Evaluation of Temporal and Spatial Sediment Dynamics in Agricultural Fields Using Lanthanide Tracers

Project: WIS-04911 Grant: 2004-3501-15006

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The University of Wisconsin Madison

Cooperative State Research, Education, and Extension Service

Case Western Reserve University

OBJECTIVES

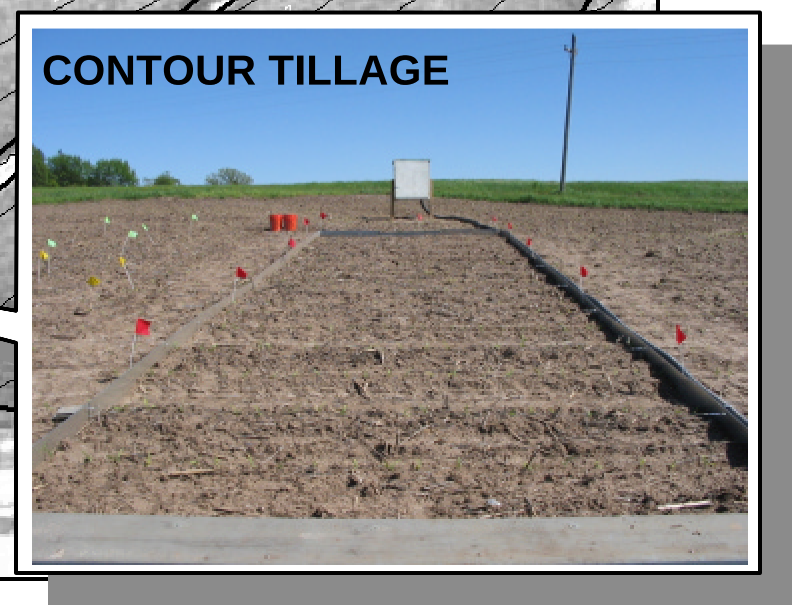
1. **Examine spatial patterns of runoff generation and sediment movement on fields managed under different tillage and cropping systems.**
   - Variable source area concepts
   - Modeling implications (WEPP)

2. **Deduce temporal patterns of erosion produced by rill-interrill sediment movement and contrast with total area degraded.**
   - Origin of sediments from surface detachment or rill formation.
   - Intrastorm detachment and transport processes.

METHODS

- **Naturally-occurring and fallout radionuclides**
  - ^{7}Be, ^{137}Cs, ^{210}Pb
  - radioactivity measured with gamma spectrometers
  - strong affinity for soil bonding
  - **differentiable signatures** in soil profiles due to $t_{1/2}$
  - low plant uptake and uniform distribution (*assumed*)
- **Lanthanide group of rare earth elements (REEs)**
  - measured in sediments using ICP Mass Spectrometry and acid-digestion (Zhang et al, 2001)
  - physico-chemically stabile
  - low background in soils and low plant uptake
  - differentiable signatures (atomic numbers 58-71)

RESEARCH STATION SITES



RUNOFF DATA COLLECTION

REE METHODS and PROCEDURE

- Batch soil preparation method (Zhang *et al*. 2001, 2003)
- Three Rare Earth Element (REE) oxide tracers mixed with Plano silt loam soil from study sites
  - REEs mixed in powderized form, then wetted for bonding.
  - Gd_2O_3 Pr_6O_{11} Nd_2O_3

2 grams sediment + Nitric acid

2 hr @ 85 °C →

H_2O_2 (30%) + HCl

2 hr @ 85 °C →

After 24 hr

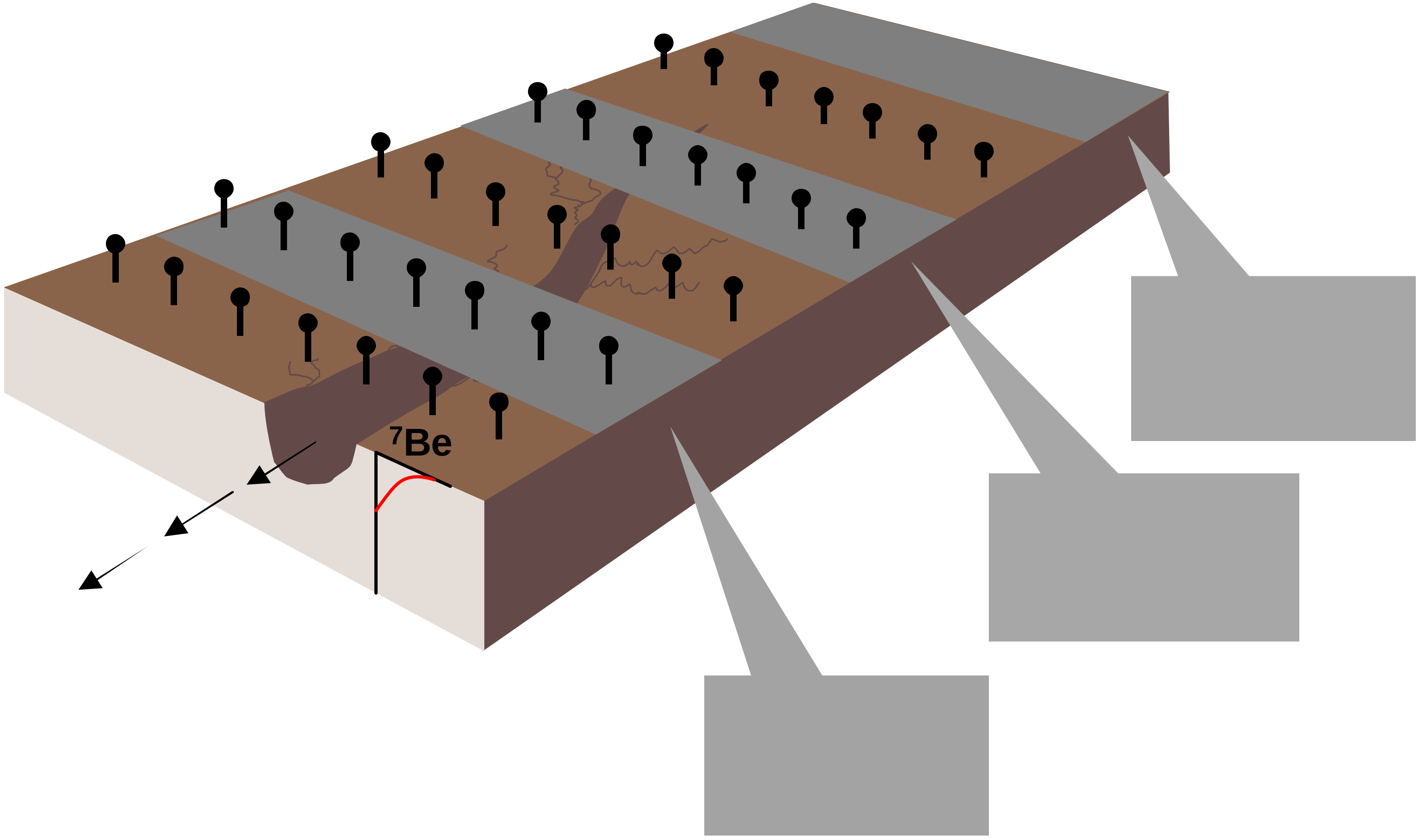
- Filter
- Elute with DI water
- ICP-MS by UW Soil and Plant Analysis Laboratory

REE FIELD APPLICATION

Table. Rare-earth element background and post-application levels.

	Site	Nd mg kg^{-1}	Pr mg kg^{-1}	Gd mg kg^{-1}	Nd mg kg^{-1}	Pr mg kg^{-1}	Gd mg kg^{-1}
03 Jun 2006	AR1	1.64	0.38	0.25	41.88	7.00	5.02
03 Jun 2006	AR2	1.31	0.29	0.20	23.91	5.30	4.31
03 Jun 2006	AR7	1.43	0.34	0.22	48.30	4.18	4.48
03 Jun 2006	AR8	1.98	0.45	0.31	43.81	8.99	3.66
MEAN		**1.59**	**0.27**	**0.34**	**39.47**	**6.36**	**4.37**
					25x	**24x**	**13x**

GENERALIZED RESEARCH PLOT



RAINFALL EVENT SUMMARY

Table. Rainfall Event Summary (2005-2006)

Date	Year	Depth		Duration	Intensity		I_{30}	Erosivity	
		in	cm	hr	in/hr	cm/hr		English	SI
20 Jun	2005	1.01	2.57	0.98	1.03	2.62	1.60	16	266
23 Jun	2005	0.20	0.51	0.38	0.53	1.34			
26 Jun	2005	0.54	1.37	0.75	0.72	1.83	0.98	5	83
25 Jun	2006	2.20	5.59	5.42	0.41	1.03	2.14	45	767
26 Jun	2006	0.44	1.12	2.13	0.21	0.52	0.36	1	19
20 July	2006	0.67	1.70	2.43	0.28	0.70	1.10	7	118

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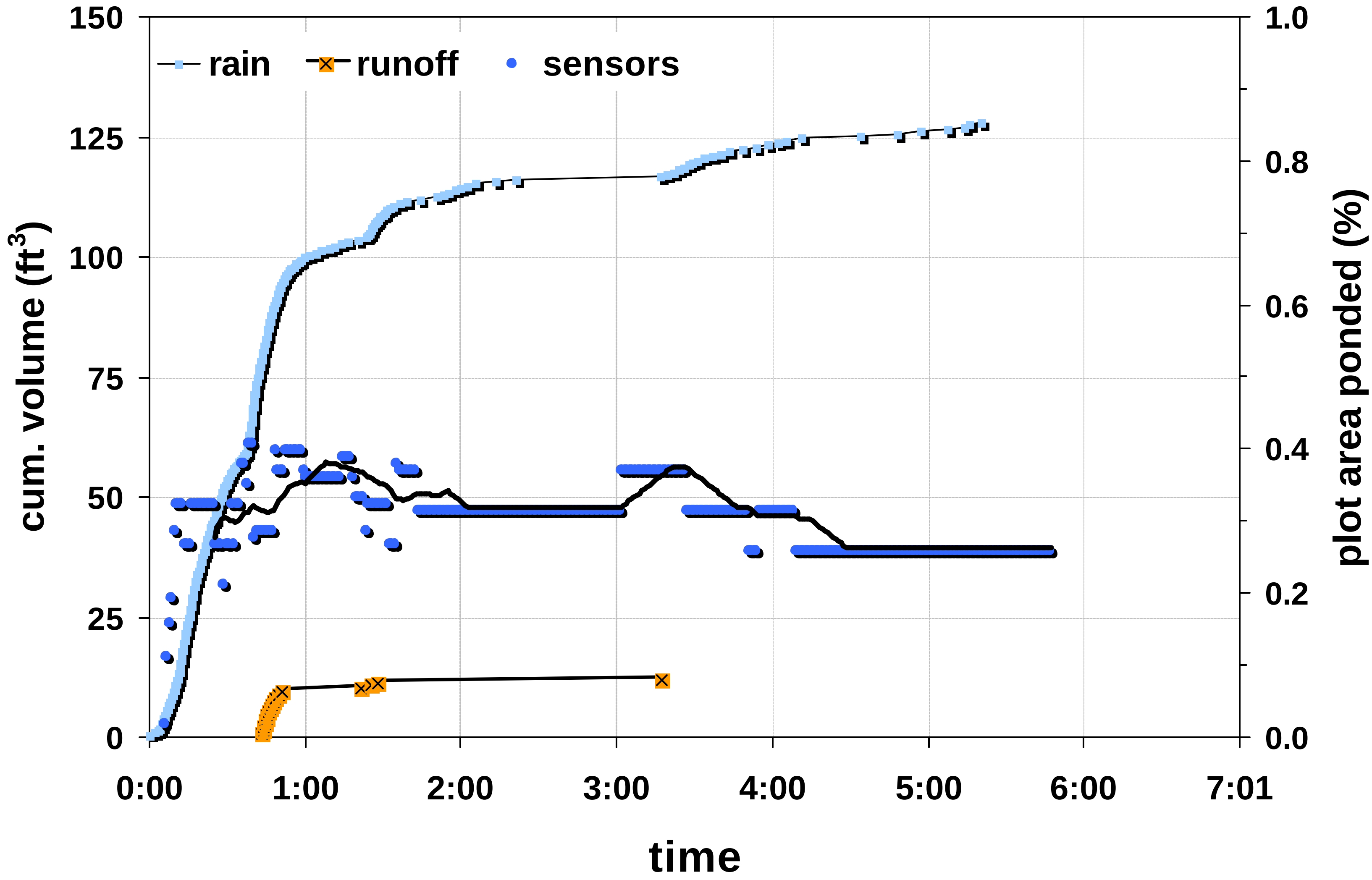
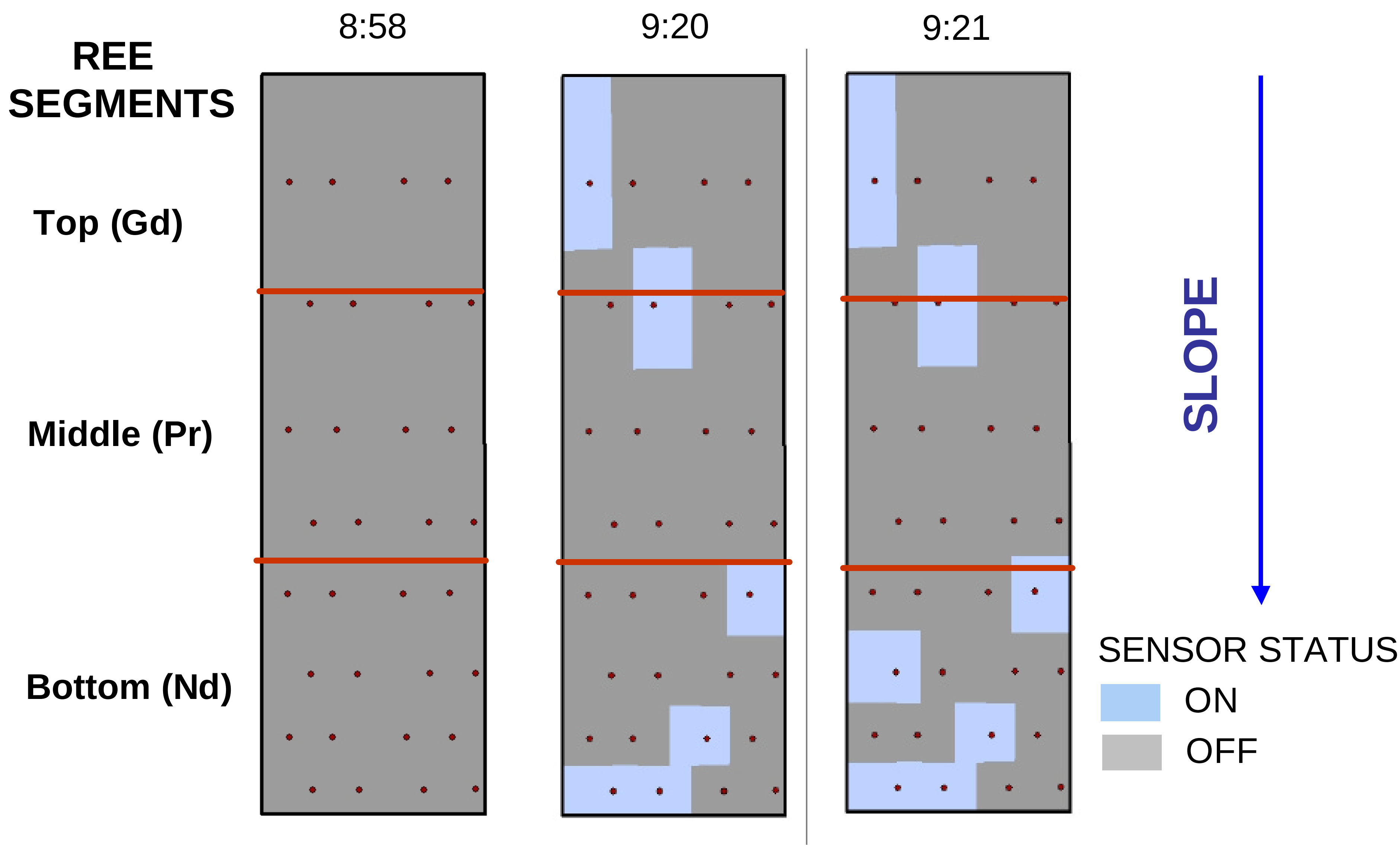
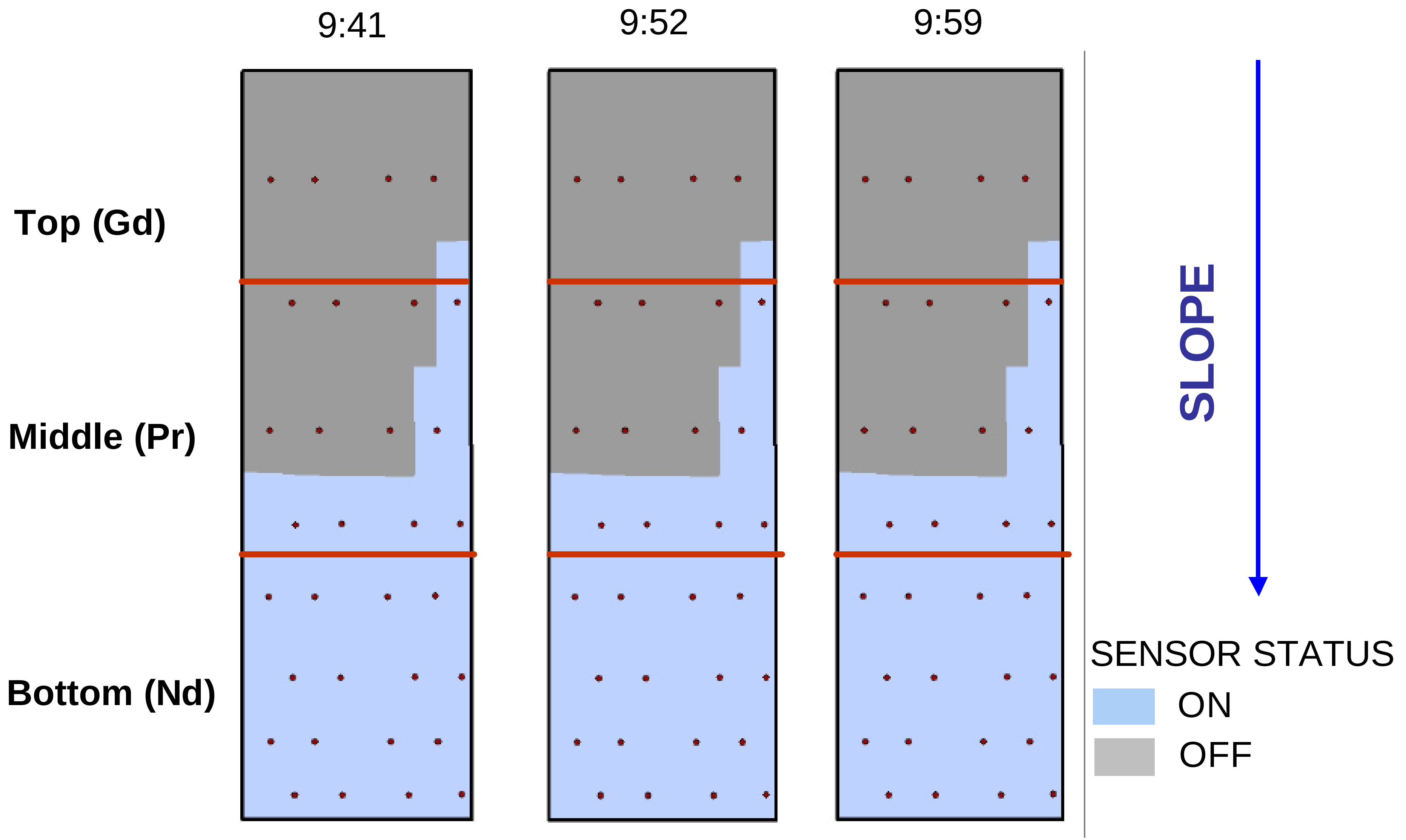
RUNOFF/PONDING SENSORS



RUNOFF/PONDING SENSORS (cont.)

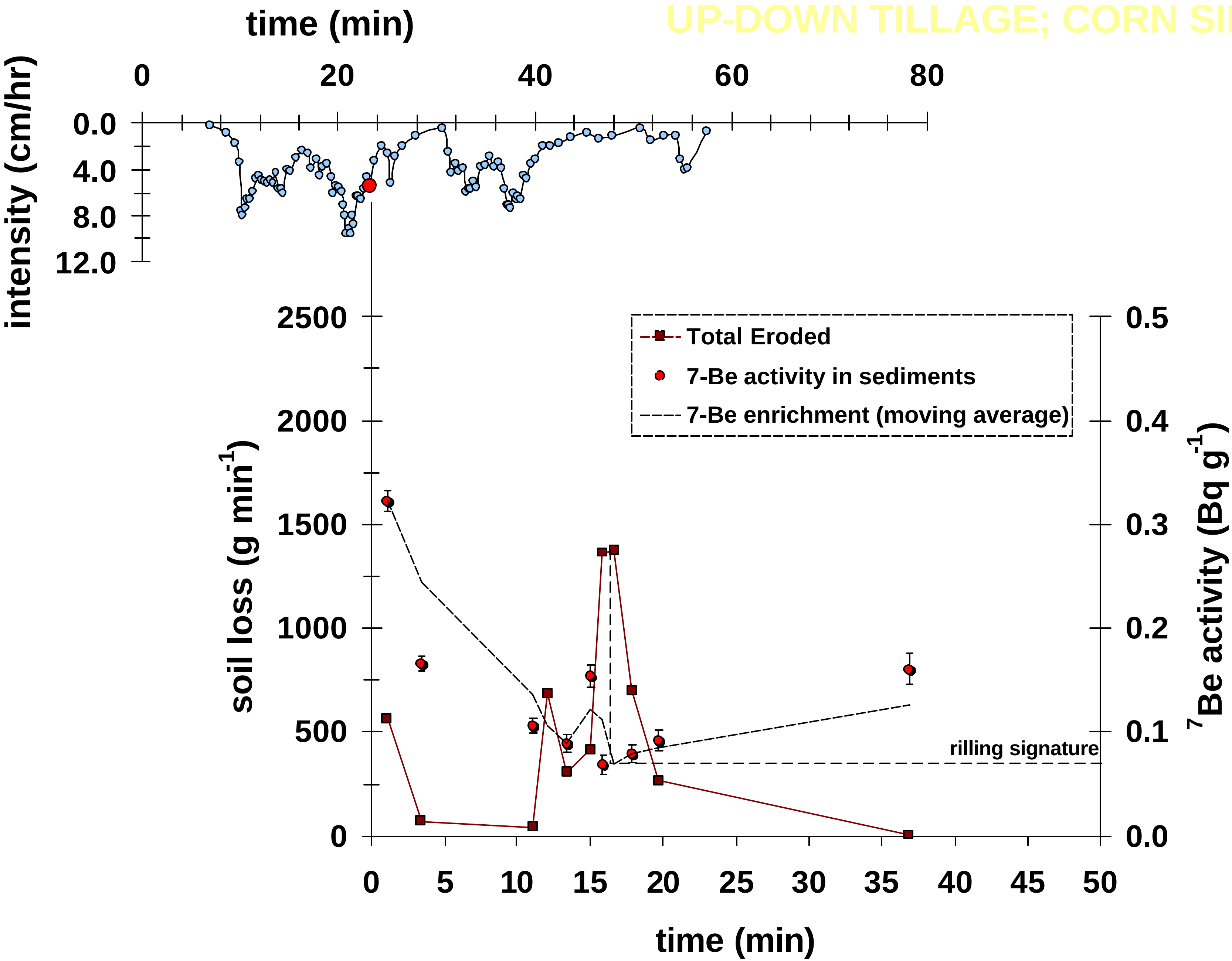


RUNOFF/PONDING SENSORS (cont.)



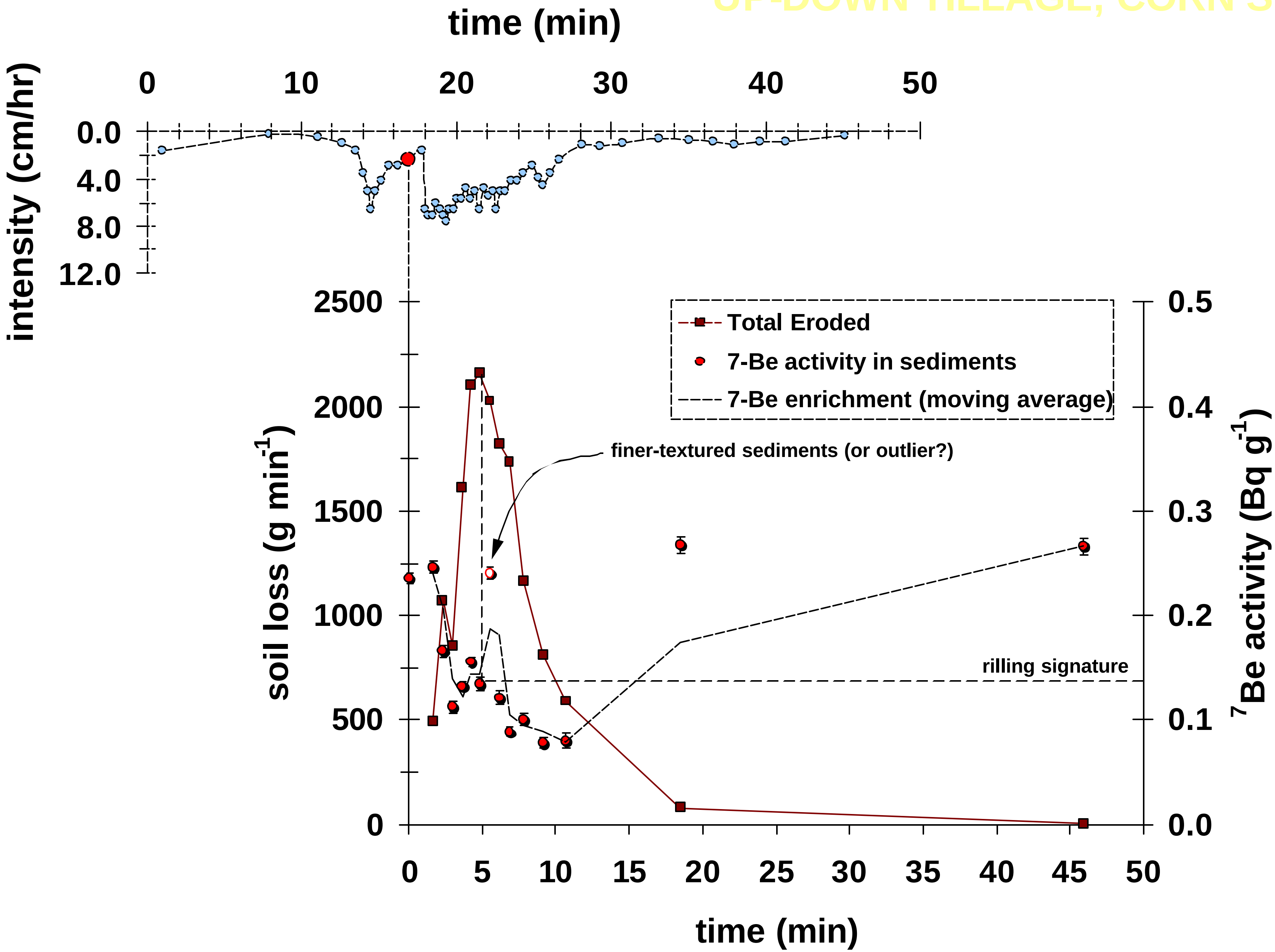
INTRASTORM SEDIMENT DYNAMICS: ^{7}Be SIGNATURE (June 20, 2005)

UP-DOWN TILLAGE; CORN SILAGE



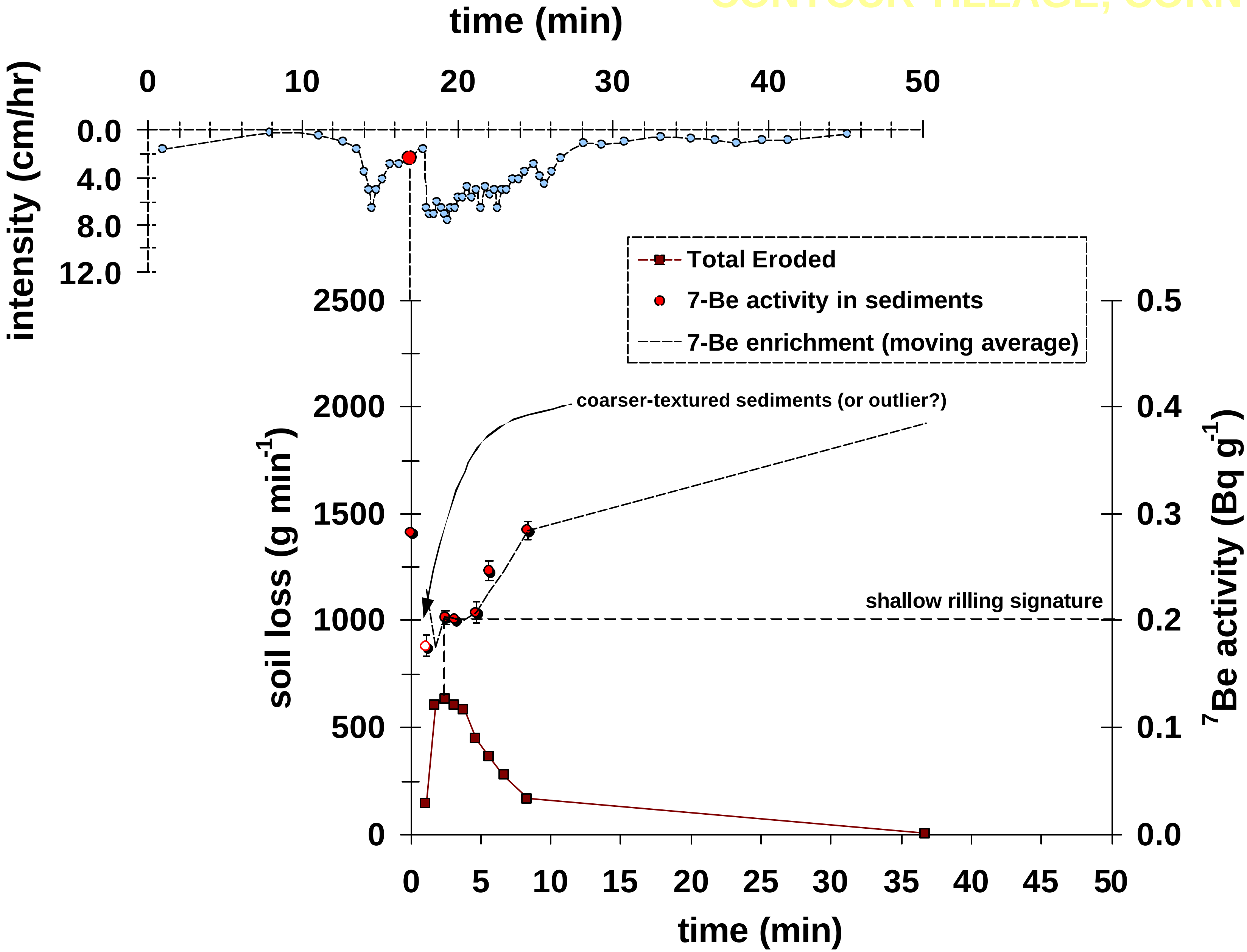
INTRASTORM SEDIMENT DYNAMICS: ^{7}Be SIGNATURE (June 26, 2005)

UP-DOWN TILLAGE; CORN SILAGE

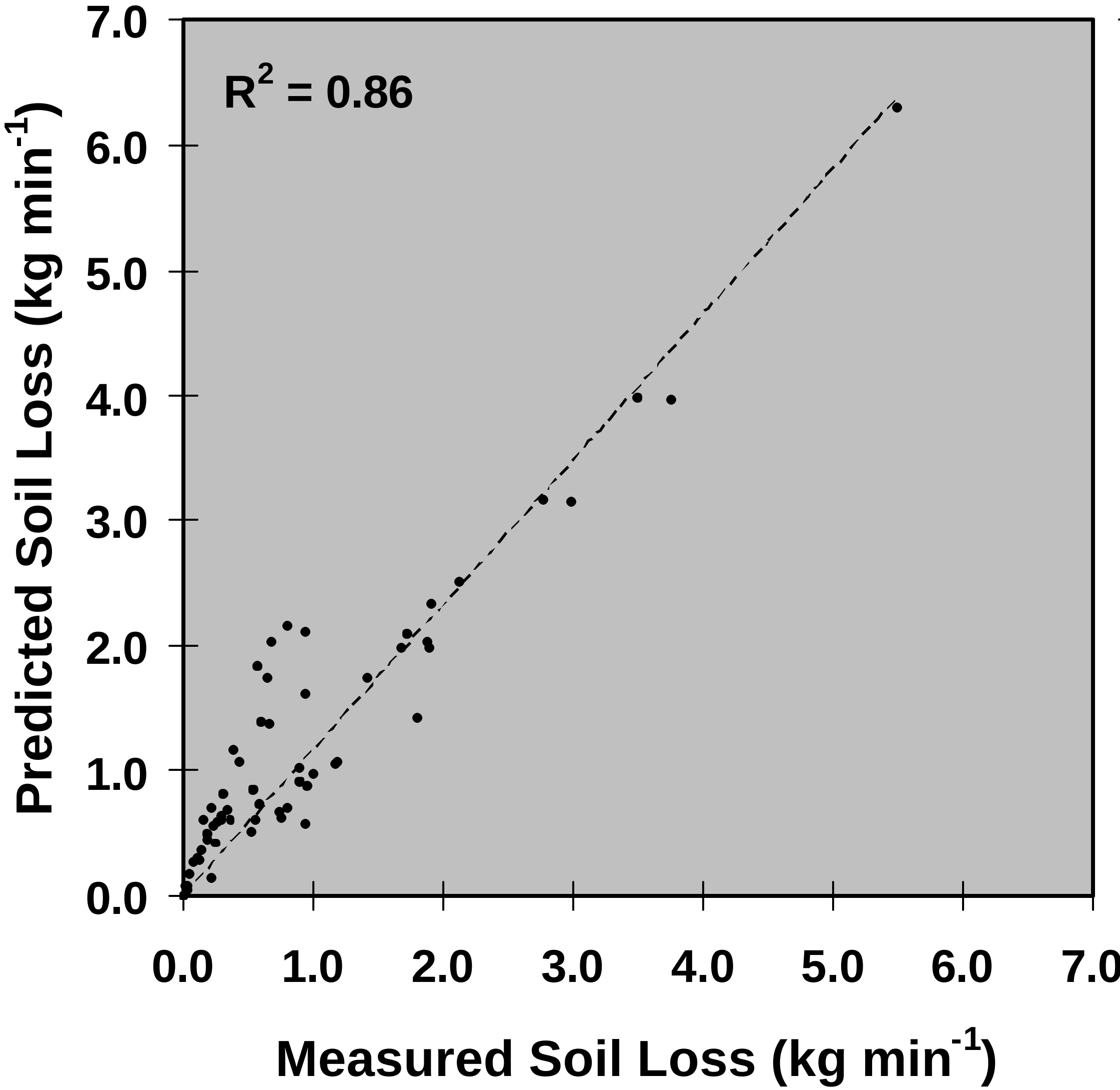


INTRASTORM SEDIMENT DYNAMICS: ^{7}Be SIGNATURE (June 26, 2005)

CONTOUR TILLAGE; CORN SILAGE



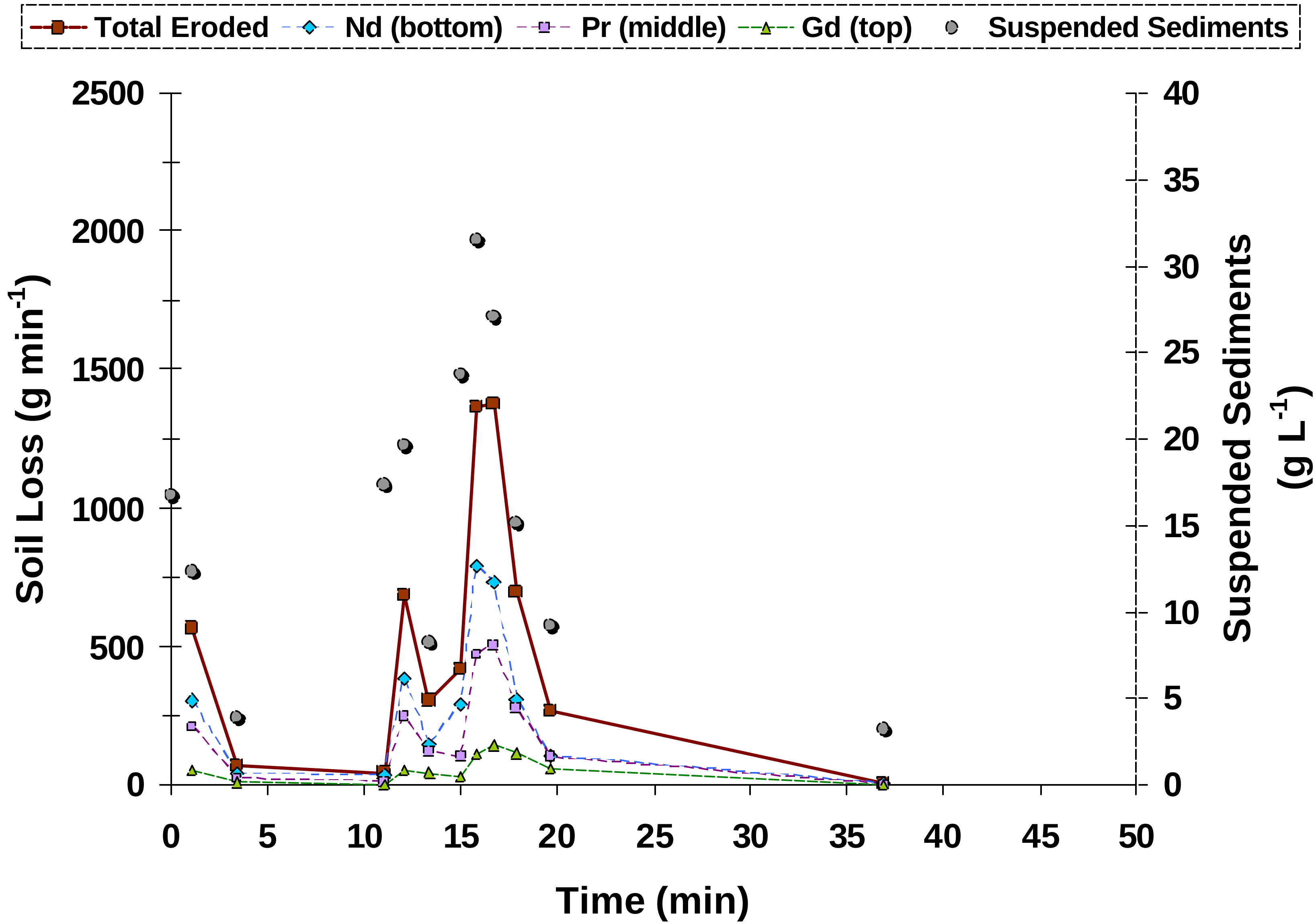
MEASURED vs PREDICTED SEDIMENT MOVEMENT



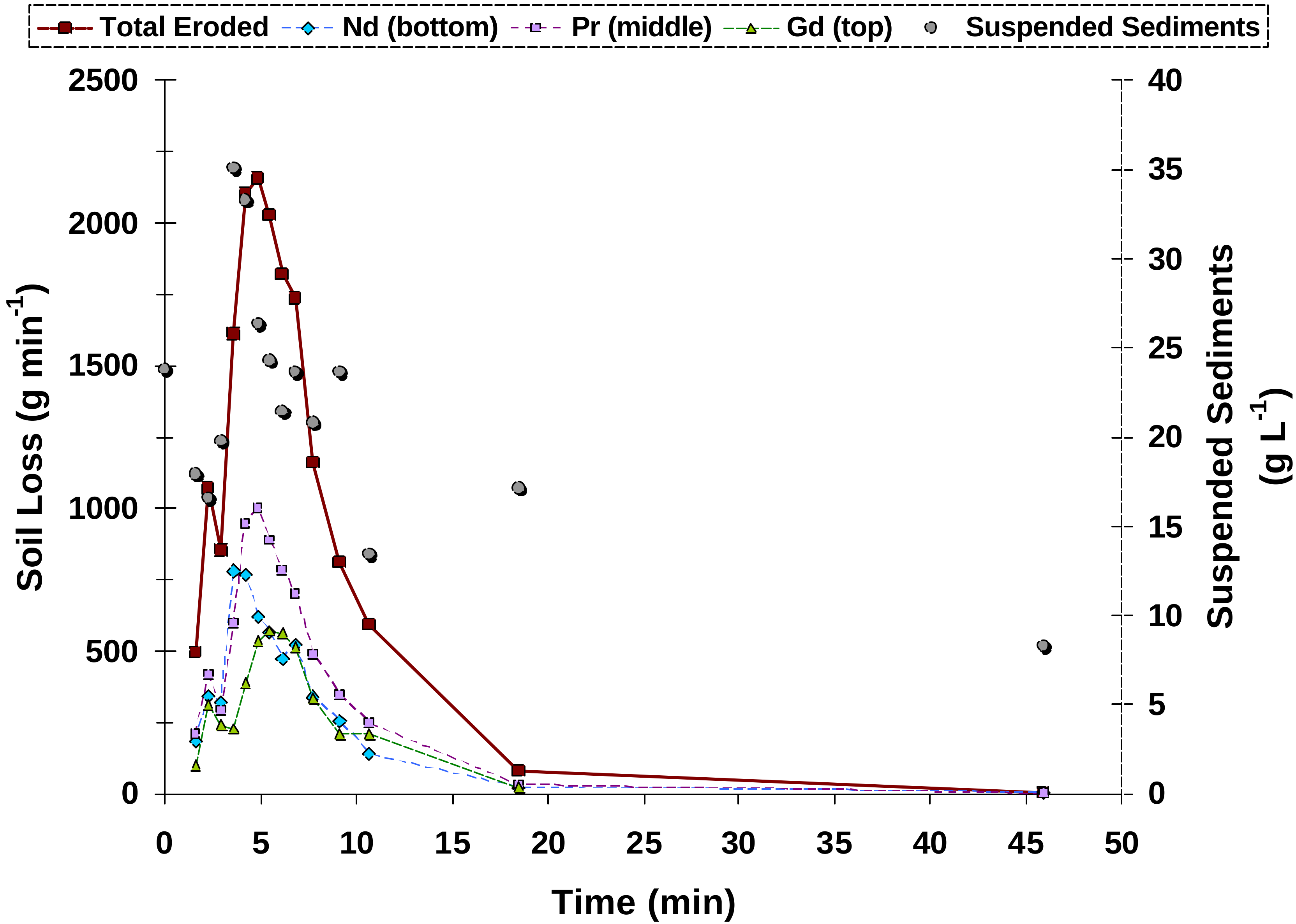
Zhang, X.C., M.A. Nearing, V.O. Polyakov, and J.M. Friedrich. 2003. Using rare earth oxide tracers for studying soil erosion dynamics. *Soil Science Society of America Journal* 67(1):279-288.

Polyakov, V.O. and M. A. Nearing. 2004. Rare earth element oxides for tracing sediment movement. *Catena* 55(3):255-276.

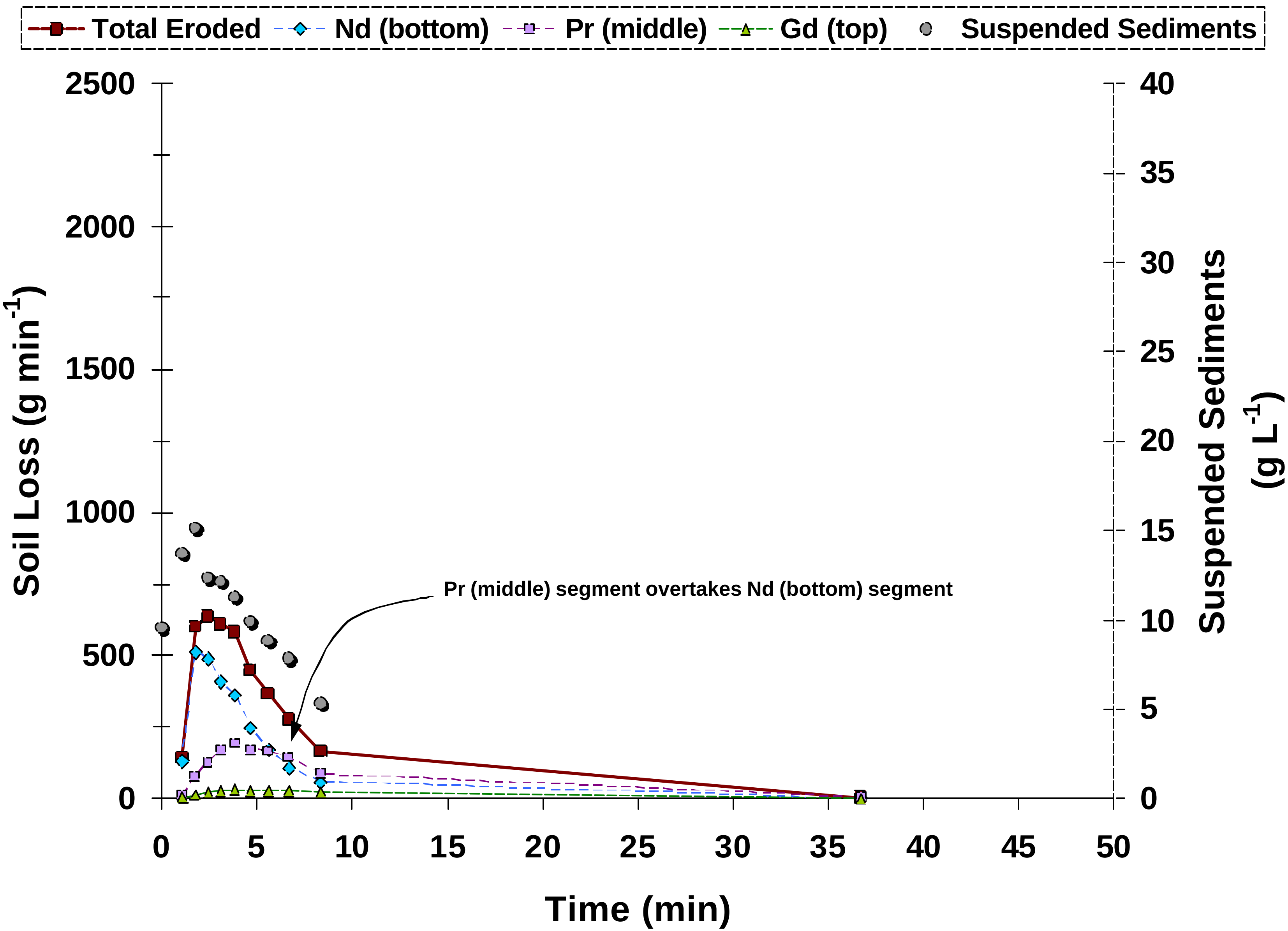
UP-DOWN TILLAGE (CS) – June 20, 2005



UP-DOWN TILLAGE (CS) – June 26, 2005



CONTOUR TILLAGE (CS) – June 26, 2005



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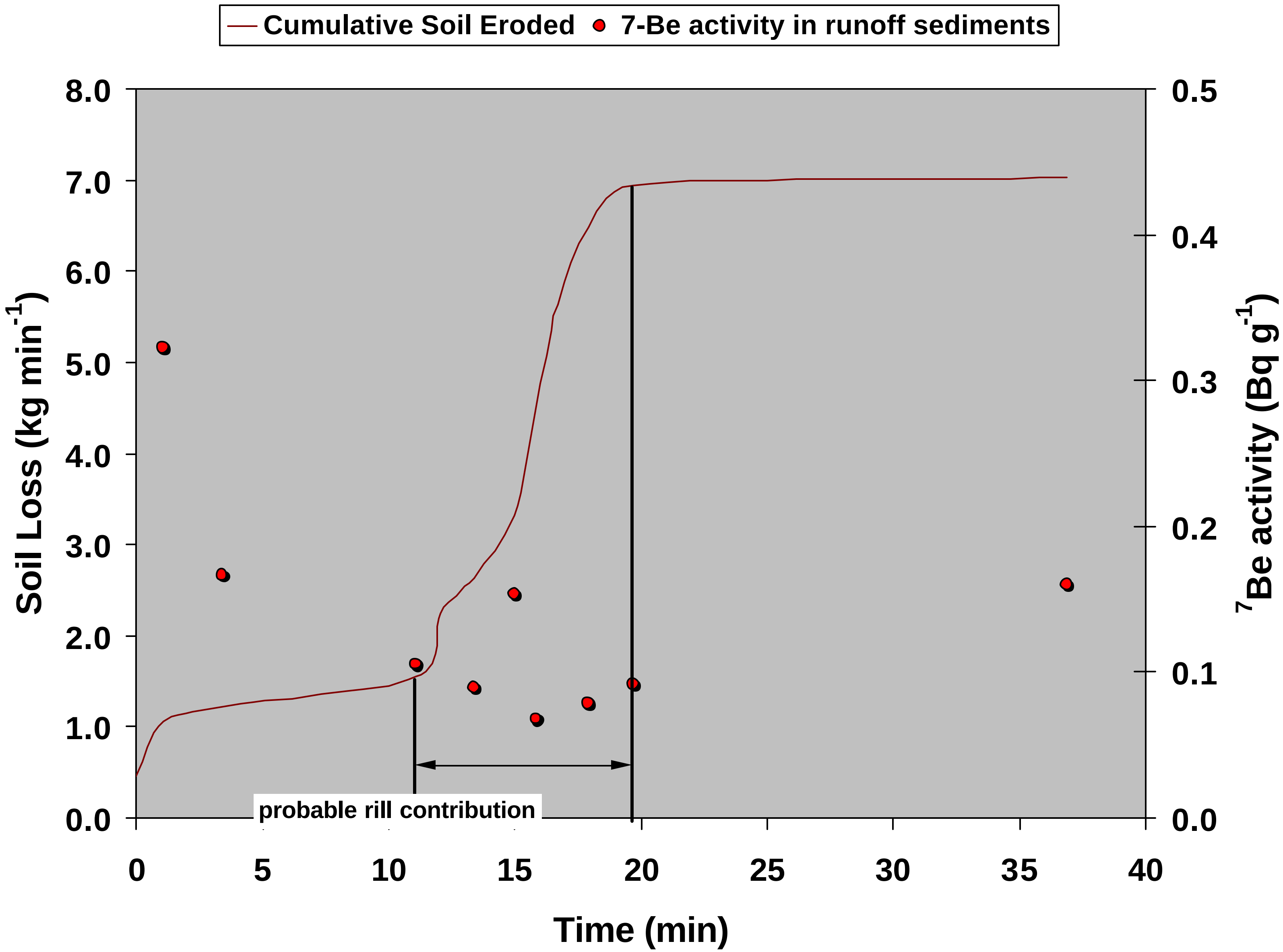

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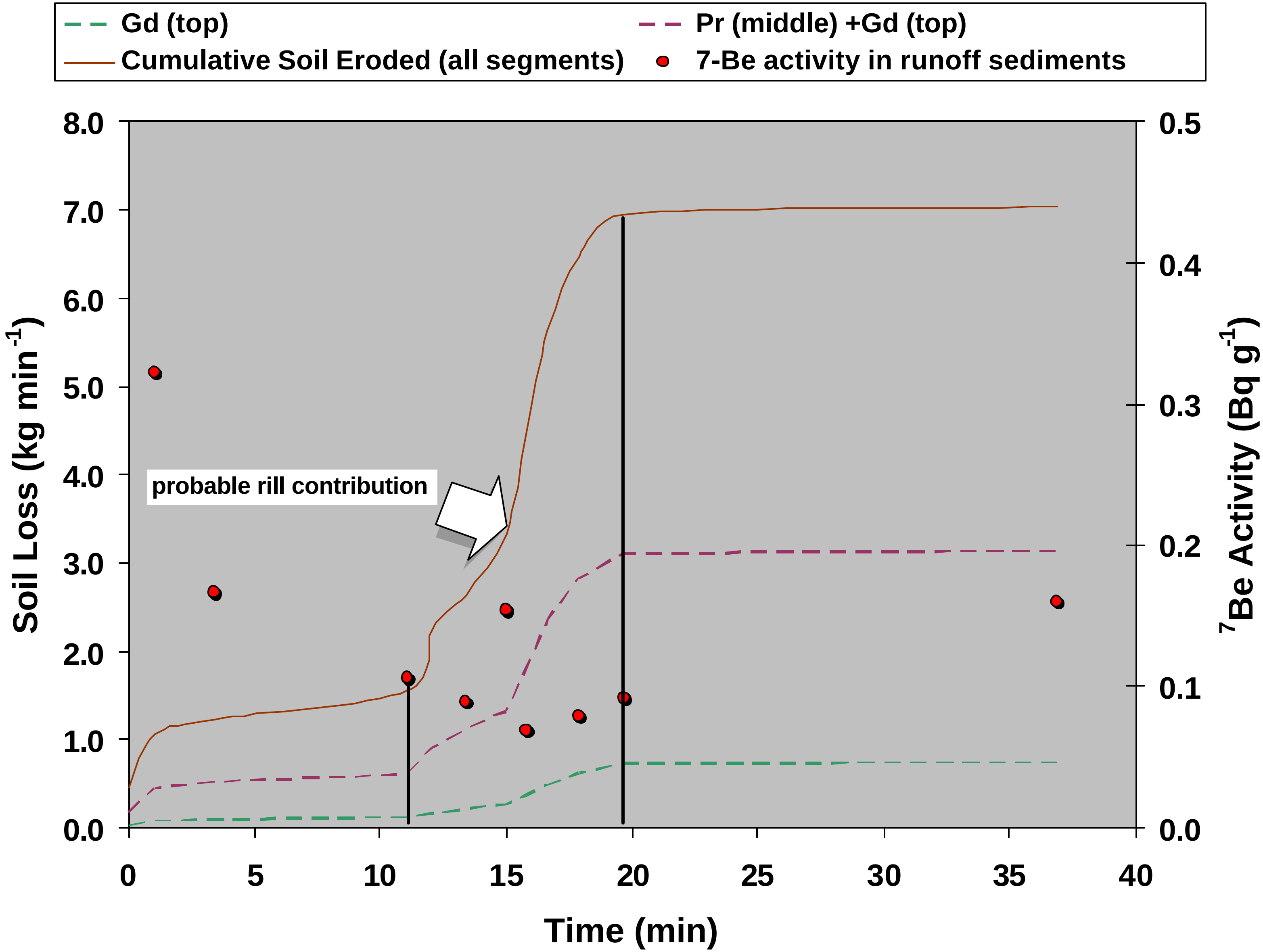


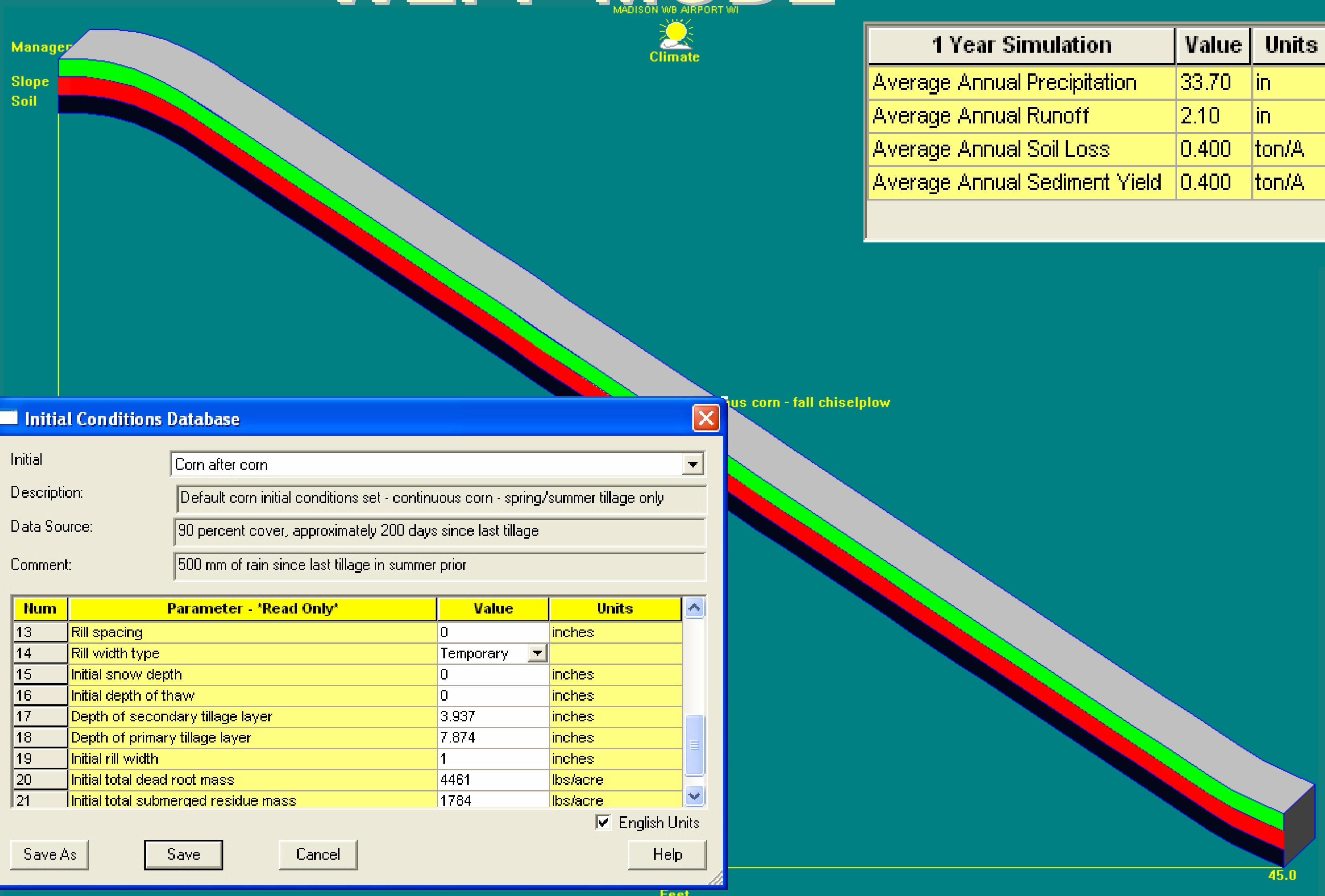
SUMMARY

- **Linking radiometric, REE and runoff sensor approaches provides intrastorm insight to sediment delivery processes.**
  - **Distinguishing the "where, when, and how" of erosion generation in a small-scale study.**
- **Approach works very well to collect model calibration data.**
  - **Limitation: ^{7}Be signature is "reset" for each storm, but REE signature is not.**

NEXT STEPS

- Continue into third year of data collection.
  - Up-Down tillage on corn silage (lower residue) and corn grain (higher residue)
  - Contour tillage on corn silage and corn grain
- Quantification of processes
  - ^{7}Be rill-interrill signature
  - Probability of subplot area or sensor area contributing
- Link sediment delivery processes to P movement in the landscape.

WEPP MODELING



1 Year Simulation	Value	Units
Average Annual Precipitation	33.70	in
Average Annual Runoff	2.10	in
Average Annual Soil Loss	0.400	ton/A
Average Annual Sediment Yield	0.400	ton/A

Initial Conditions Database

Initial: Corn after corn

Description: Default corn initial conditions set - continuous corn - spring/summer tillage only

Data Source: 90 percent cover, approximately 200 days since last tillage

Comment: 500 mm of rain since last tillage in summer prior

Num	Parameter - 'Read Only'	Value	Units
13	Rill spacing	0	inches
14	Rill width type	Temporary	
15	Initial snow depth	0	inches
16	Initial depth of thaw	0	inches
17	Depth of secondary tillage layer	3.937	inches
18	Depth of primary tillage layer	7.874	inches
19	Initial rill width	1	inches
20	Initial total dead root mass	4461	lbs/acre
21	Initial total submerged residue mass	1784	lbs/acre

☑ English Units

Save As | Save | Cancel | Help

WEPP MODELING (cont.)

HILLSLOPE 1 RESULTS

I. ABBREVIATED EVENT-BY-EVENT HYDROLOGY

Overland flow element number: 1
Event date: sep 26, year 1

precipitation amount	56.90	rainfall amount	56.90
snow melt amount	0.00	runoff amount	26.01
rain/melt duration	379.20	effective duration	15.05
peak runoff rate	103.70	effective length	10.97

note: amounts = mm, durations = min, rates = mm/hr, length = meters

II. ON SITE EFFECTS ON SITE EFFECTS ON SITE EFFECTS

A. AREA OF NET SOIL LOSS

** Soil Loss (Avg. of Net Detachment Areas) = 0.127 kg/m2 **
** Maximum Soil Loss = 0.187 kg/m2 at 9.88 meters **

** Interrill Contribution = 0.104 kg/m2 for OFE # 1

III. OFF SITE EFFECTS OFF SITE EFFECTS OFF SITE EFFECTS

A. SEDIMENT LEAVING PROFILE for sep 26 1 1.394 kg/m

Predicted sediment leaving side of OFE 1 is 0.000 kg/m width

B. SEDIMENT CHARACTERISTICS AND ENRICHMENT

Sediment particle information leaving profile

Class	Diameter (mm)	Specific Gravity	Particle Composition % Sand	% Silt	% Clay	% O.M.	Detached Sediment Fraction	Fraction In Flow Exiting
1	0.002	2.60	0.0	0.0	100.0	24.7	0.039	0.039
2	0.010	2.65	0.0	100.0	0.0	0.0	0.370	0.370
3	0.030	1.80	0.0	81.0	19.0	4.7	0.270	0.270
4	0.300	1.60	51.3	22.5	26.2	6.5	0.228	0.228
5	0.200	2.65	100.0	0.0	0.0	0.0	0.093	0.093

SSA enrichment ratio leaving profile for sep 26 1 = 1.00

HILLSLOPE 1 RESULTS

I. ABBREVIATED EVENT-BY-EVENT HYDROLOGY

Overland flow element number: 1
Event date: jul 21, year 1

precipitation amount	24.80	rainfall amount	24.80
snow melt amount	0.00	runoff amount	1.77
rain/melt duration	130.20	effective duration	6.67
peak runoff rate	15.91	effective length	10.97

note: amounts = mm, durations = min, rates = mm/hr, length = meters

II. ON SITE EFFECTS ON SITE EFFECTS ON SITE EFFECTS

A. AREA OF NET SOIL LOSS

** Soil Loss (Avg. of Net Detachment Areas) = 0.003 kg/m2 **
** Maximum Soil Loss = 0.003 kg/m2 at 5.60 meters **

** Interrill Contribution = 0.003 kg/m2 for OFE # 1

III. OFF SITE EFFECTS OFF SITE EFFECTS OFF SITE EFFECTS

A. SEDIMENT LEAVING PROFILE for jul 21 1 0.030 kg/m

Predicted sediment leaving side of OFE 1 is 0.000 kg/m width

B. SEDIMENT CHARACTERISTICS AND ENRICHMENT

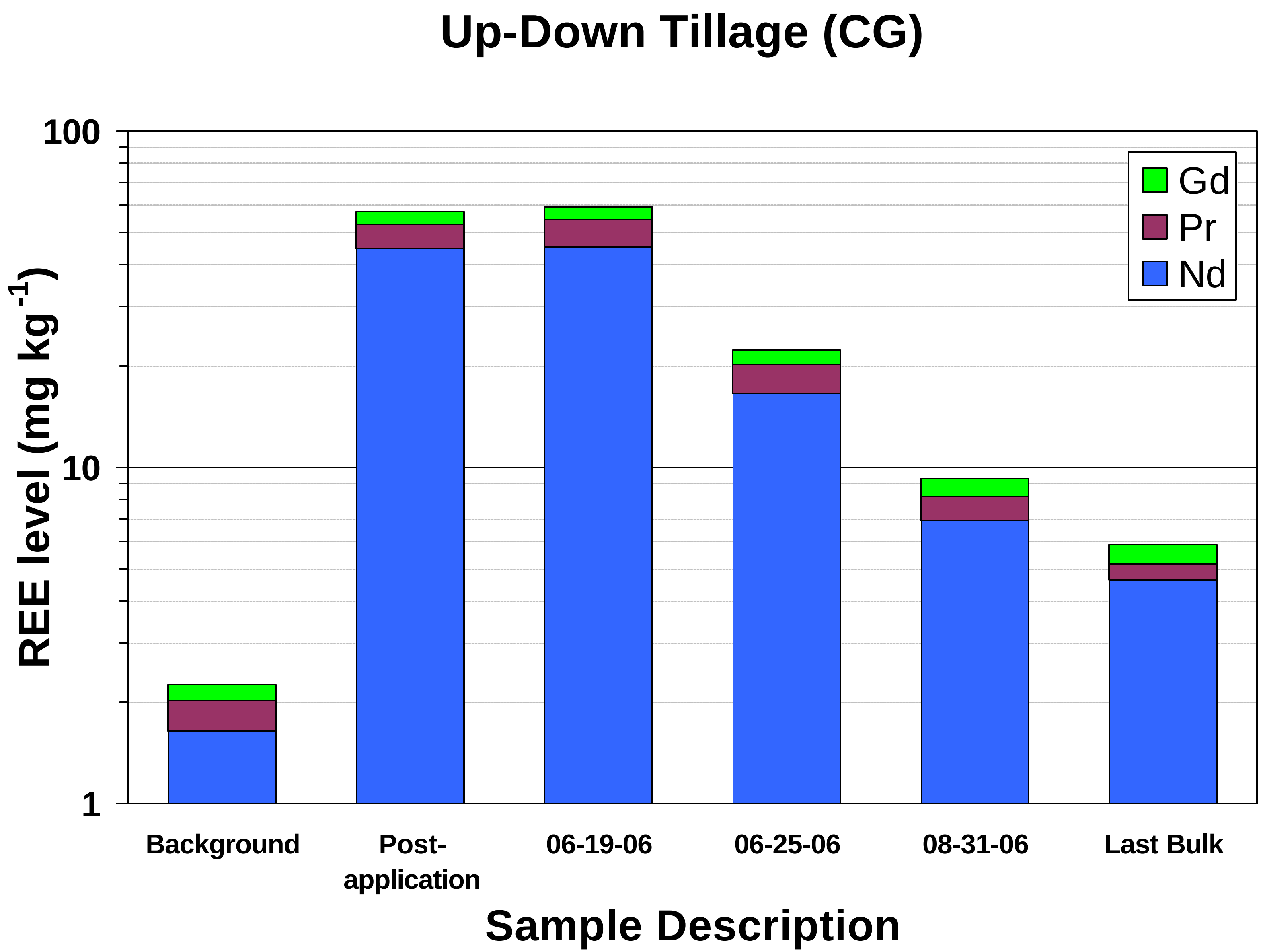
Sediment particle information leaving profile

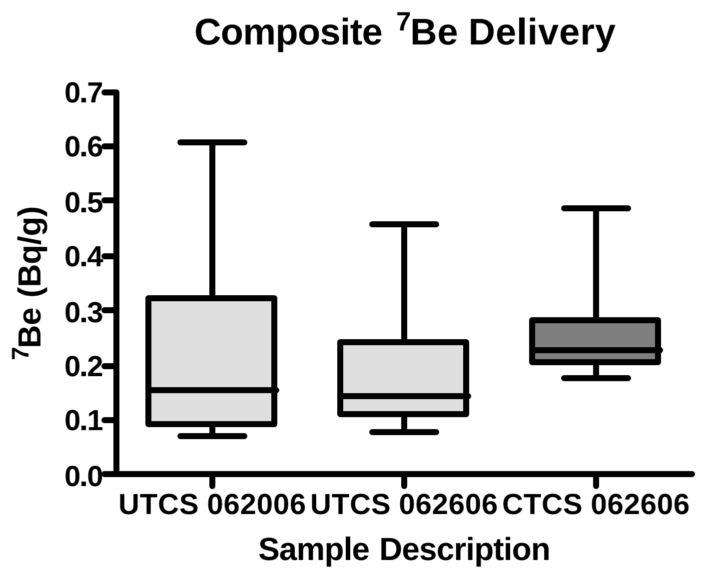
Class	Diameter (mm)	Specific Gravity	Particle Composition % Sand	% Silt	% Clay	% O.M.	Detached Sediment Fraction	Fraction In Flow Exiting
1	0.002	2.60	0.0	0.0	100.0	24.7	0.039	0.040
2	0.010	2.65	0.0	100.0	0.0	0.0	0.370	0.382
3	0.030	1.80	0.0	81.0	19.0	4.7	0.270	0.279
4	0.300	1.60	51.3	22.5	26.2	6.5	0.228	0.213
5	0.200	2.65	100.0	0.0	0.0	0.0	0.093	0.087

SSA enrichment ratio leaving profile for jul 21 1 = 1.00

The End

Thank you for staying to the end of the session!


Up-Down Tillage (CG)
100
10
1
REE level (mg kg-1)
Gd
Pr
Nd
Background
Post-application
06-19-06
06-25-06
08-31-06
Last Bulk
Sample Description



Composite ^{7}Be Delivery
^{7}Be (Bq/g)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
UTCS 062006
UTCS 062606
CTCS 062606
Sample Description