

**SIMULATING NITRATE LEACHING UNDER DRYLAND CONDITIONS:
MODEL VALIDATION FOR WATER AND SOLUTE MOVEMENT**

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ABSTRACT

There is an increased awareness of the possible leakage of nitrate out of agricultural systems and its potential to contaminate underground and surface water. This has led to the use of simulation models for studying the dynamics and movement of nitrate-nitrogen within and beyond the root zone of crops. Before these models can be applied to field situations they need to be tested and validated against realistic field conditions. We tested the water flow and solute movement portion of LEACHM (Leaching Estimation And CHEMistry Model), and validated it with respect to moisture and chloride changes of a prairie soil under fallow conditions during the growing season. The retentivity and conductivity functions proposed by Campbell (1974), as used in the original version of the model behaved poorly for our soil. We modified the model using the Van Genuchten function and used this to simulate water content changes during the 1975 and 1976 growing seasons. The "pan coefficient" was used as an optimization factor to calibrate the 1976 moisture data. A pan coefficient of 0.4-0.5 was found to be appropriate under fallow while a value of 0.7 was used for wheat crop. Moisture distribution with depth, and changes with time, were well simulated by the model. The distribution of 171 kg/ha of chloride applied as KCl at a depth of 10 cm was simulated using LEACHM. There was good agreement between the predicted and measured chloride distribution in 1975 and 1976.

INTRODUCTION

The use of simulation model as a means of studying the dynamics and possible leakage of Nitrate-Nitrogen from agricultural soil is on the increase in recent years. This is partly due to increased environmental awareness of possible ground water pollution by nitrogen leached out of the vadose zone. Also, simulation models with varying degrees of complexity are emerging that attempt to synthesize the current knowledge on the different aspects of the nitrogen cycle. The models reduce the complex chemical, biological, physical and hydrological interactions that govern nitrate dynamics and movement in the soil into mathematical scheme that describe the system as realistic as possible.

Before these models can be applied to field situations, they need to be tested and validated against realistic field situations. The dearth of appropriate data for model validation and the cost involved in the process, are some of the factors limiting the widespread use of simulation models

The LEACHM model (Hutson and Wagenet, 1991; Wagenet and Hutson, 1987) was selected for validation with the main goal of using the model to construct Nitrogen balance under various long term crop rotation. This paper reports on the work carried out with the water and solute movement portion of the model.

MATERIAL AND METHODS

The data that was used for testing LEACHM was obtained from a lysimeter experiment carried out in 1975 and repeated, in part, in 1976 at Swift Current on a Swinton Loamy soil. For the detail description of this experiment the reader is referred to papers by Campbell and Paul (1978) and Campbell et al (1977)

Briefly the experiment was conducted using lysimeters that were 120 cm long with an internal diameter of 15 cm. The lysimeter experiment involved two moisture regimes: natural rainfall and irrigated plots. There were five levels of nitrogen and chloride was added to all the plots as a tracer. The experiment was conducted using wheat crop as well as under fallow. Detailed measurements were made from 0-120 cm depth. The measurements made include: gravimetric moisture content; NO_3 ; exchangeable NH_4 ; chloride; bulk density; and temperature. As well, records were kept of the amounts and date of rainfall, irrigation, pan evaporation, date of sampling, root distribution, dry matter yield, etc. Measurements were made at 2-4 week intervals.

Soil physical and hydraulic properties were measured at the beginning of these experiments for each distinct horizon or soil layer. Initial soil moisture, nitrate, NH_4 and chloride content of each 2.5 cm segment were also taken from the soil surface down to a depth of 45 cm and at 5 cm interval thereafter.

In 1975, each lysimeter received 171 kg/ha of chloride as potassium chloride which was added at a depth of 10 cm. The chloride level was increased to 342 kg/ha in 1976 when the experiment was repeated to simulate fallow conditions only.

LEACHM is a research type model which in its original form has been described in detail by (Hutson and Wagenet, 1991; Smith et al, 1991; Wagenet and Hutson, 1987). A preliminary evaluation of the model using some of the data obtained from the experiment described above revealed that the model permitted too rapid transmission of water through the soil. The Campbell function (Campbell 1974) used to describe the matric potential-theta-hydraulic conductivity relationships seems to be inappropriate for describing the results obtained from the field. The model was modified to use the van Genuchten function (van Genuchten, 1980). The modified LEACHMN was used to simulate the data generated in the field without any optimization of the hydraulic parameters.

As a result of the better precision of the data generated from fallow lysimeter in 1976, these data were chosen for calibrating the model for water and chloride movement. The parameters that were used to calibrate the model, their values and a sample scenario simulated in 1975 are shown in Table 1. The model was also used to simulate moisture changes under wheat crop in 1982 from the crop rotation experiment (Campbell et al 1983a and 1983b). A 24 year model simulation of this rotation was carried out by running the model from March to November of each year and assuming that no moisture movement occurred during the winter period.

RESULTS AND DISCUSSION

Figure 1 shows the comparison between the moisture content measured on the field and that simulated by the water balance portion of the LEACHMN at different dates during the 1975 season. Overall, the model simulated the moisture content under fallow fairly well. The distribution of water with depth, as well as the changes during the growing season, were well simulated by the model. The result show the gradual increase in moisture with time under fallow condition. Most of the storage of moisture occurred below 20 cm depth as the topsoil was very dry for the most part during the season. The high surface moisture shown in August was due to a rainfall event a day before sampling.

There was a tendency to over predict the moisture content at or near the soil surface, especially at the very low end of soil moisture content following period of long dry spell. This was the case for both outputs made in July where measured surface soil moisture (v/v) was 0.09 but the model predicted 0.16. This discrepancy is probably due to the surface boundary potential specified in the model as the model appears to be unable to lower surface moisture to the level obtained under very dry conditions. Unlike the gradual increase in moisture obtained in 1975 under fallow the result of the simulation made in 1982, a very wet year shows the depletion of moisture under wheat crop (Figure 2). At harvest

(September 13) the moisture content was reduced to 0.10 from the surface to the rooting depth, assumed to be 120 cm. Between harvest and late fall there was a gradual replenishment of surface moisture by late fall showers. These changes were correctly predicted by the model.

When chloride movement was simulated for the soil under fallow in 1975 (Figure 3), a good agreement was obtained between the predicted chloride concentration and that measured in field. The output made on June 16 indicated that most of the chloride was located at the 10 cm depth, the depth of application. With time, there was a gradual decline in chloride peak as the salt moved away from the point of application. Both the center of mass and the chloride front were correctly simulated by LEACHMN. As a result of the high moisture deficit in 1975, the penetration of chloride into the profile was limited and by the end of the growing season very little was found beyond the 40 cm depth. The non-interacting nature of chloride made such a good fit possible. The parameters obtained with chloride could now be used to simulate nitrate movement with confidence.

Figure 4 shows the results obtained by running LEACHMN for a period of 24 years to simulate the moisture content under a fallow-wheat rotation. The plot shows that a linear relationship existed between the predicted and observed moisture profile at various points during the growing season over the 24 years. The coefficient of variation obtained by regression analysis of the data was 0.96, it was highly significant.

It is concluded that the LEACHMN model performed well in simulating both water and solute transport under the fallow and moisture profile under wheat crop.

Table 1 - Parameters obtained from model calibration and the scenario simulated in 1975.

| | | | |
|---|--------------------|--------|--|
| Starting date: | May 21 1975 | | |
| End of Simulation: | September 8 1975 | | |
| Profile Depth: 120 cm | Depth Increment: | 2.5 cm | |
| 'BBC = 1 (Water Table) | Water table Depth: | 30 M | |
| Diffusion Coefficient: 120 mm ² /day | Dispersibility: | 12 mm | |
| 'Pan Factor = 0.5 (fallow) | 0.7 (Cropped) | | |
| Output Dates: June 16, July 11, July 23, August 25 | | | |
| Physical and Hydrological parameters were as measured at the experimental site. | | | |

'BBC is the soil profile's bottom boundary condition.

'Pan factor is the coefficient relating the measured pan evaporation to the maximum potential evapotranspiration.

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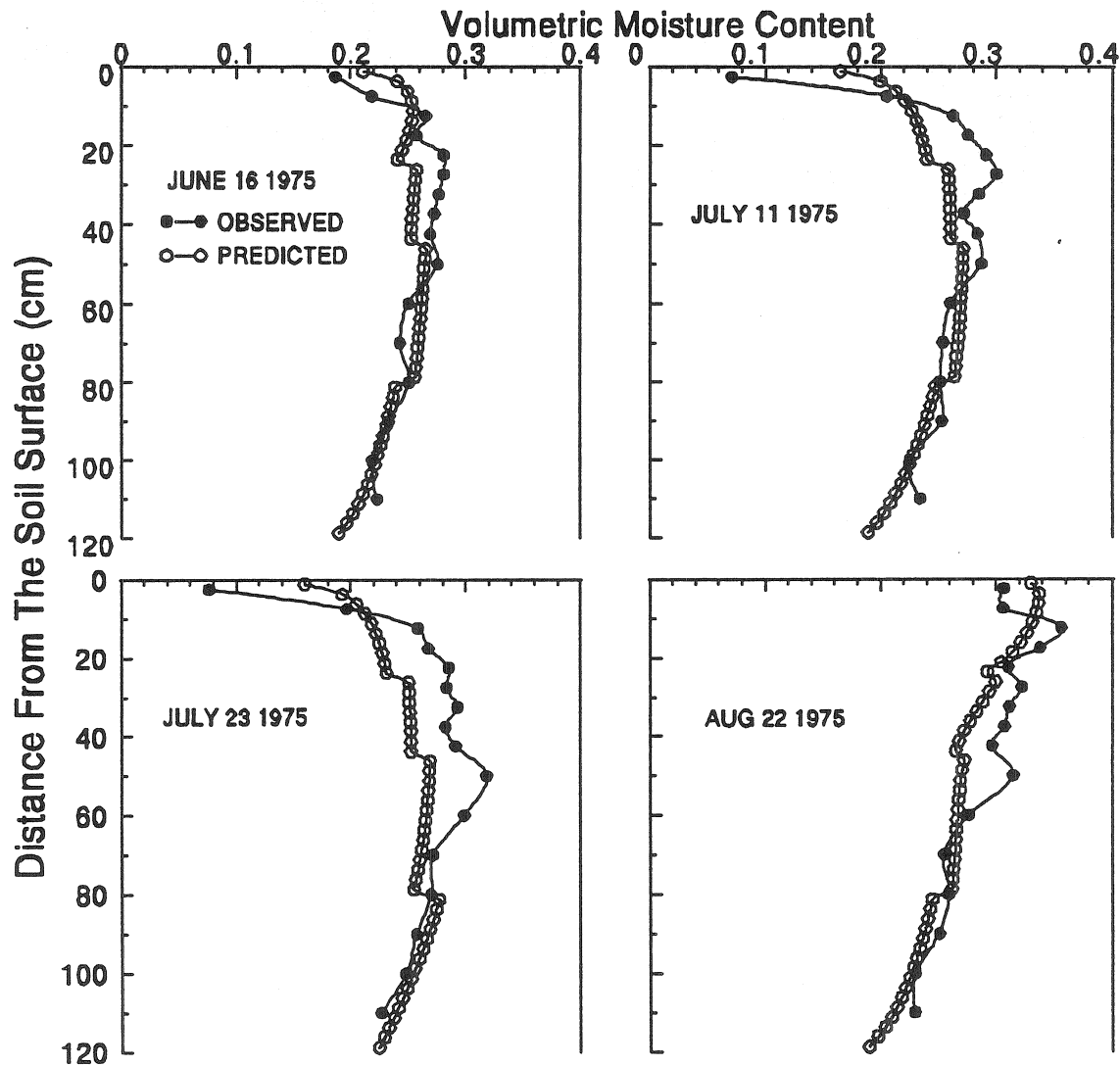


Figure 1 - Simulated moisture profile under fallow at Swift Current in 1975

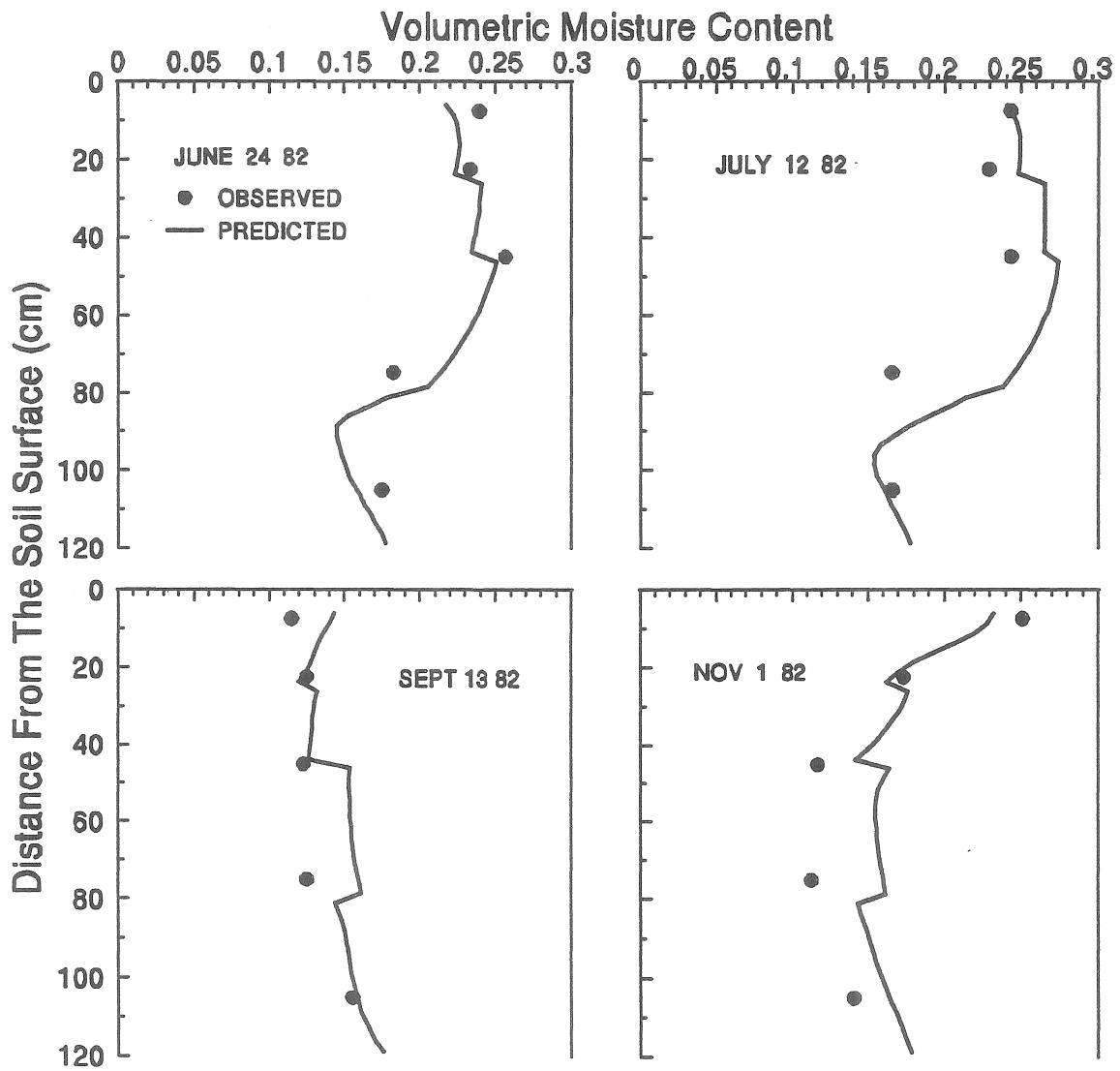


Figure 2 - simulated moisture profile³⁵ under wheat at Swift Current in 1982.

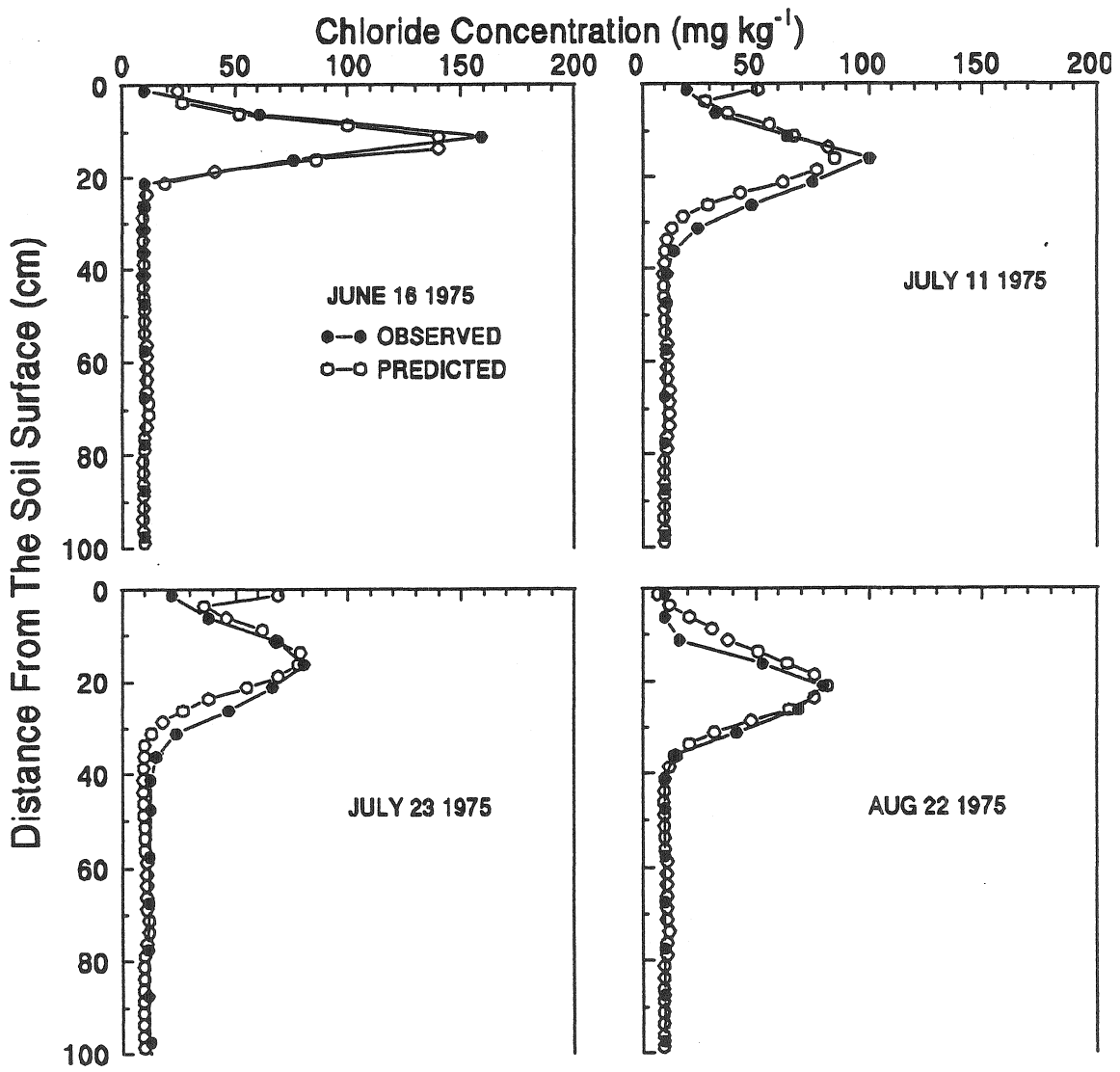


Figure 3 - Simulated chloride distribution under fallow at Swift Current in 1975.

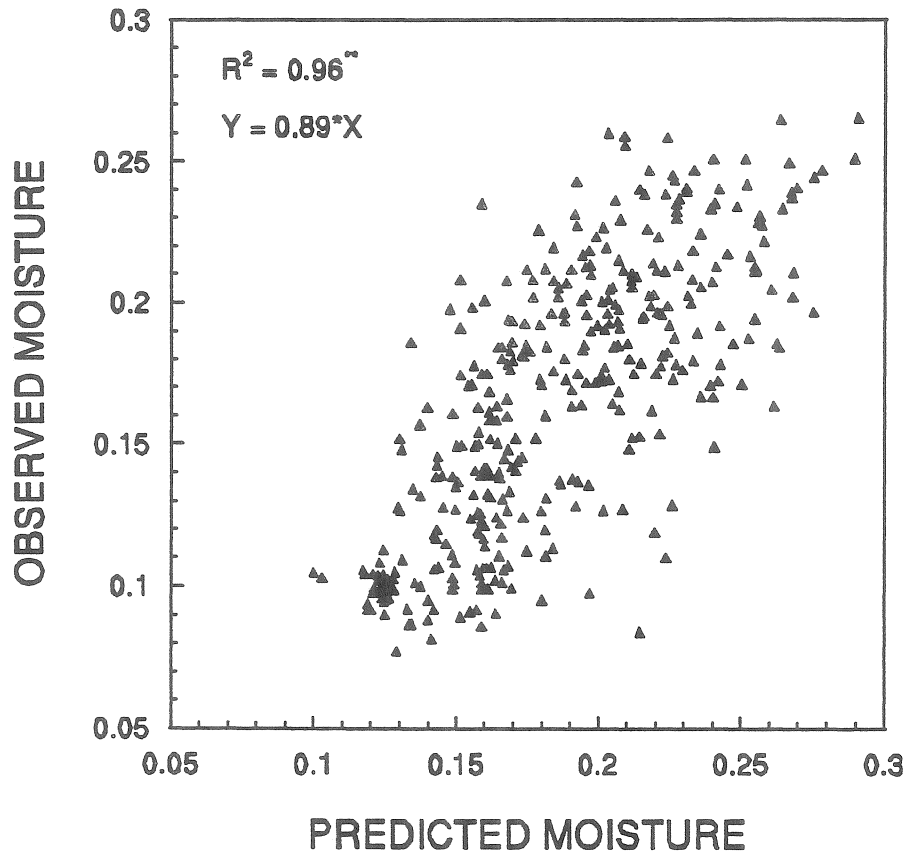


Figure 4 - Moisture content under F-W rotation at Swift Current (1967-1991)