spring wheat (*Triticum aestivum* L.) grain yield over time (Moulin and Beckie 1993).

Since these and other models are used by policy makers and extension workers, information is required on both their usefulness and limitations in simulating the nitrate-N and water status of soil. Therefore, the objective of this study is to evaluate these four simulation models for predicting amount and distribution of nitrate-N and water in the soil profile in August of 1990, using data from long-term spring wheat rotations at Melfort, Saskatchewan.

## MATERIALS AND METHODS

The long-term spring wheat rotations, which were established in 1957 at Melfort, are listed in Table 1. The experiment was arranged in a randomized complete block design. Each crop rotation was established such that every phase of the rotation would occur each year. Katepwa wheat was seeded at a rate of 100 kg $ha^{-1}$ on May 29 in 1990. Fertilizer was applied based on fall soil test levels and the recommendation criteria of the Saskatchewan Advisory Council on Soils. Urea fertilizer was broadcast at a rate of 67 kg N $ha^{-1}$ and shallowly incorporated in the soil, whereas fertilizer P was applied with the seed at a rate of 46 kg $P_2O_5$ $ha^{-1}$. Weeds were controlled by spraying as required. Wheat was swathed on August 30 and harvested on September 12. On summerfallow, weeds were controlled by tillage with four operations with a field cultivator.

On August 21 in 1990, the fallow (F) plots of the fallow-wheat (F-W) rotations as well as the continuous wheat (W) plots were sampled to 300-cm depth. Each 30-cm increment of soil was analyzed for nitrate-N concentration (ppm), gravimetric water content, and bulk density. The latter was used to express nitrate-N results in kg $ha^{-1}$ and water content on a volumetric basis (cm water per 30-cm soil increment).

Model simulations were run over the 1990 growing season using four major sets of data. The first data set is daily weather including maximum and minimum temperature and precipitation. Average amounts of precipitation occurred during the year prior to soil sampling. The second data set contains general information of the site such as latitude, longitude, and topographical and hydrological properties. Data on the physical and chemical characteristics of the soil profile (Table 2) comprise the third data set. Spring soil nitrate-N and volumetric water content for each rotation were input to initialize the simulations. To facilitate comparisons between model results, amount of nitrate-N and water were simulated to 150-cm depth in soil (NLEAP simulates nitrate-N only). The profile was divided into three layers, based on the soil horizon boundaries - 0 to 30 cm (Ah), 30 to 60 cm (Bm), and 60 to 150 cm (Ck). The final major set of data contains crop management information for each rotation such as dates and methods of tillage, fertilization, planting, and harvesting operations.

*Table 1.* Long-term spring wheat rotations and fertilizer treatments at Melfort.

| Rotation[a] | Fertilizer treatment |
|---|---|
| Fallow-wheat (F-W) | N & P |
| Fallow-wheat-wheat (F-W-W) | N & P |
| Fallow-wheat-wheat (F-W-W) | None |
| Continuous wheat (W) | N & P |
| Continuous wheat (W) | None |

[a]Phase of the crop rotation sampled is underlined.

*Table 2*. Description of Melfort silty clay (Orthic Black Chernozem), by layer.

| | Soil layer number | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Lower boundary (m) | 0.15 | 0.30 | 0.60 | 0.90 | 1.5 |
| Bulk density ($Mg/m^3$)[a] | 1.2 | 1.2 | 1.4 | 1.4 | 1.4 |
| Sand (%)[a] | 16 | 16 | 13 | 8 | 8 |
| Clay (%)[a] | 44 | 44 | 59 | 75 | 74 |
| pH[b] | 6.0 | 6.5 | 7.0 | 8.0 | 8.0 |
| Organic carbon (%)[b] | 5.5 | 3.5 | 1.3 | 0.5 | 0.5 |

[a]Data from C. A. Campbell (unpublished data).

[b]Data from W. F. Nuttall et al. (1986) and the Canada Soil Information System (CanSIS), Land Resource Research Institute, Agriculture Canada, Ottawa, ON.

## RESULTS AND DISCUSSION

Measured and predicted soil nitrate-N levels from the long-term wheat rotations at Melfort on August 21 in 1990 are given in Table 3. Overall, EPIC poorly simulated amount and distribution of nitrate-N in the profile. In the top 30-cm layer of the F plots, model predictions were high, possibly due to overestimation of the amount of N mineralized over the fallow period. There was good agreement between measured and simulated results for the B horizon, but not the C horizon. The model greatly underpredicted amount of nitrate-N in the profile of fertilized W, but the simulated values for the A and B horizons of the unfertilized W rotation were in close agreement with measured results. Both CERES and NTRM generally predicted amount and distribution of nitrate-N in soil satisfactorily, with the exception of the unfertilized W rotation, where simulated results were high. The NLEAP model, which only simulates amount of nitrate-N in two layers - 0 to 30 cm and 30 to 150 cm - overestimated nitrate-N in the top layer but predicted total soil nitrate-N in the profile reasonably well. However, similar to CERES and NTRM, simulated results for the unfertilized W rotation were high. These three models may be underestimating uptake of soil nitrate-N by the crop or N immobilization in this unfertilized rotation.

The EPIC, CERES, and NTRM models generally predicted amount and distribution of water in soil satisfactorily (Table 4). Simulated EPIC values for the A horizon of the F rotations were in close agreement with measured results, but tended to be high for the B and C horizons. Opposite results were obtained for the W rotations, where EPIC overestimated water content of the A horizon but simulated volumetric water levels reasonably well for the B and C horizons. The CERES predictions were in close agreement with measured results for the A horizon, but the model tended to overestimate the amount of water in the B horizon and underestimate water levels in the C horizon. The NTRM model

*Table 3.* Comparison of measured (standard errors in parentheses) and predicted soil nitrate-N levels from long-term spring wheat rotations at Melfort, Saskatchewan on August 21, 1990.

| Rotation[a] | Fertilizer treatment | Soil depth | Soil horizon | Soil nitrate-N level: Measured | Predicted: EPIC | Predicted: CERES | Predicted: NTRM | Predicted: NLEAP |
|---|---|---|---|---|---|---|---|---|
| | | cm | | kg ha$^{-1}$ | | | | |
| F-W | √ | 0-30 | Ah | 68 (6) | 171 | 78 | 78 | 104 |
| | | 30-60 | Bm | 55 (16) | 71 | 68 | 50 | |
| | | 60-150 | Ck | 120 (15) | 43 | 116 | 124 | |
| | | 0-150 | | 243 (23) | 285 | 262 | 252 | 262 |
| F-W-W | | 0-30 | Ah | 72 (3) | 142 | 67 | 80 | 90 |
| | | 30-60 | Bm | 27 (3) | 27 | 24 | 41 | |
| | | 60-150 | Ck | 42 (4) | 43 | 31 | 57 | |
| | | 0-150 | | 141 (6) | 212 | 122 | 178 | 134 |
| F-W-W | √ | 0-30 | Ah | 89 (5) | 296 | 121 | 103 | 132 |
| | | 30-60 | Bm | 123 (9) | 122 | 104 | 61 | |
| | | 60-150 | Ck | 137 (14) | 43 | 168 | 169 | |
| | | 0-150 | | 349 (17) | 461 | 393 | 333 | 364 |
| W | | 0-30 | Ah | 9 (1) | 11 | 36 | 123 | 53 |
| | | 30-60 | Bm | 5 (1) | 4 | 20 | 42 | |
| | | 60-150 | Ck | 32 (10) | 13 | 24 | 54 | |
| | | 0-150 | | 46 (10) | 28 | 80 | 219 | 83 |
| W | √ | 0-30 | Ah | 113 (30) | 41 | 83 | 101 | 129 |
| | | 30-60 | Bm | 67 (19) | 4 | 46 | 45 | |
| | | 60-150 | Ck | 73 (21) | 13 | 64 | 83 | |
| | | 0-150 | | 253 (42) | 58 | 193 | 229 | 218 |

[a]Phase of the crop rotation sampled is underlined.

*Table 4*. Comparison of measured (standard errors in parentheses) and predicted soil water levels from long-term spring wheat rotations at Melfort, Saskatchewan on August 21, 1990.

| Rotation | Fertilizer treatment | Soil depth | Soil water level: Measured | Predicted: EPIC | Predicted: CERES | Predicted: NTRM |
|---|---|---|---|---|---|---|
| | | cm | cm | | | |
| F-W | √ | 0-30 | 11.0 (0.1) | 11.4 | 11.1 | 13.2 |
| | | 30-60 | 11.3 (0.2) | 12.6 | 12.0 | 10.5 |
| | | 60-150 | 33.9 (0.7) | 35.1 | 28.8 | 31.5 |
| | | 0-150 | 56.1 (0.8) | 59.1 | 51.9 | 55.2 |
| F-W-W | | 0-30 | 11.4 (0.2) | 11.4 | 11.4 | 13.8 |
| | | 30-60 | 10.9 (0.3) | 12.6 | 12.3 | 9.9 |
| | | 60-150 | 32.7 (0.8) | 36.9 | 27.0 | 30.6 |
| | | 0-150 | 55.0 (0.8) | 60.9 | 50.7 | 54.3 |
| F-W-W | √ | 0-30 | 11.0 (0.4) | 11.4 | 11.1 | 12.9 |
| | | 30-60 | 11.0 (0.5) | 12.6 | 12.0 | 10.5 |
| | | 60-150 | 33.9 (0.7) | 34.2 | 28.8 | 31.5 |
| | | 0-150 | 55.8 (0.9) | 58.2 | 51.9 | 54.9 |
| W | | 0-30 | 6.5 (0.4) | 9.6 | 7.8 | 9.9 |
| | | 30-60 | 7.1 (0.2) | 7.2 | 9.3 | 9.6 |
| | | 60-150 | 30.2 (0.9) | 26.1 | 25.2 | 29.7 |
| | | 0-150 | 43.8 (1.0) | 42.9 | 42.3 | 49.2 |
| W | √ | 0-30 | 6.4 (0.3) | 9.9 | 7.5 | 10.8 |
| | | 30-60 | 7.2 (0.5) | 7.2 | 9.0 | 10.8 |
| | | 60-150 | 29.4 (0.8) | 27.9 | 27.0 | 31.5 |
| | | 0-150 | 43.0 (1.0) | 45.0 | 43.5 | 53.1 |

[a]Volumetric soil water at field capacity (33 kPa): 0-30 cm: 0.48, 30-60 cm: 0.50, 60-150 cm: 0.58; permanent wilting point (1500 kPa): 0-30 cm: 0.27, 30-60 cm: 0.30, 60-150 cm: 0.37.

overestimated soil water in the A horizon for all rotations, and also in the B horizon of the W rotations.

In conclusion, differences existed between models in accurately simulating the nitrate-N and water status of soil from the long-term wheat rotations at the end of the 1990 growing season. Overall, CERES and NTRM were useful in roughly estimating both nitrate-N and water in the soil. Further model testing using data from other sites and years are required to more fully evaluate their usefulness and limitations in predicting amount and distribution of nitrate-N and water in soil.

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