Bromide and Nitrate Transport in Agricultural Sandy Soils

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INTEGRATED CROPPING SYSTEMS FOR IRRIGATED FARMING

Variable rate irrigation, nutrients and chemicals

Spatial variability yield monitoring

N uptake, fate and budget

Management of potatoes and rotational crops

Optimize farm profitability and environmental sustainability

Develop decision support system


USDA

INTRODUCTION

- Sandy soils in some parts of the Pacific Northwest (PNW) and southeastern agricultural regions in the United States contain 95 to 98% sand in the soil profile to a depth of up to 2.5 m with no confining soil horizons.

- The saturated hydraulic conductivities of these soils range from 5.2 to 9.5 m d^{-1}. In some areas, these soils may have shallow groundwater, thus providing favorable conditions for leaching of surface applied chemicals and soluble nutrients that could contaminate the surface waters as well as subsurface aquifers.

Quincy Fine Sand

		--Particle size distribution ($g\ kg^{-1}$)--		
Soil Depth (cm)	Bulk Density ($kg\ m^{-3}$)	Sand	Silt	Clay
0-10	1.33	917	56	27
20-30	1.54	927	52	21
30-60	1.61	936	48	16
60-90	1.60	928	48	24
90-120	1.58	948	38	14

Candler Fine Sand

		--Particle size distribution (g kg^{-1})--		
Soil Depth (cm)	Bulk Density (kg m^{-3})	Sand	Silt	Clay
0-20	1.59	973	9	18
20-50	1.52	974	12	14
50-90	1.51	978	8	14
90-130	1.61	976	15	9
130-245	1.55	977	14	9
245-275	1.55	544	49	407

INTRODUCTION

- In some parts of the intensely irrigated agricultural production region in eastern Washington state, there has been an increase in groundwater NO_3-N concentration in the shallow aquifer in excess of 10 mg per liter, which is the maximum contaminant level (MCL)for drinking water quality standards, per U.S. Environmental Protection Agency regulations.

- The Columbia Basin region in the PNW represents the premier potato production region of the U.S. with maximum production (- 78 Mg/ha) of high quality processed potatoes. Studies are in progress to improve nutrient and irrigation management aimed to minimize NO_3^- transport below the root zone.

U.S. Department of the Interior
U.S. Geological Survey

Nitrate Concentrations in Ground Water of the Central Columbia Plateau

Open-File Report 95-445

Sarah J. Ryker and Joseph L. Jones

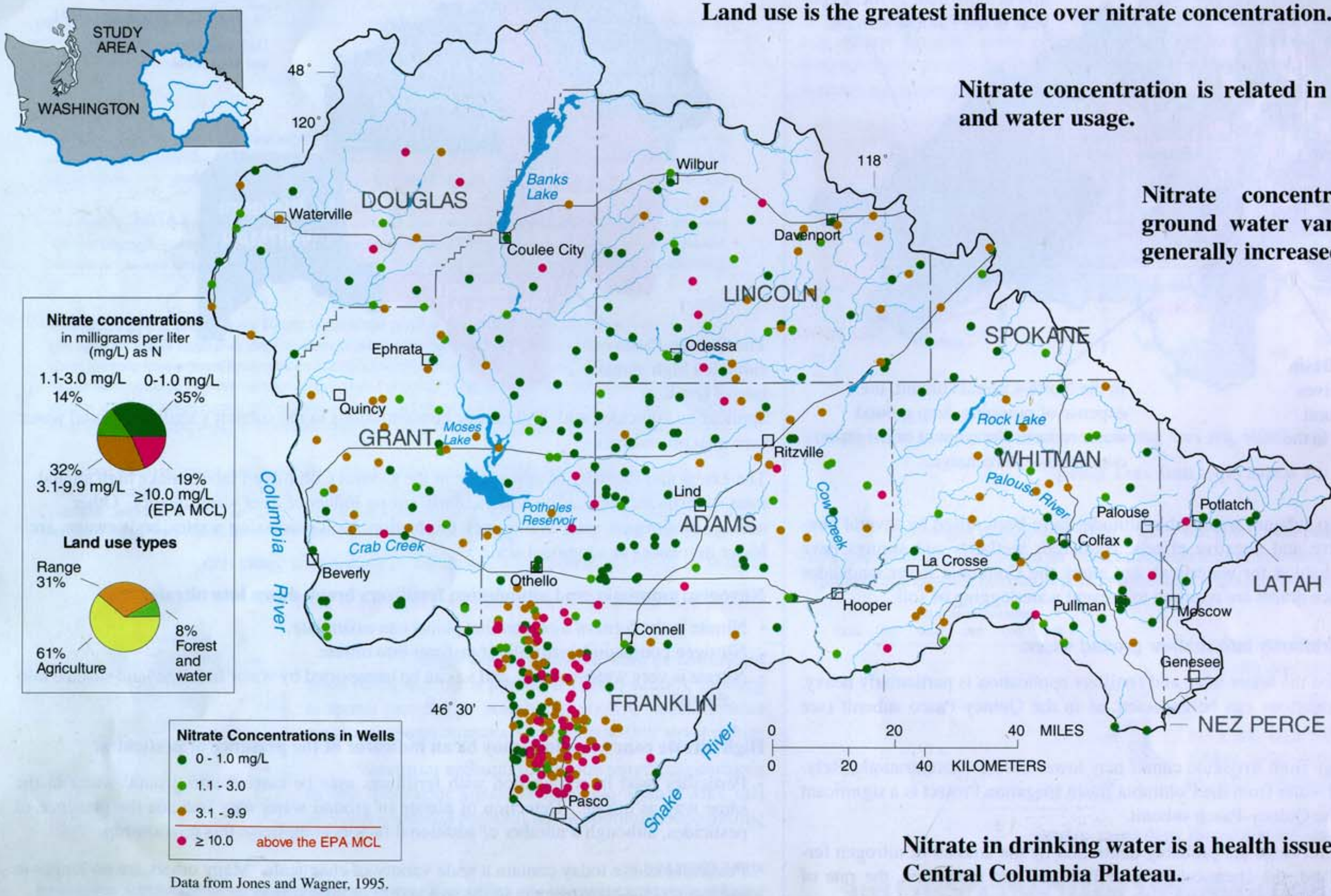
USGS

The U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program is designed to assess the status of and trends in the quality of the Nation's water resources, and to gain a better understanding of the natural and human factors that affect water quality. The Central Columbia Plateau is one of 60 NAWQA study units (major river basins and parts of aquifer systems) located throughout the Nation. In the Central Columbia Plateau, nitrate concentrations for 19% of the 573 wells shown below exceed the U.S. Environmental Protection Agency (EPA) maximum contaminant level (MCL) for drinking water. These concentrations include USGS samples from 1942-94, although 93% of the data are from 1980-94. Where more than one analysis was available for a well, this document refers to the mean concentration as the nitrate concentration for the well.

Land use is the greatest influence over nitrate concentration.

Nitrate concentration is related in general to fertilizer and water usage.

Nitrate concentrations in shallow ground water vary greatly, but have generally increased since the 1950's.



Data from Jones and Wagner, 1995.

Nitrate in drinking water is a health issue in parts of the Central Columbia Plateau.

INTRODUCTION

- Sandy soils provide a well aerated, deep rooting zone which is ideal for improved crop growth and production under optimal management of irrigation, nutrients and other soil applied agrichemicals.

- Increased levels of nitrate-nitrogen (NO_3-N) in shallow groundwater are reported in sandy soil regions in the Columbia Basin irrigated regions in Washington and Oregon, and also in the citrus production regions of central Florida.

INTRODUCTION

- An improved understanding of soil characteristics that influence water and nutrient transport is important to the development of best management practices that minimize leaching losses and improve the uptake efficiency of nutrients by the crop plants.

- Bromide has been used as a tracer to predict the transport of nitrate in soil.

- Bromide tracer can also be used to study the lateral flow of groundwater.

MATERIALS AND METHODS

- Field experiments were conducted in a sandy soil in Florida (Tavares fine sand - hyperthermic, uncoated, Typic Quartzipsamments) in a commercial grove with 25+ year old Hamlin orange trees on Cleopatra mandarin rootstock.

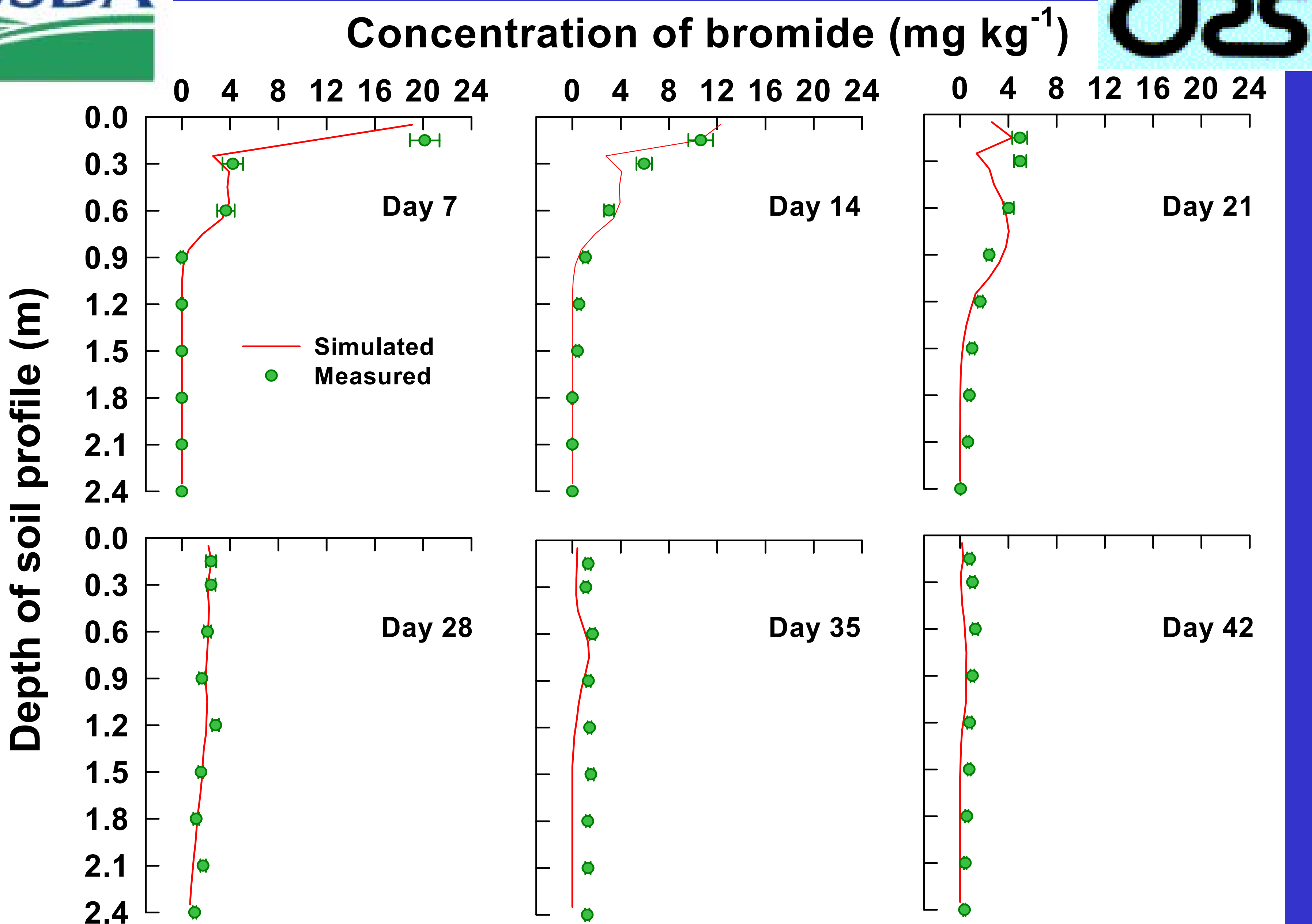
- Bromide was applied at a 112 kg ha^{-1} rate (as KBr) under the tree canopy area which represented wetting zone by under the tree sprinklers. Various rates of N was also applied in dry granular form using ammonium nitrate.

- Irrigation was scheduled when the soil moisture content was depleted to 66% of available soil moisture in the top 1.2 m depth soil which represents the rooting depth for mature citrus trees.

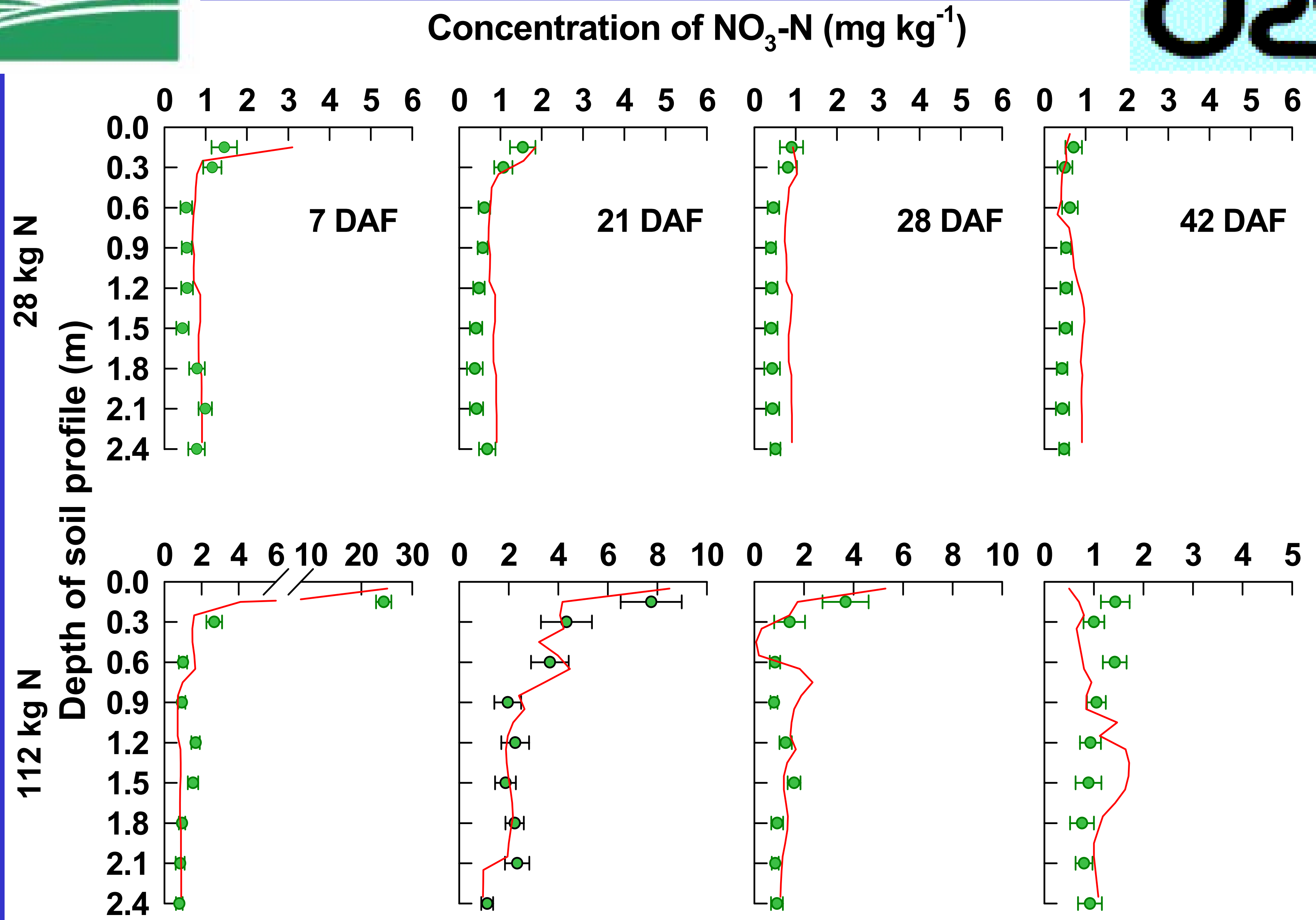
MATERIALS AND METHODS

- The quantity of each irrigation was adjusted to replenish the soil moisture content to field capacity within the rooting depth in order to minimize leaching of water, and soluble nutrients and chemicals below the rooting depth.

- The transport of Br^- and nitrate in the soil profile was monitored by soil sampling to 2.4 m depth at various time intervals after the application of Br^-.



Concentration of bromide (mg kg-1)
0 4 8 12 16 20 24
Depth of soil profile (m)
0.0 0.3 0.6 0.9 1.2 1.5 1.8 2.1 2.4
Day 7
Day 14
Day 21
Day 28
Day 35
Day 42
Simulated
Measured



Concentration of NO3-N (mg kg-1)
Depth of soil profile (m)
28 kg N
112 kg N
7 DAF
21 DAF
28 DAF
42 DAF

Nitrogen mass balance for different fertilization rates as simulated by LEACHM. (All values are in kg/ha)

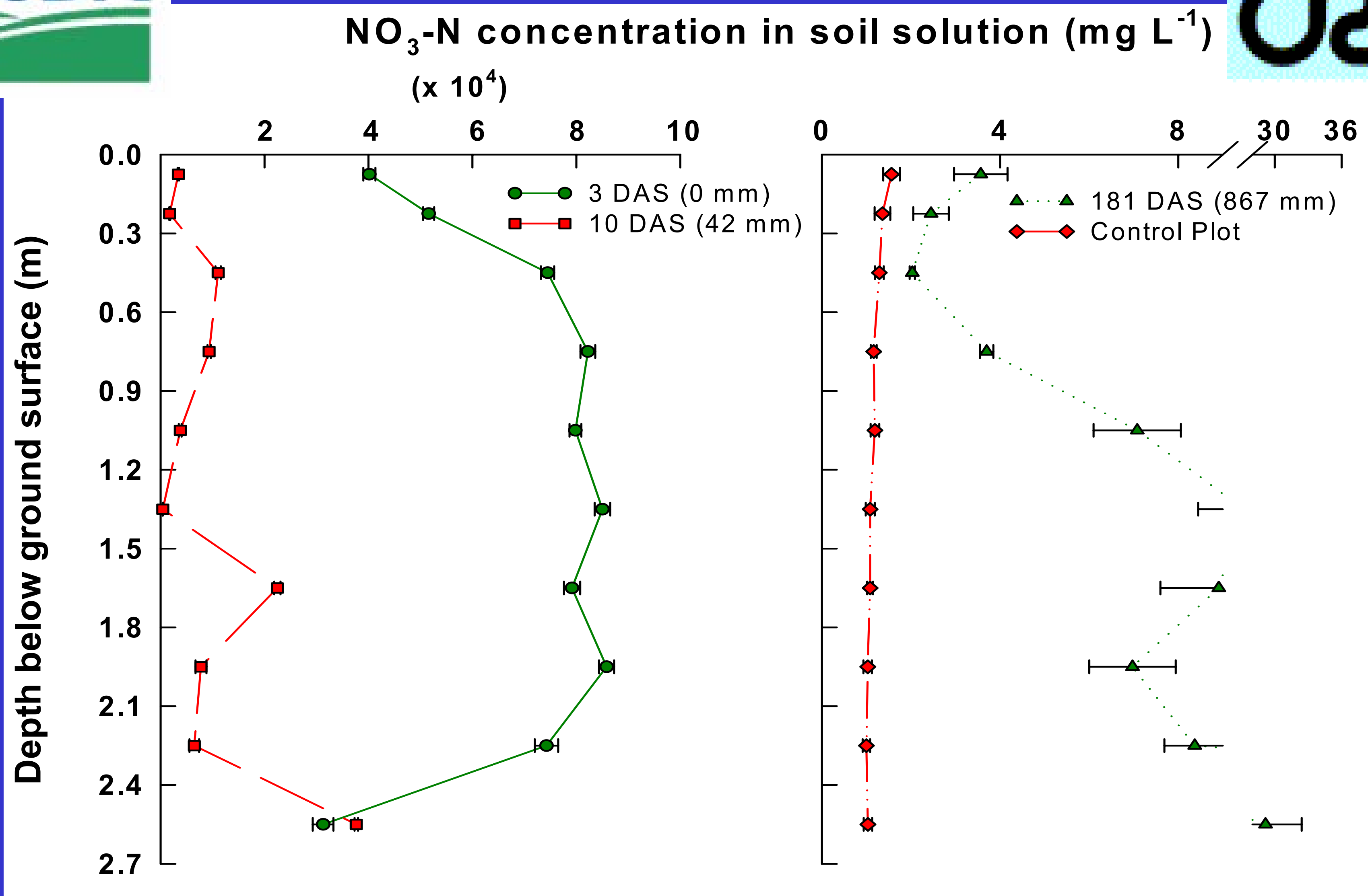
Variable	Input		Output Removal or Losses				Soil Storage (Input-Removal or Losses)
	Mineral form	Organic form	Plant Uptake	Leaching	Volatilization	Microbial assimilation	
N	28	14	20	15	10	2	-5
	56	14	32	15	14	2	7
	84	14	39	28	19	2	10
	112	14	51	30	29	2	14
Br	80	0	32	48	NA	NA	0

Water mass balance as sumulated by LEACHM (in mm)

Input		Removal or Loss		Soil Storage (Input-Removal or Loss
Rain	Irrigation	Plant Uptake	Drainage	
1612	335	920	985	-39

MATERIALS AND METHODS

- **In a parallel experiment using the similar soil series, transport of nitrate was evaluated in an area impacted by an accidental spill of heavy dose of N as liquid N (as ammonium nitrate), P, K blend intended to be used for fertigation.**



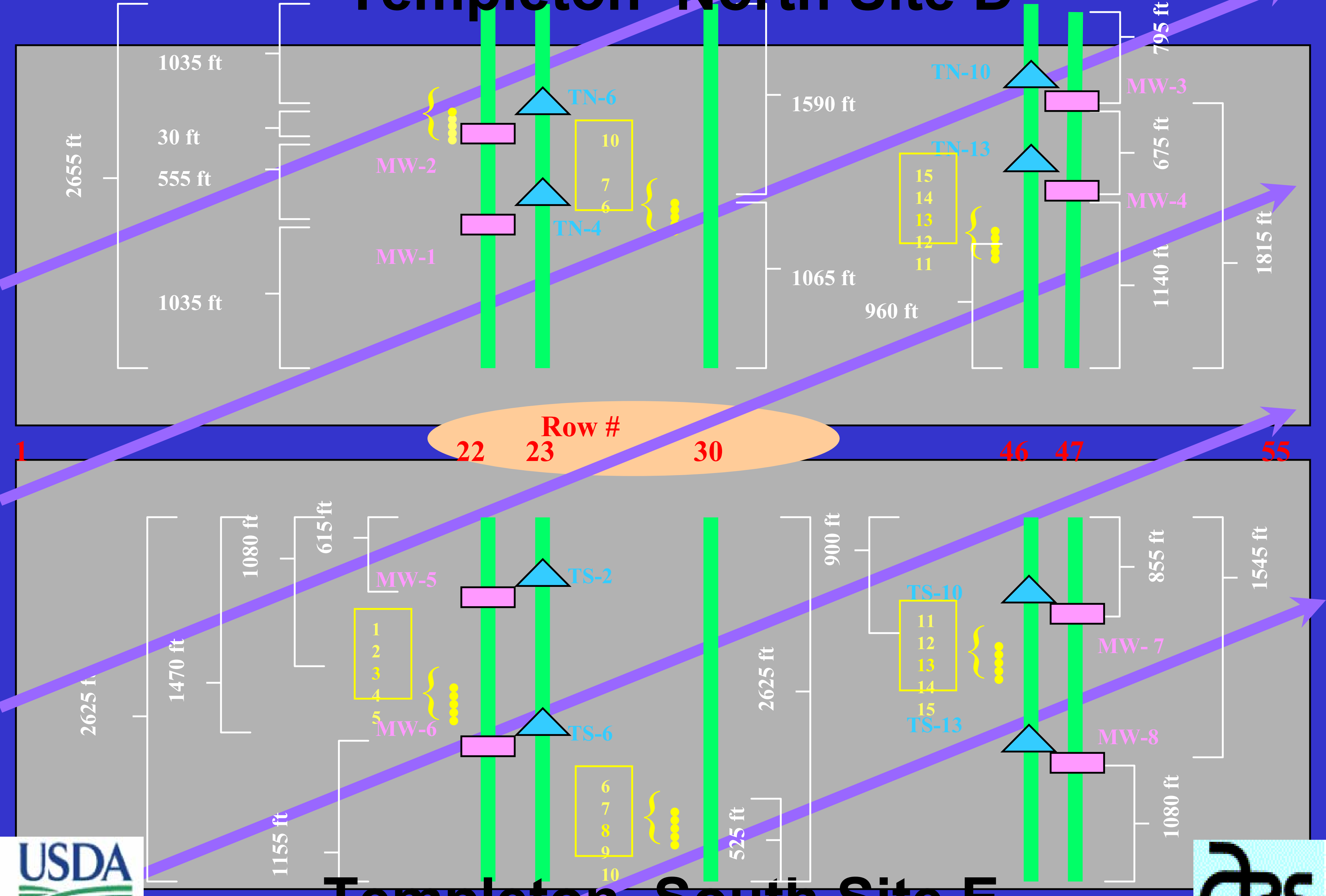
NO3-N concentration in soil solution (mg L-1)
(x 10^4)
2
4
6
8
10
0
4
8
30
36
Depth below ground surface (m)
0.0
0.3
0.6
0.9
1.2
1.5
1.8
2.1
2.4
2.7
3 DAS (0 mm)
10 DAS (42 mm)
181 DAS (867 mm)
Control Plot

INTRODUCTION

- Evaluation of the direction and rate of lateral flow of groundwater is important to understand the potential impact of pollutants from an area of its source of origin into adjacent areas in the direction of groundwater flow.

- Br can be used to determine the lateral flow rate of groundwater.

Templeton North Site D



Templeton South Site E

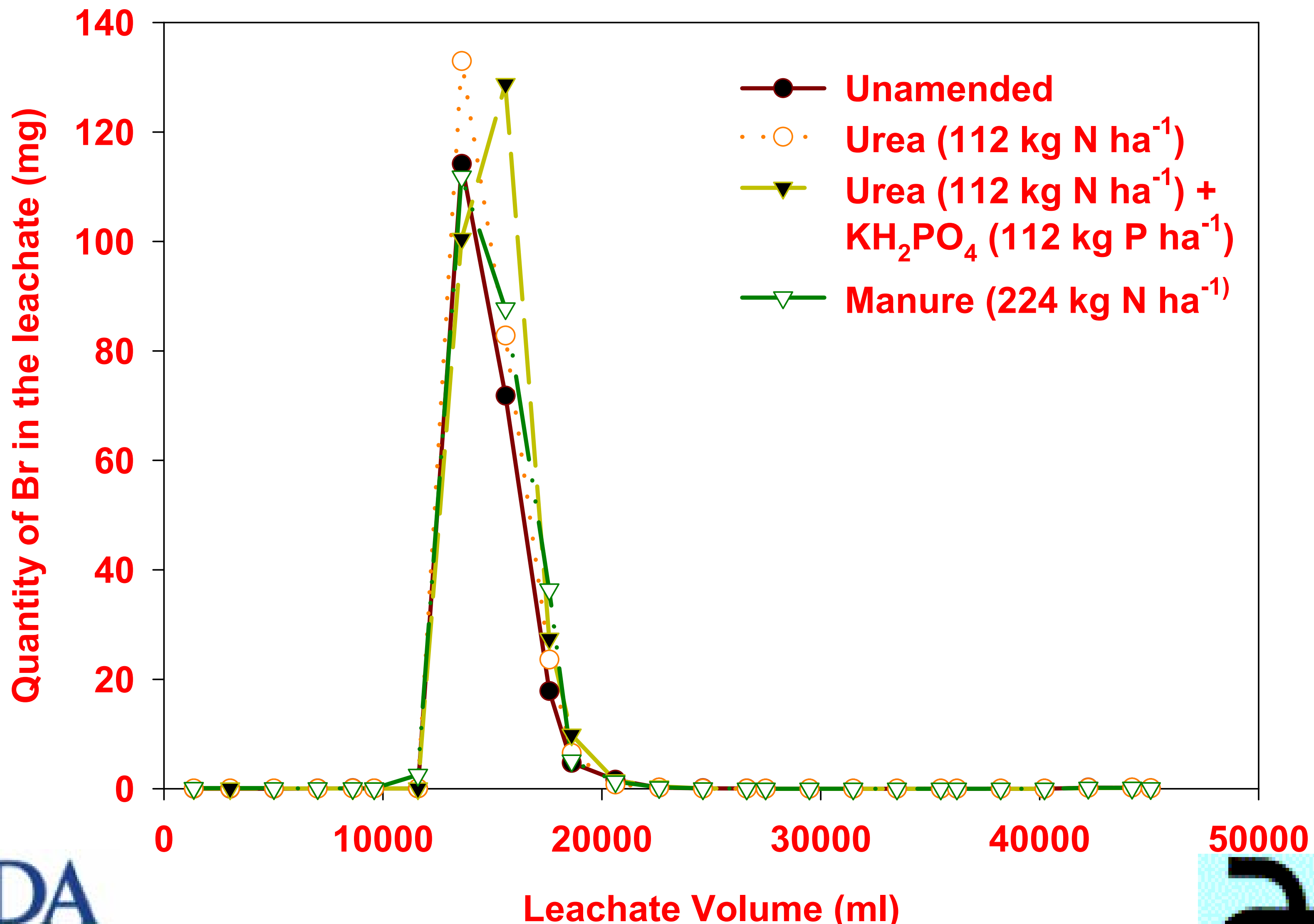
RESULTS AND DISCUSSION

- **A study conducted in an Entisol showed that the lateral flow rate of surfacial groundwater was 0. 08 m d $^{-1}$.**

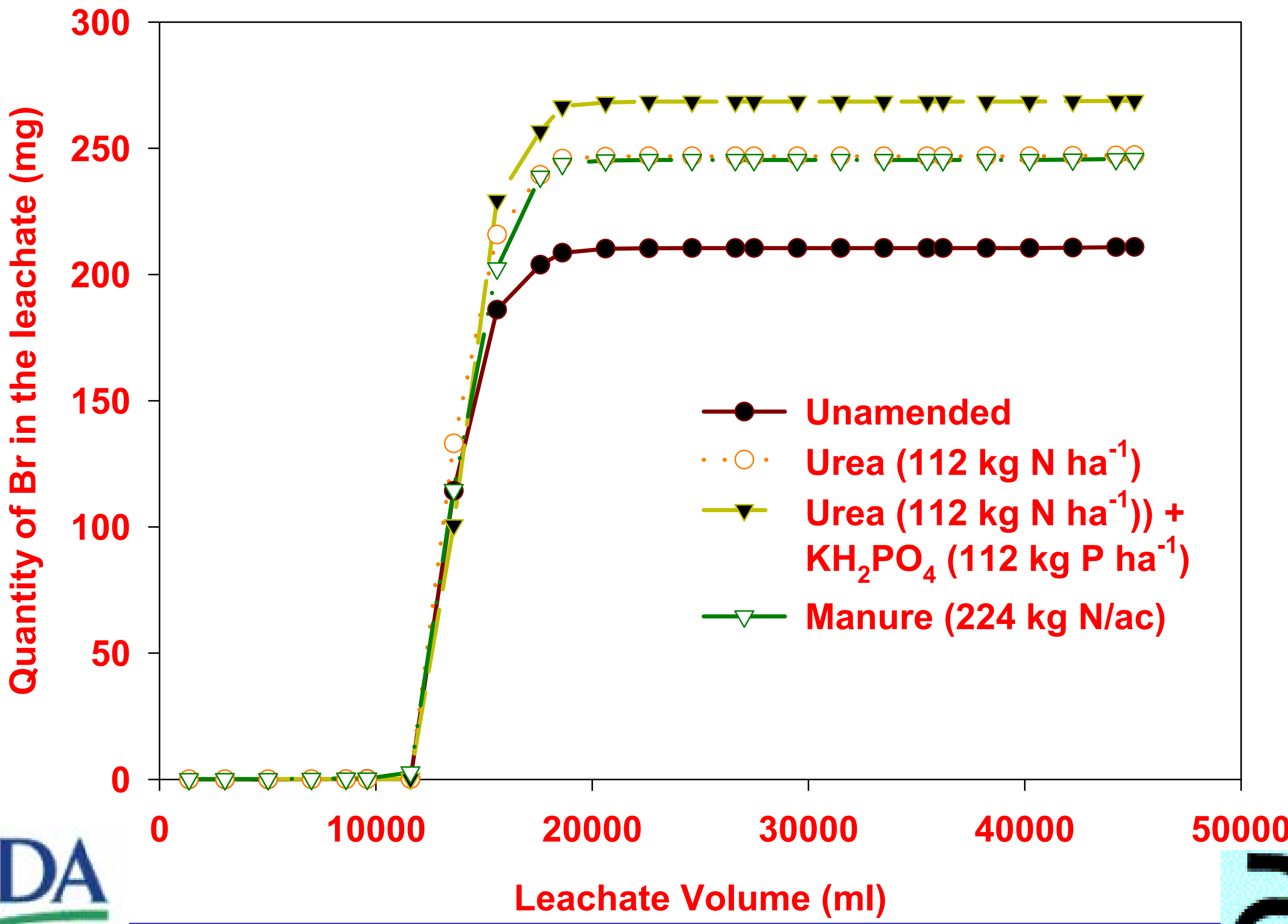
MATERIALS AND METHODS

- A leaching column experiment was conducted using a Quincy fine sand to evaluate the leaching of N from Urea or manure, and Br applied as KBr.

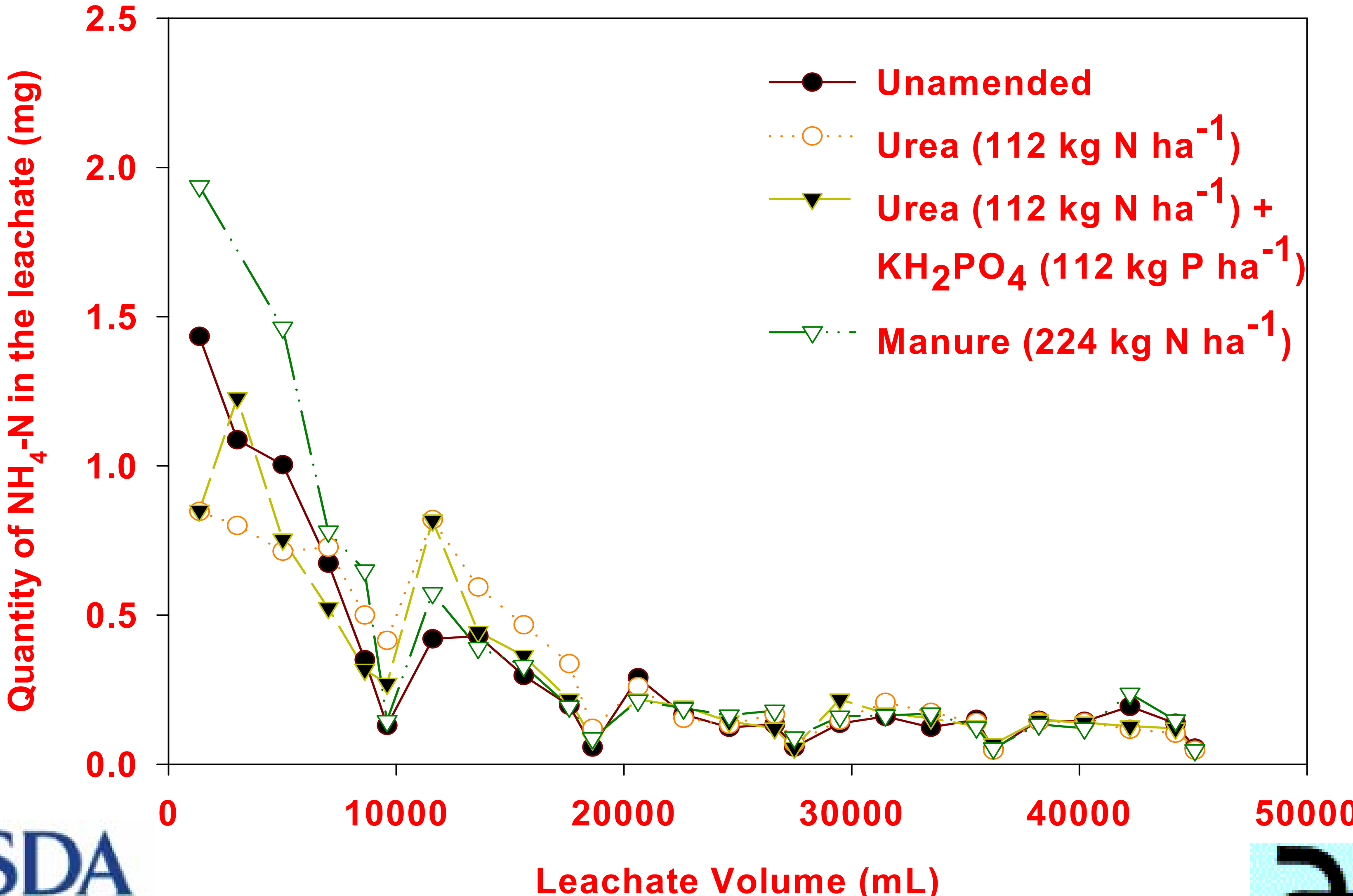
- The columns were leached with one pore volume of water followed by a dry period to mimic the intermittent wet and dry conditions (five wet and dry cycles) and the effects on N transformation leaching.



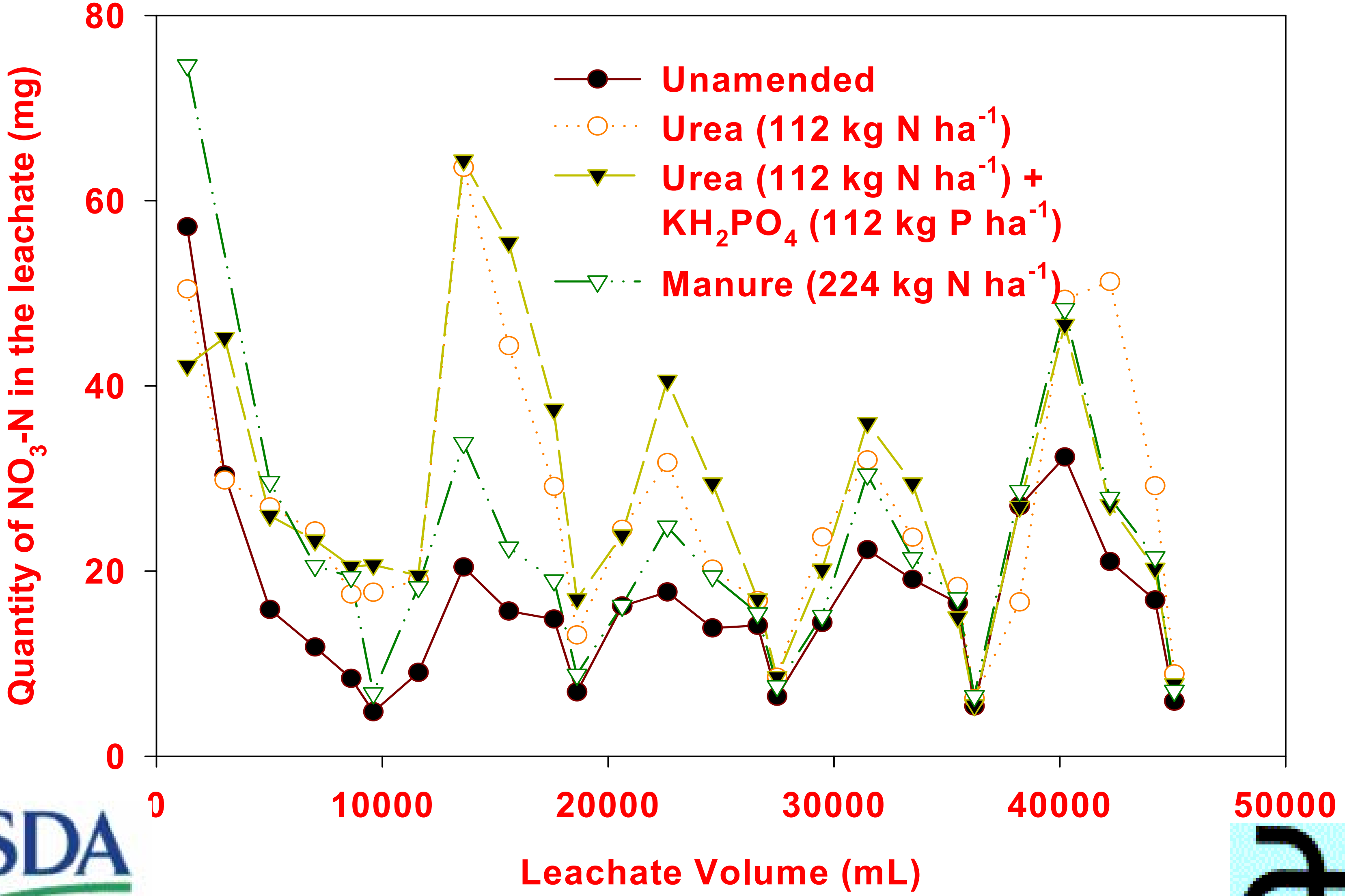
Quantity of Br in the leachate (mg)
140
120
100
80
60
40
20
0
0
10000
20000
30000
40000
50000
Leachate Volume (ml)
Unamended
Urea (112 kg N ha-1)
Urea (112 kg N ha-1) +
KH2PO4 (112 kg P ha-1)
Manure (224 kg N ha-1)



Quantity of Br in the leachate (mg)
300
250
200
150
100
50
0
0
10000
20000
30000
40000
50000
Leachate Volume (ml)
Unamended
Urea (112 kg N ha-1)
Urea (112 kg N ha-1)) +
KH2PO4 (112 kg P ha-1)
Manure (224 kg N/ac)



2.5
2.0
1.5
1.0
0.5
0.0
Quantity of NH_4-N in the leachate (mg)
0
10000
20000
30000
40000
50000
Leachate Volume (mL)
Unamended
Urea (112 kg N ha^{-1})
Urea (112 kg N ha^{-1}) +
KH_2PO_4 (112 kg P ha^{-1})
Manure (224 kg N ha^{-1})



Quantity of NO_3-N in the leachate (mg)
0
20
40
60
80
0
10000
20000
30000
40000
50000
Leachate Volume (mL)
Unamended
Urea (112 kg N ha^{-1})
Urea (112 kg N ha^{-1}) +
KH_2PO_4 (112 kg P ha^{-1})
Manure (224 kg N ha^{-1})

CONCLUSIONS

- Br was leached completely in the second pore volume regardless of amendments. The cumulative amount of Br leached across different treatments varied form 211 to 269 mg.
- Leaching of nitrate and ammonium followed a cyclic pattern. It appears that intermittent mineralization of organic N which was subject to leaching in the subsequent leaching event.
- Cumulative leaching of N was 704 to 733 mg from urea and was 572 mg from manure, despite total N application from the latter was twice than that from the former N source.

CONCLUSIONS

- Transport of Br in a field experiment with Candler fine sand was quite rapid. All of applied Br (112 kg/ha) was leached from the top 2.4 m soil within 28 to 35 DAA.

- In the same soil, Nitrate_N in the top 2.4 m attained the background levels within 28 and 42 DAA of 28 and 112 kg/ha N, respectively.

CONCLUSIONS

- **LEACHMN predictions of Nitrate concentration distribution in the soil profile compared favorably with those measured in the soil.**
- **The lateral flow rate of surfacial groundwater in an Entisol was 0.08 m/day.**