Quantifying Phosphorus Loses From Agricultural Fields

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Overall Grant Objectives:

- Research: (Emphasis in 2005-2006)
  - Modify an existing Precision Agricultural-Landscape Modeling System (PALMS) to estimate erosion and P-losses on farm fields
  - Measure runoff, sediment and P losses from farm fields
- Extension: (Emphasis in 2004-2005)
  - Identify P-loss reduction strategies with farmer and implement one such strategy
  - Work with regulatory agency on evaluating P-Index approaches
- Education: (Emphasis in 2004-2005)
  - Prepare instruction modules for a course in Small Watershed Engineering to study strategies for reducing P losses from farm fields
  - Prepare materials for the Wisconsin Association of Vocational Agriculture Instructors on P losses from farm fields.

Quantifying Phosphorus Loses From Agricultural Fields

- Overall objective:
  - To estimate runoff, soil loss and phosphorus loss from agricultural fields with complex topography
- Outline:
  - PALMS Model description
  - Comparison runoff & soil loss with WEPP
    - Idealized field
    - Historical erosion plots
  - Validation of PALMS runoff & soil loss with field measurements
  - Validation of PALMS phosphorus loss with field measurements
  - Conclusions

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DISCOVERY FARMS

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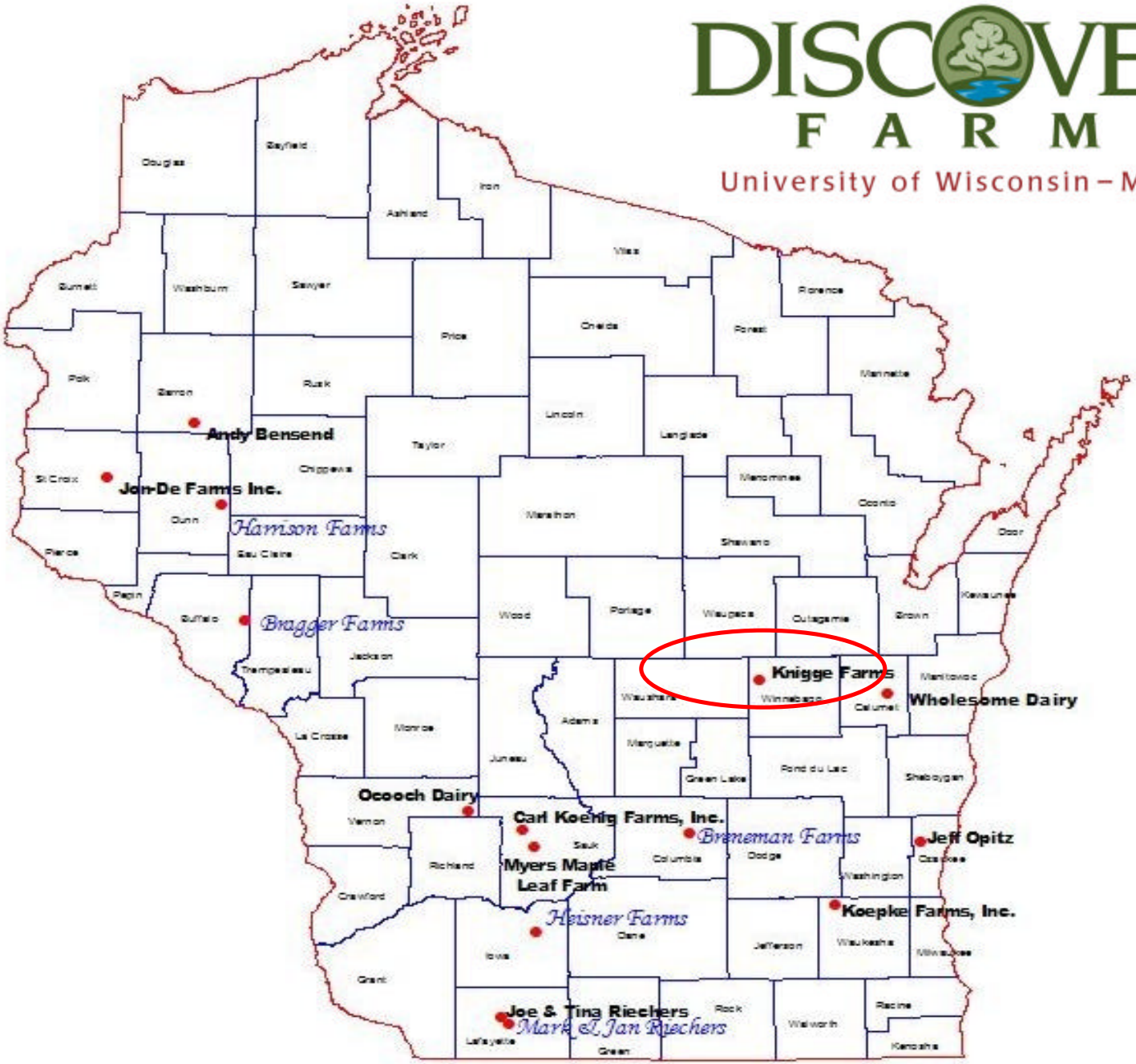
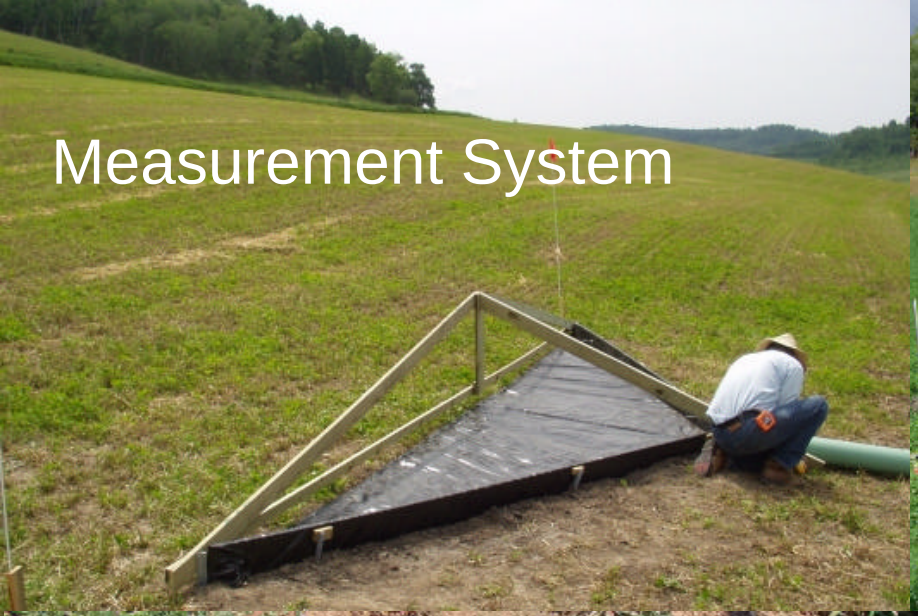
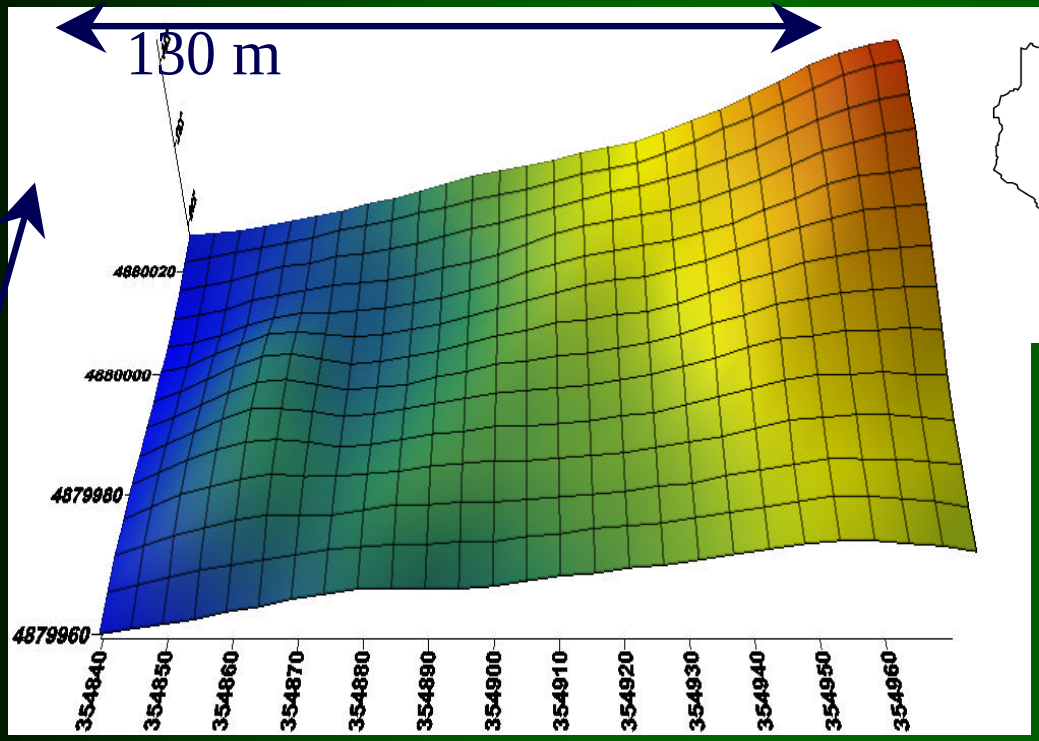


Measurement System



Validation with field measurements



0.85 ha (2 ac)
Ave. slope 5%
Clay loam

Winter Tillage Winnebago Co.

Surface water flow

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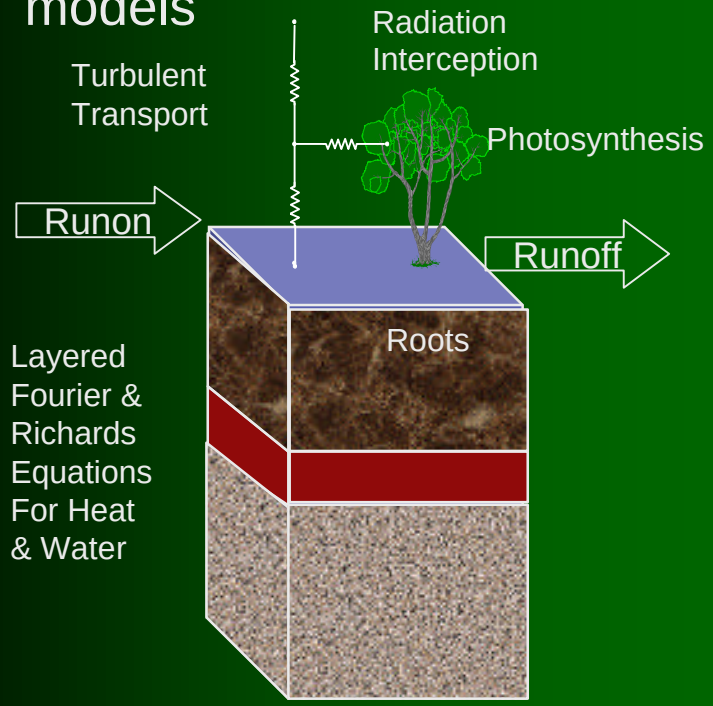
Precision Agricultural-Landscape Modeling System

PALMS (Molling et al. JAWRA, Dec. 2005)

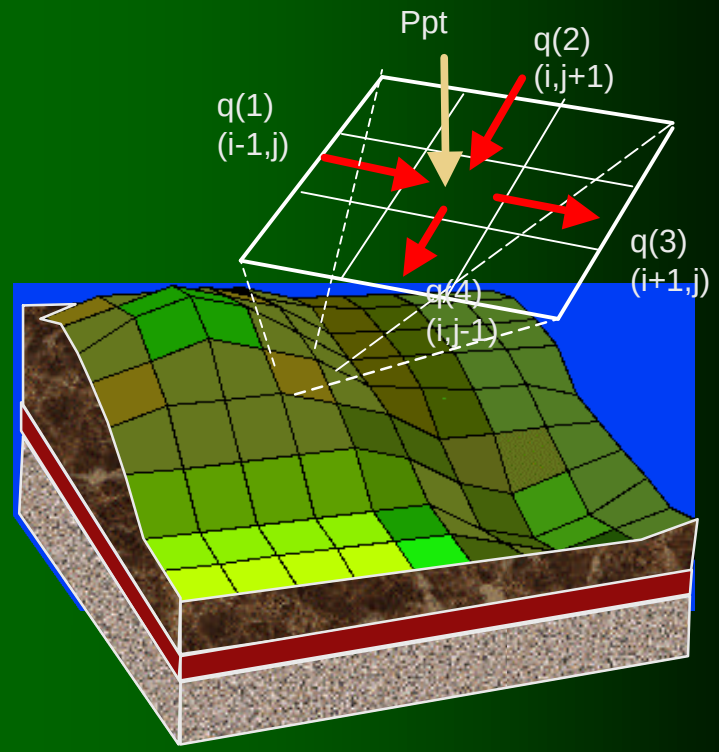
1) Vertical transport in soil and canopy models



Soil/canopy model

Integrated Biosphere Simulator (IBIS)

2) Overland flow



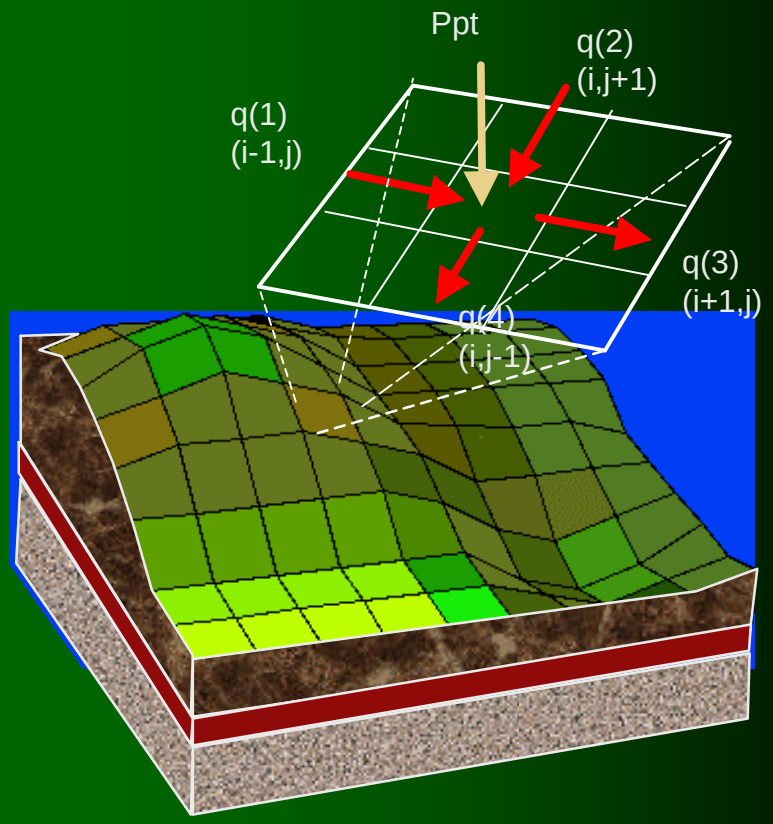
Distributed runoff model

Diffusive Wave

PALMS

Distributed runoff (routing) model:

- Diffusive wave model
- Surface routing
- Tillage effects
- Row direction effects on surface roughness
- Surface sealing
- Run-on and closed depressions



Schematic for water and sediment balance at raster (i,j)

PALMS

Distributed runoff (routing) model:

- Diffusive wave model
- Surface routing
- Tillage effects
- Row direction effects on surface roughness
- Surface sealing
- Run-on and closed depressions

Grid erosion subroutine:

- Based on equations developed for WEPP (Nearing et al., 1989; Flanagan and Nearing, 2000)
- Detachment, deposition, and sediment transport
- Estimates soil erosion in the rill and interrill
- Operates on a 2-D grid network
- High temporal resolution to resolve changing conditions during rainfall events
- Responds to a wide range of agricultural practices and soil properties by building on existing knowledge

Interconnecting grid-cells in PALMS

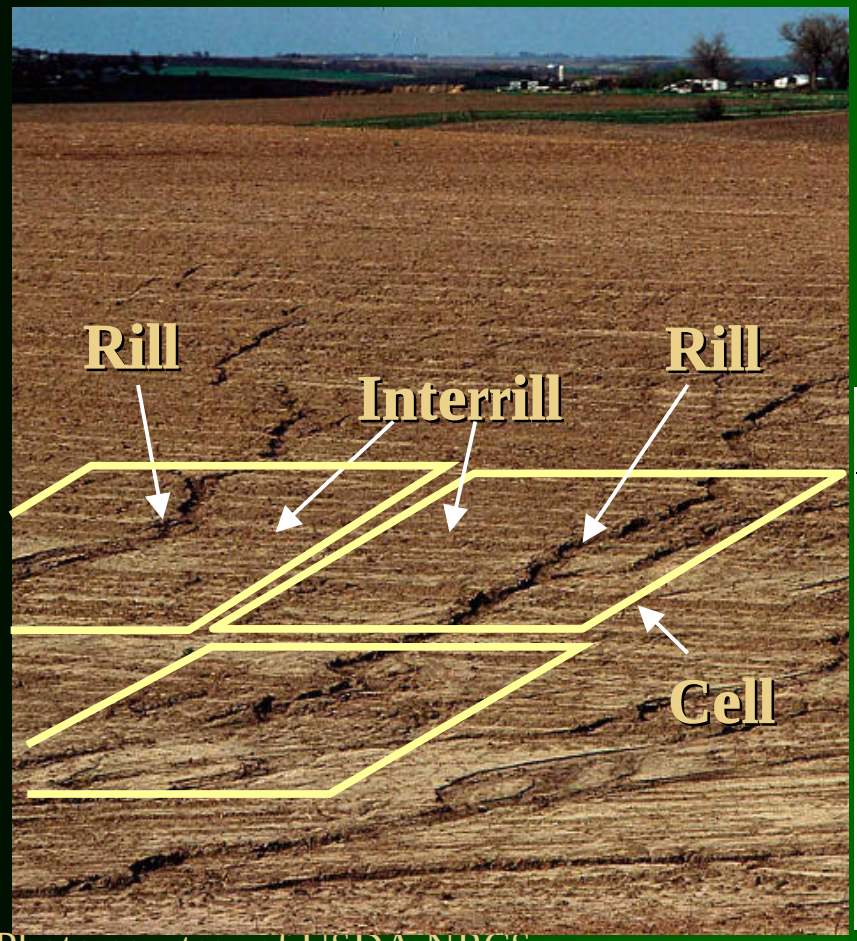
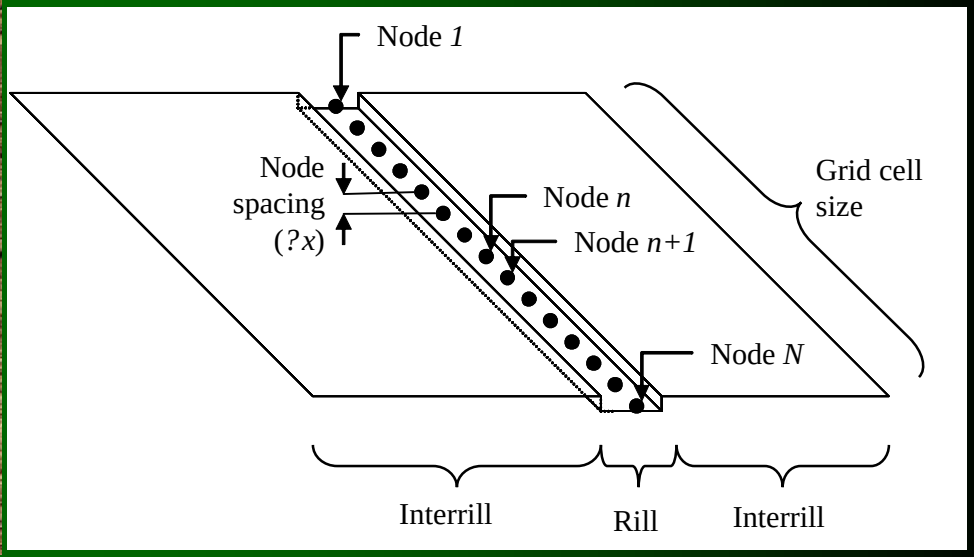


Photo courtesy of USDA NRCS.

- Steady-state sediment continuity equation within grid cell
  - Euler numerical method
- Water and sediment

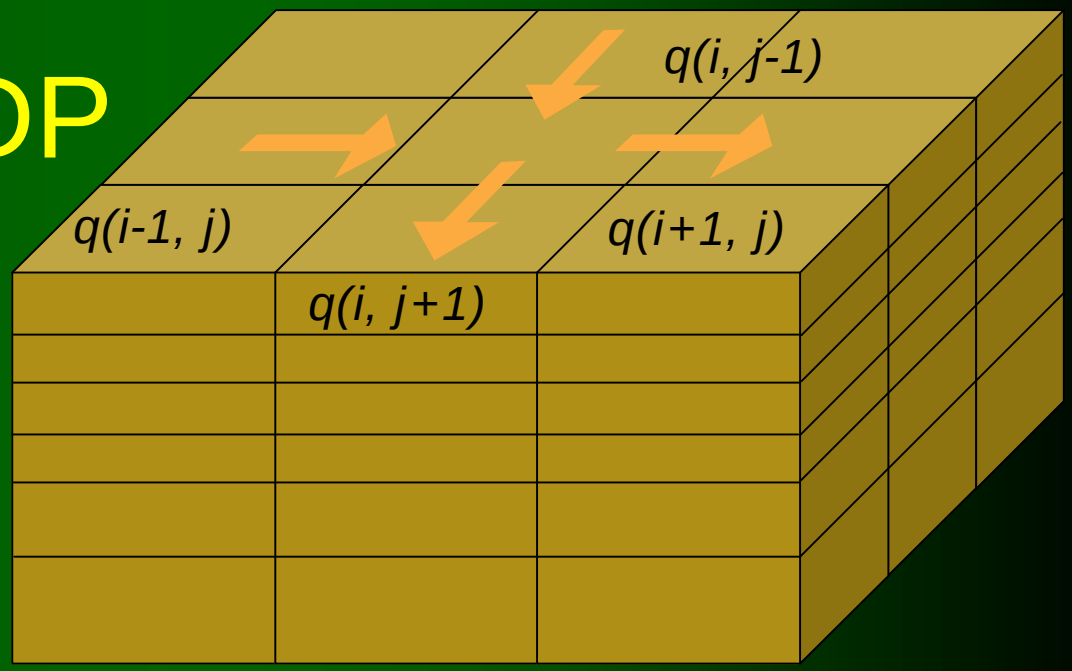


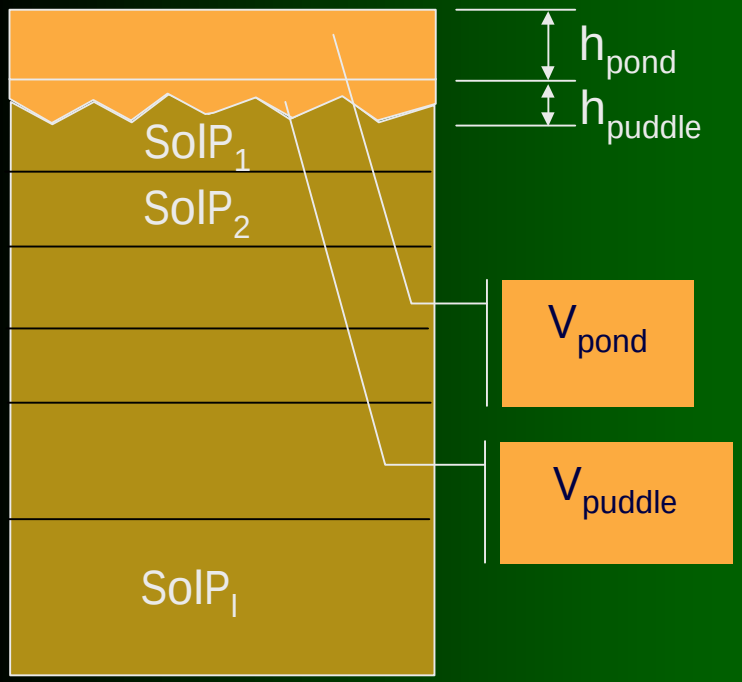
P Submodel - 4DP

- A Dynamic Model
  - Linking runoff and sediment loss to dissolved and particulate P losses
  - Based on Jones et al. (1984)
  - Used in APEX, EPIC, and SWAT (among others)
  - PAPRAN formulation (Seligman and van Keulen, 1981)
- Our Role
  - Hillslope to complex topography
    - Numerical hydrologic modeling and sediment transport
    - Link source areas with losses
    - Design buffer and upland modifications

Routing Flow/DP

- Runon and runoff
  - Directional Roughness

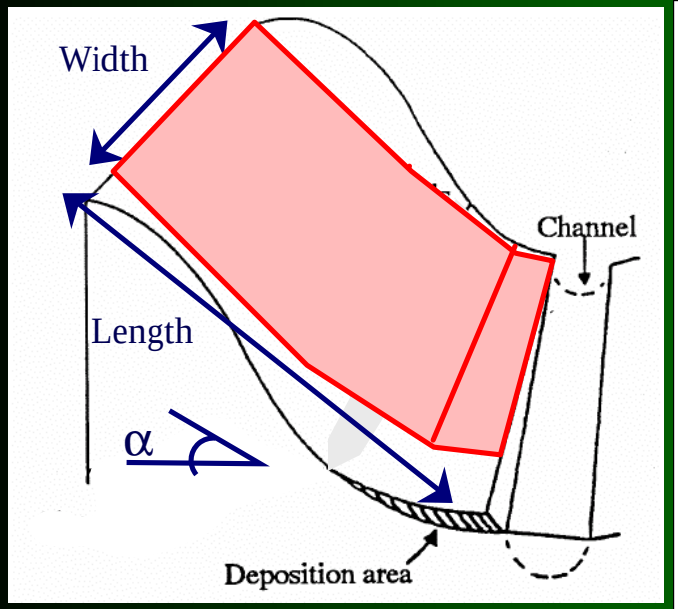


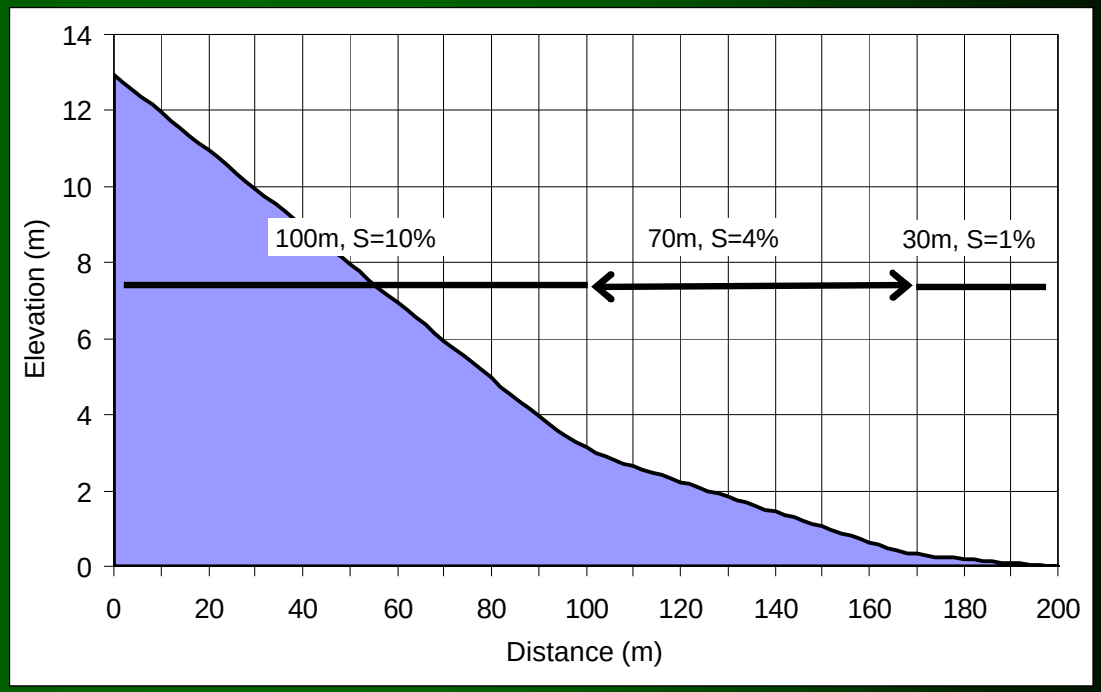


- $V_{pond} = h_{pond}$*cellsize
- $V_{puddle} = h_{puddle}$*cellsize
- V_{puddle} interacts with P in surface soil layer (DP)
- V_{pond} = has already had P calculated
  - Same cell or runon
- Mix DP by Mass balance
- Pond Vs Puddle may be significantly different

Comparison with WEPP

Idealized field

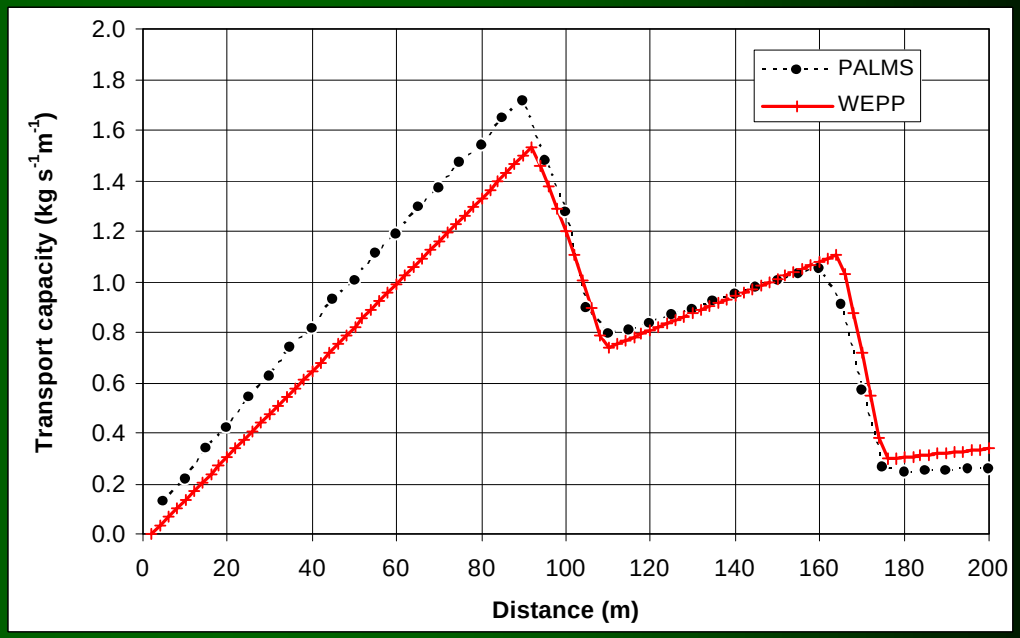




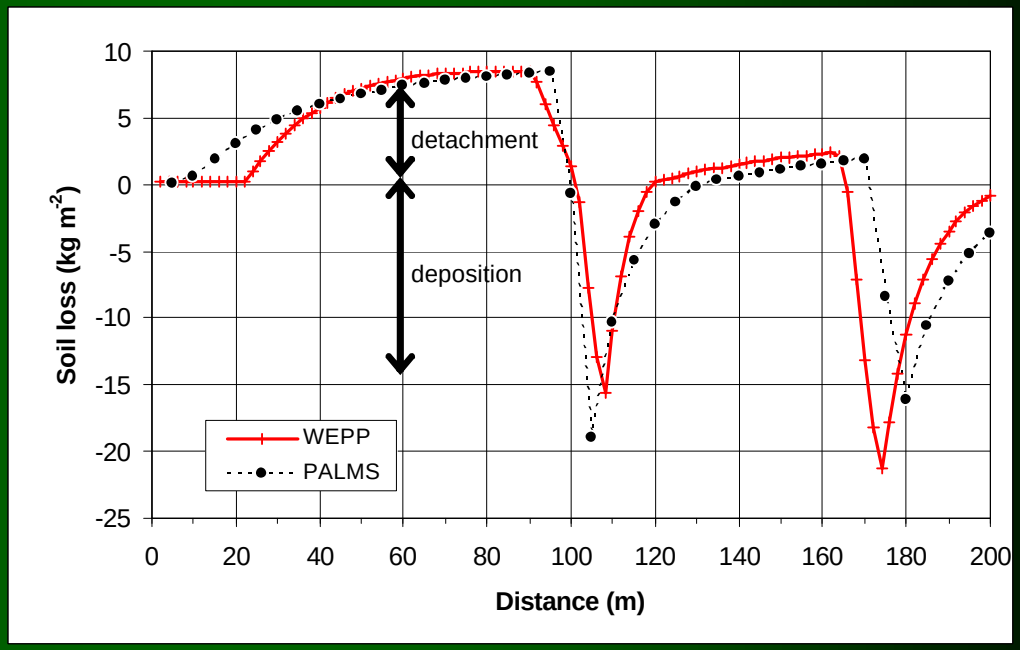
Slope profile used as idealized field

- Rainfall: 20 mm, 1 hr
- Silt loam (15 % clay, 65% silt, 20% sand)

Sediment transport capacity



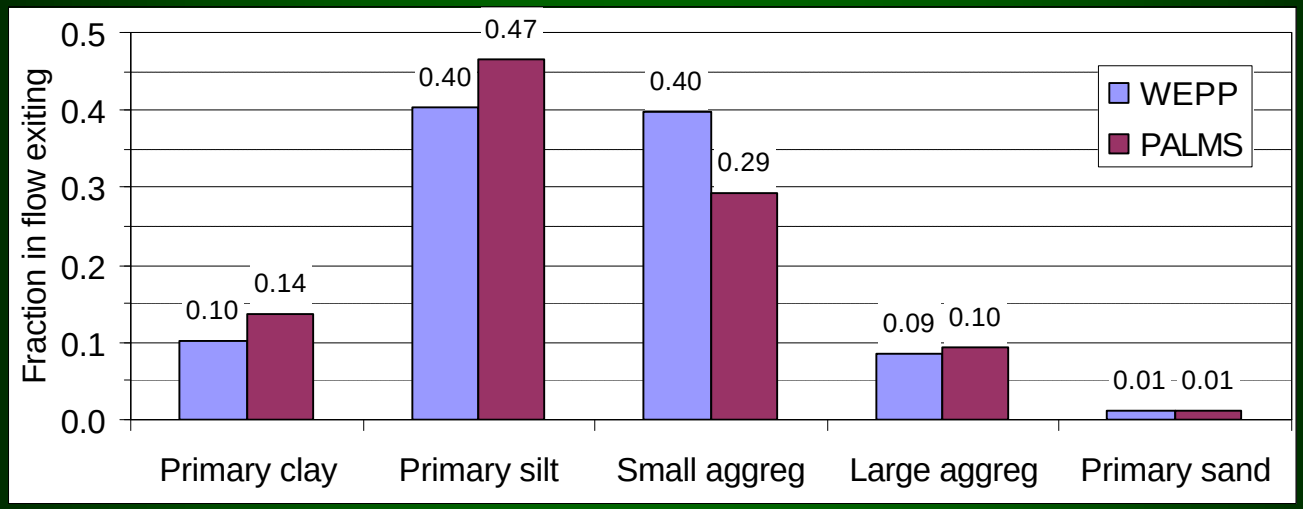
Detachment and deposition



WEPP and PALMS comparison on idealized field

	WEPP	PALMS
Interrill contribution (kg m^{-2})	0.16	0.13
Average of net detachment areas (kg m^{-2})	3.96	4.43
Total sediment load (kg m^{-3})	45	41
Sediment leaving profile (kg m^{-1})	172	148

Particle size distribution in flow exiting the field

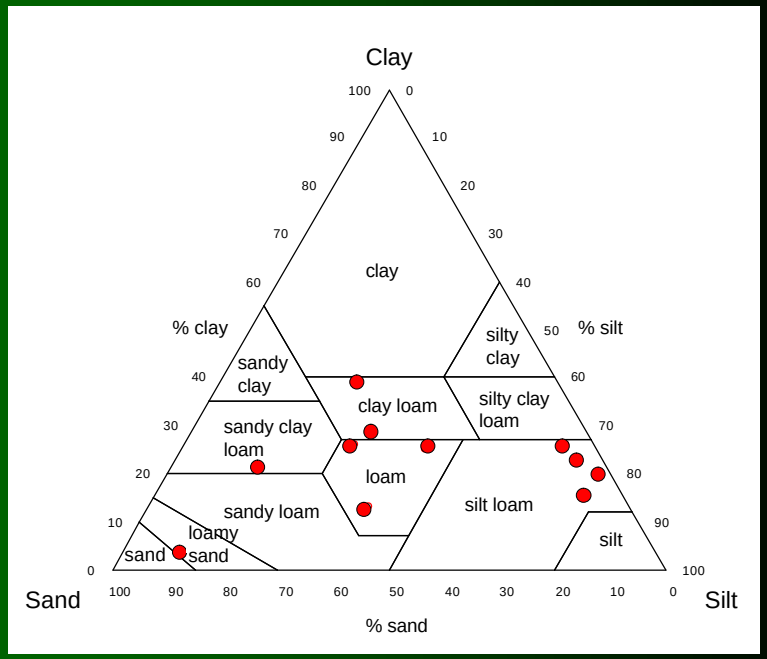


Comparison with WEPP

Erosion Plots

Field data:

- Gilley et al. 1990 (Trans. ASAE 33(6): 1900-1906)
- 11 sites located throughout the eastern US
- 3.7 x 10.7 m, slope 4- 10%
- Plowed, disked lightly, and raked by hand prior to testing
- Portable rainfall simulator
  - Rainfall rate: 57 mm hr^{-1}, 1 hr
- Runoff samples for sediment content determinations collected at 5-min intervals

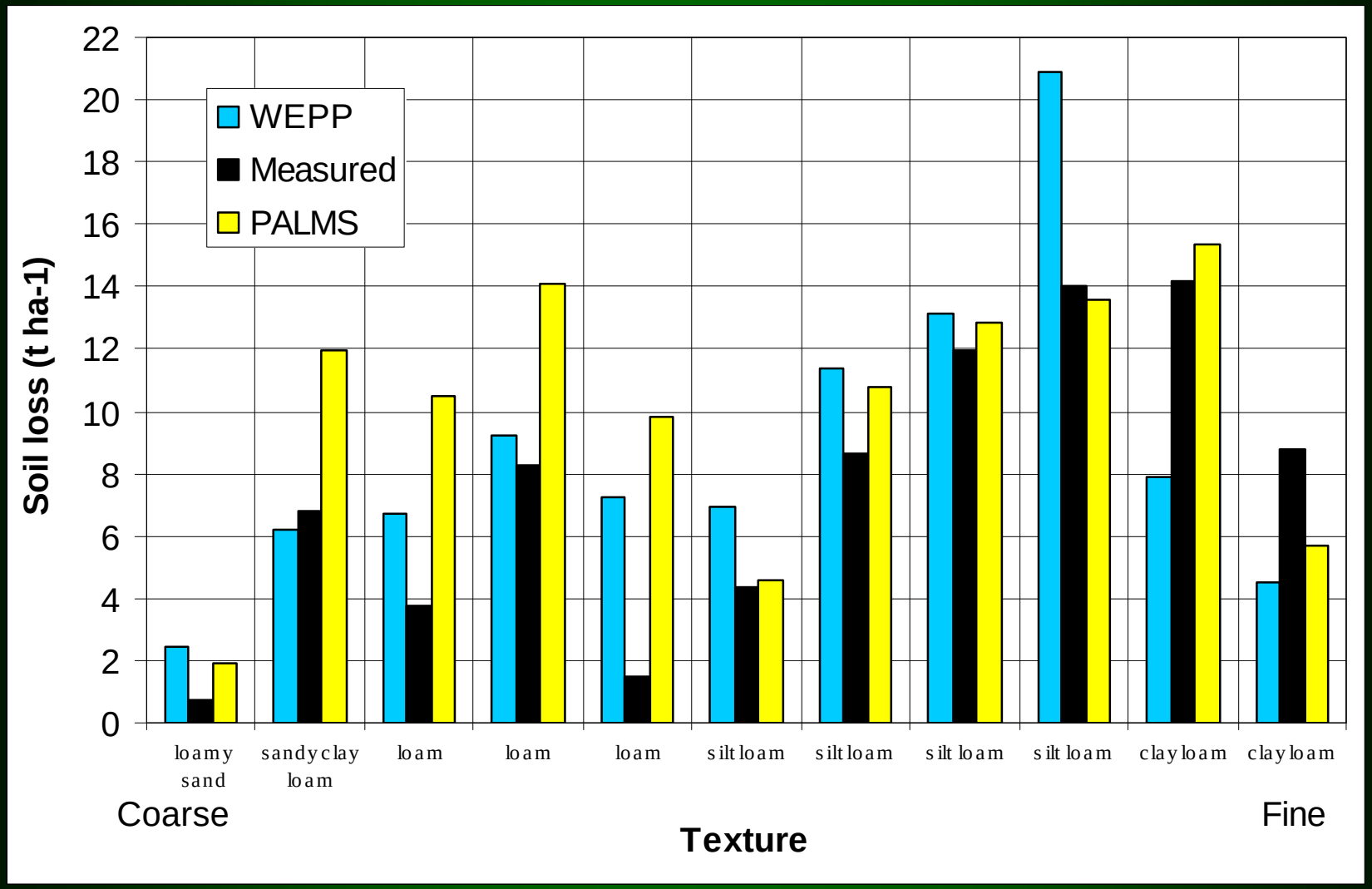


Particle size analysis of selected soils

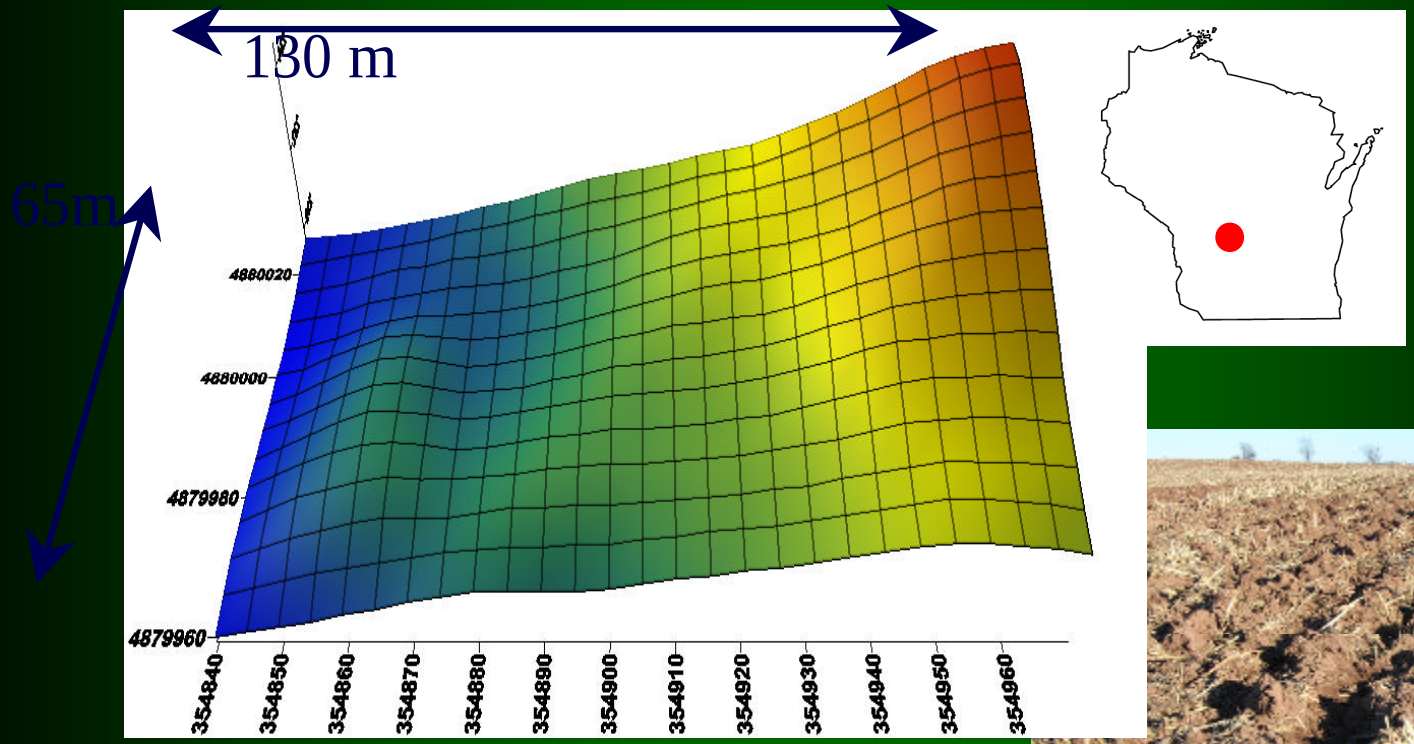
WEPP and PALMS comparison on field plots

	Runoff (mm)		Soil loss (t ha^{-1})	
	RMSE	R^2	RMSE	R^2
WEPP	8.77	0.19	3.89	0.46
PALMS	9.07	0.40	3.62	0.43
Ksat adjusted so measured runoff = predicted runoff				
WEPP	0.11	1.00	2.73	0.76
PALMS	0.24	1.00	4.00	0.62

Soil loss measured and estimated with WEPP and PALMS



Validation with field measurements

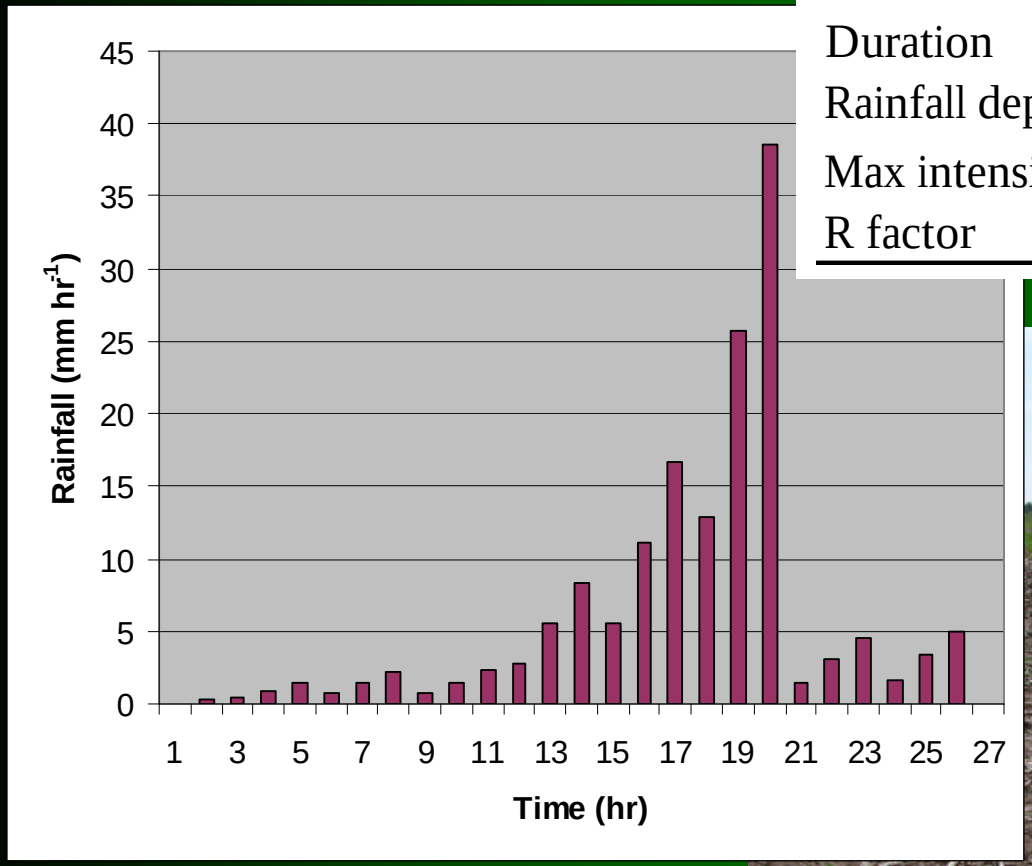


0.85 ha (2 ac)
Ave. slope 5%
Clay loam

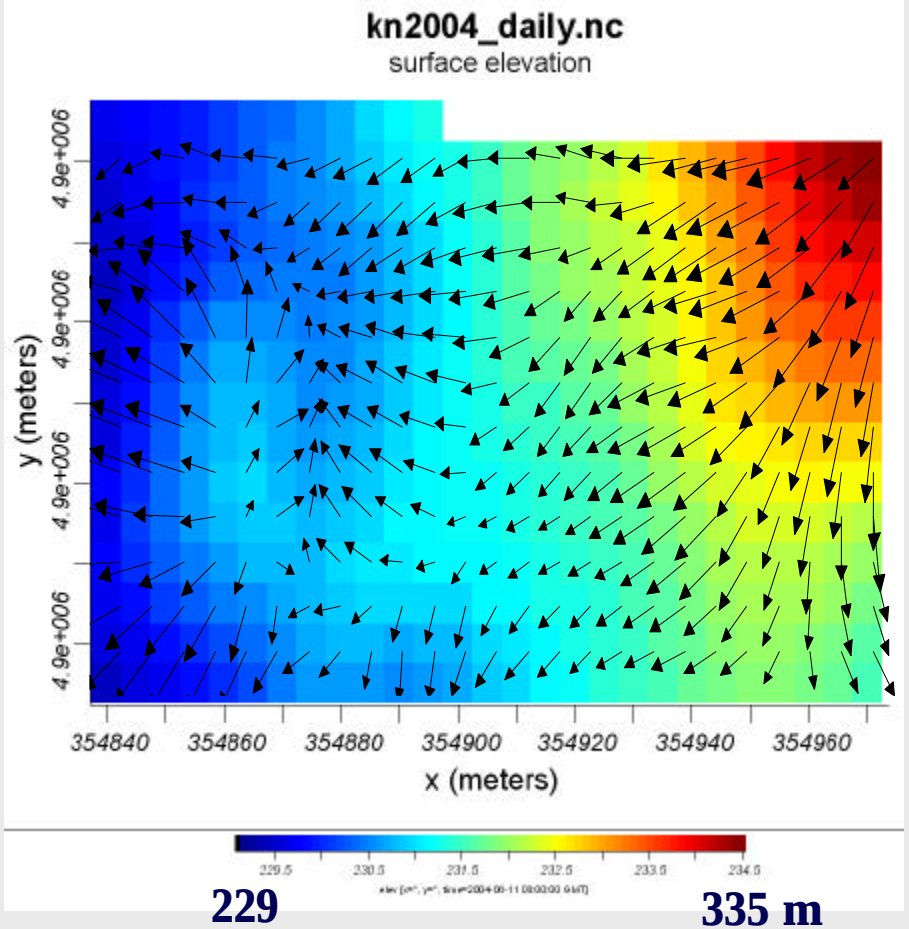
Rainfall event

Rainfall description

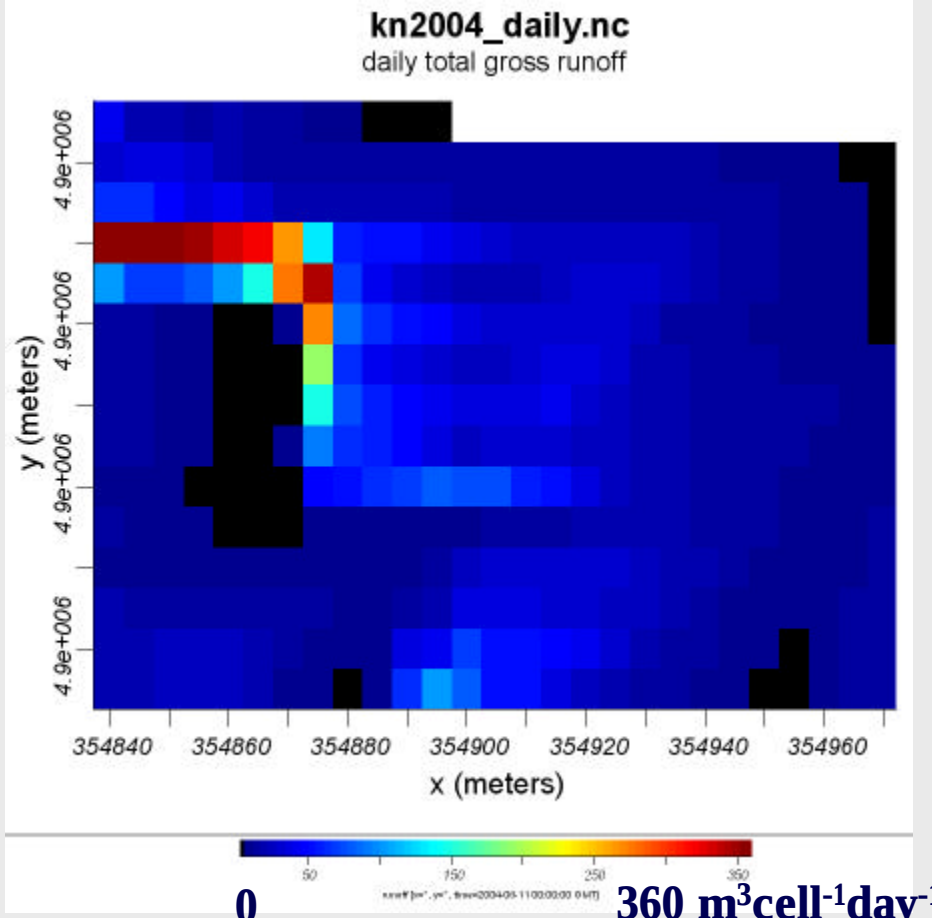
Date	June 10, 2004
Duration	24 hr
Rainfall depth	158 mm (6 in)
Max intensity	39 mm hr^{-1} (1.5 in)
R factor	77 (English) (aver. year 120)



Runoff

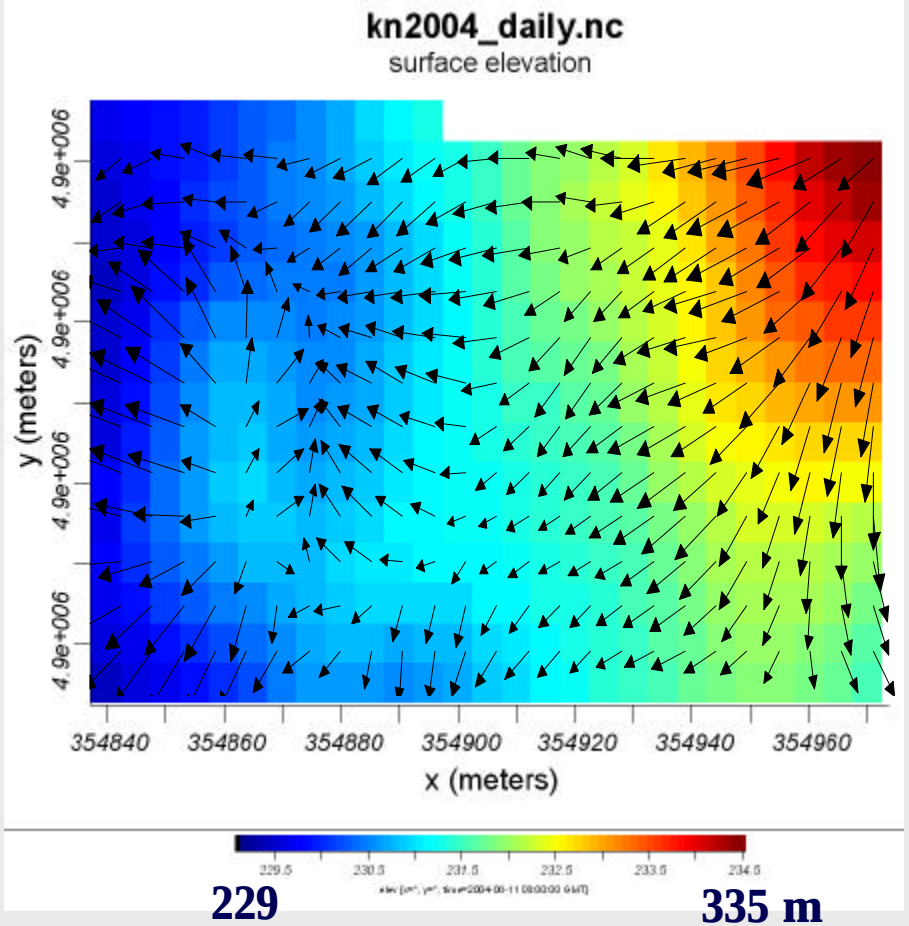


229 335 m



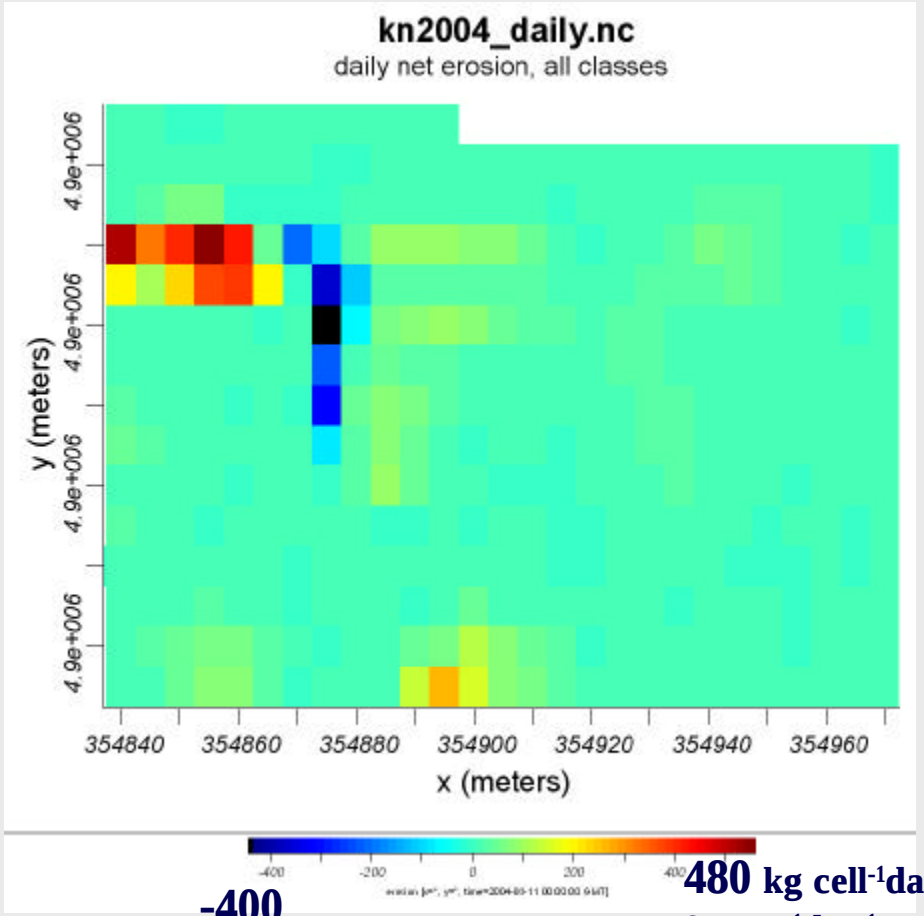
0 360 $m^3 cell^{-1} day^{-1}$

Soil erosion



229

335 m



-400

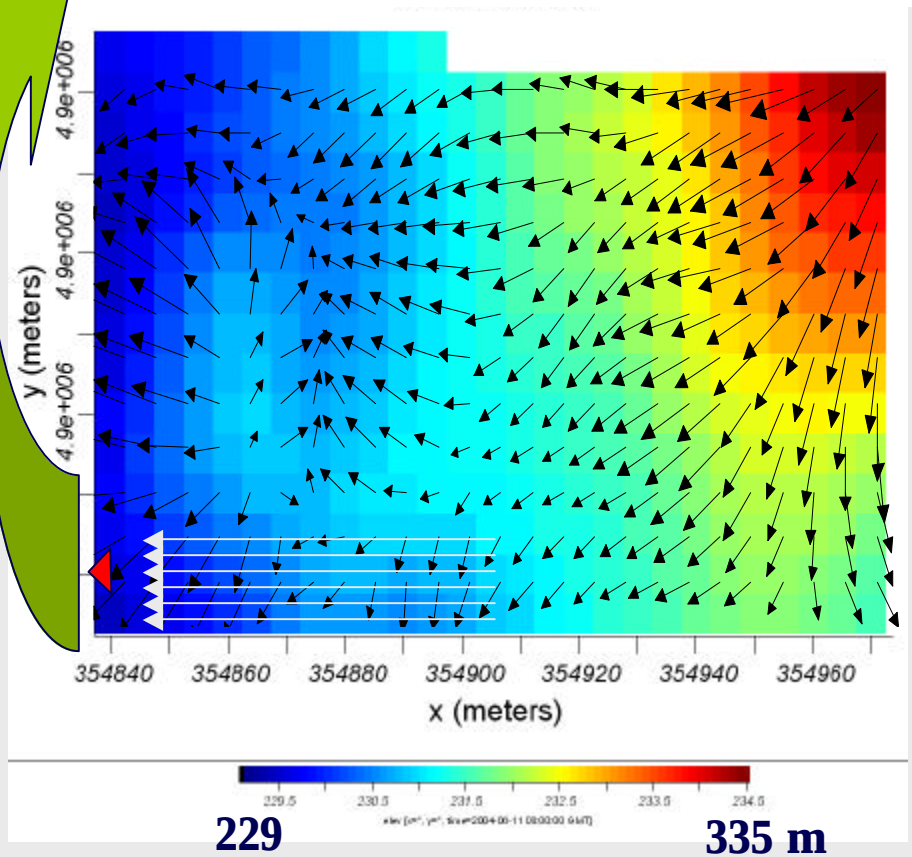
480 kg cell^{-1}day^{-1}

85 t ac^{-1}day^{-1}

Soil erosion

Runoff and soil loss measured and predicted with PALMS

	Measured	PALMS
Runoff (mm)	31.8	32.3
Soil loss (t ha^{-1})	0.90	0.95



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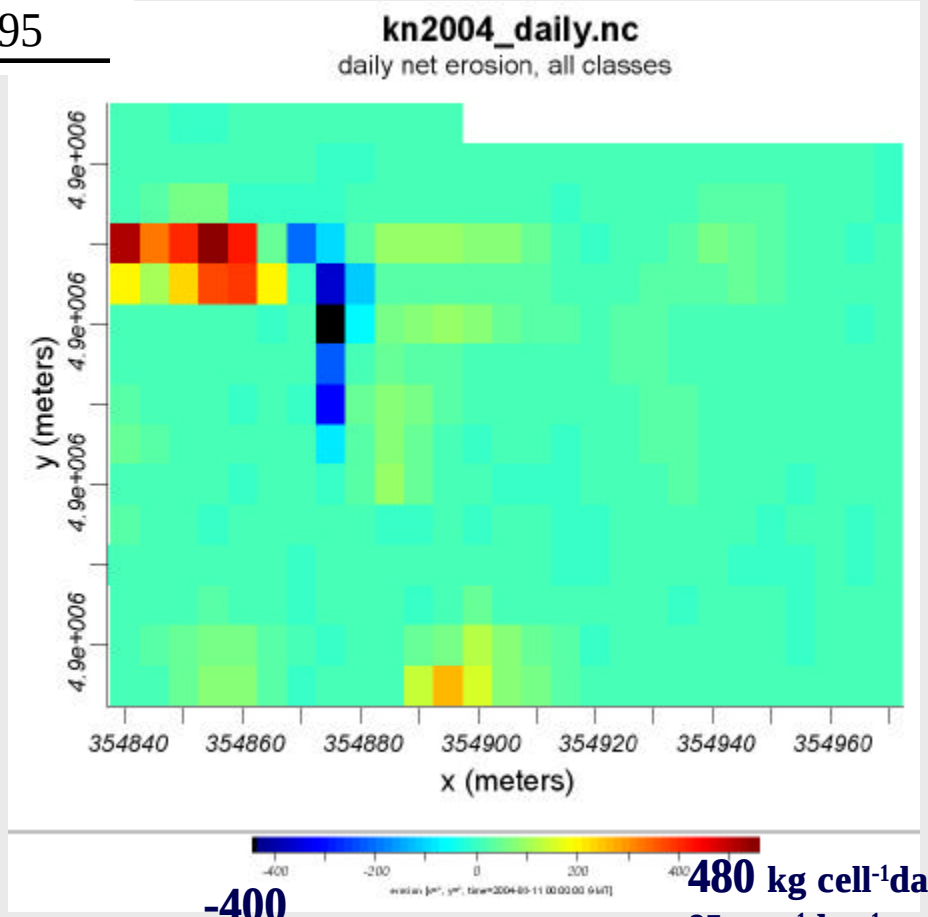


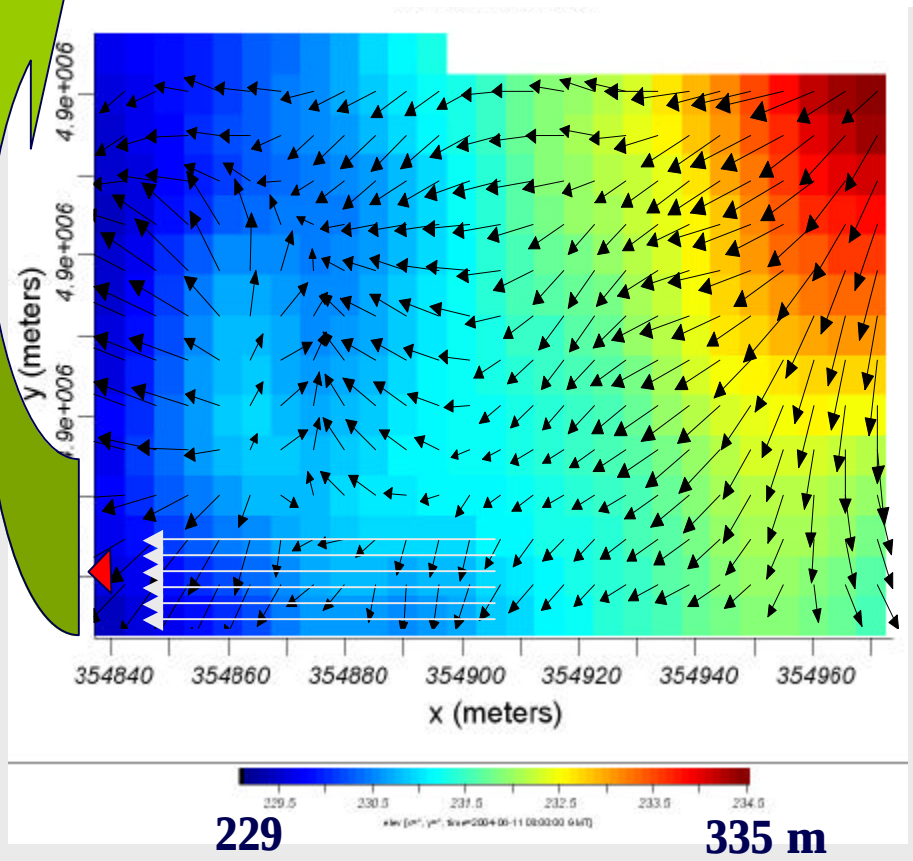
-400 480 kg $cell^{-1}day^{-1}$

85 t $ac^{-1}day^{-1}$

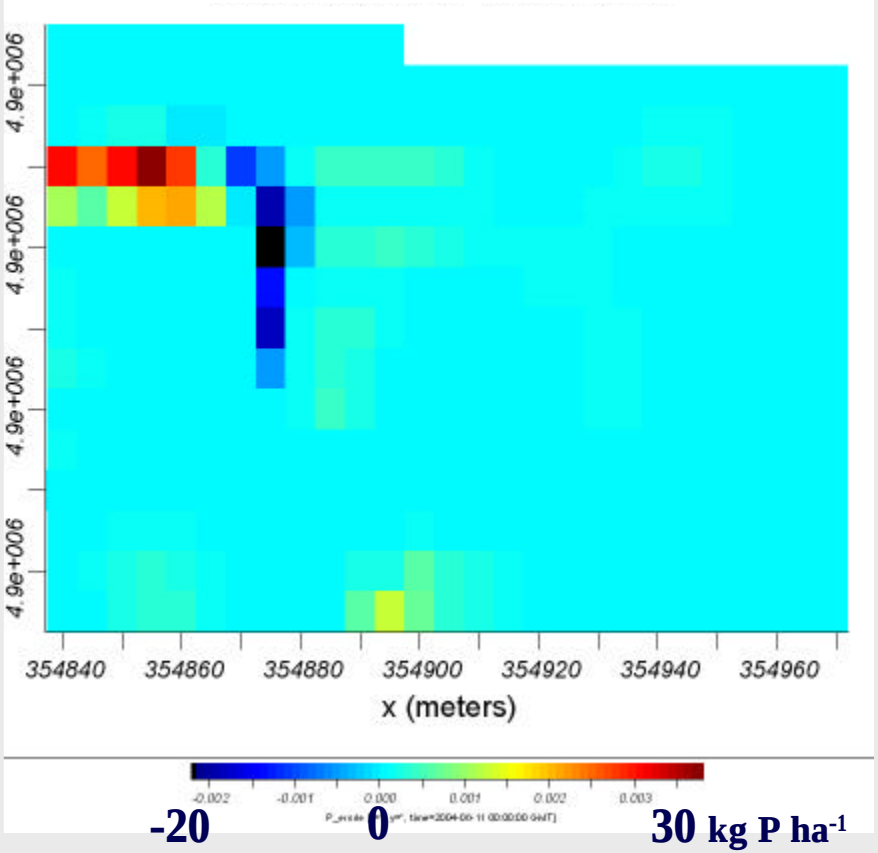
Soil Total-P Loss

Runoff and Total P-loss measured and predicted with PALMS

	Measured	PALMS
Runoff (mm)	31.8	32.3
Soil P-Loss (kg/ha)	0.36	0.26



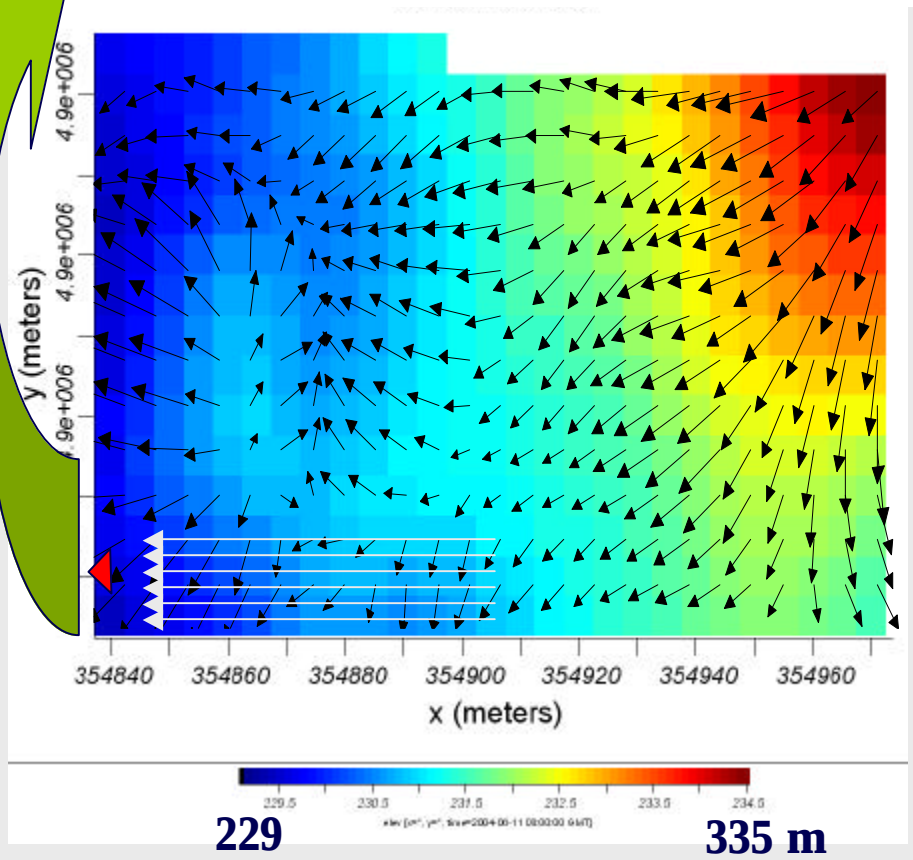
Total P Losses for June 10 storm



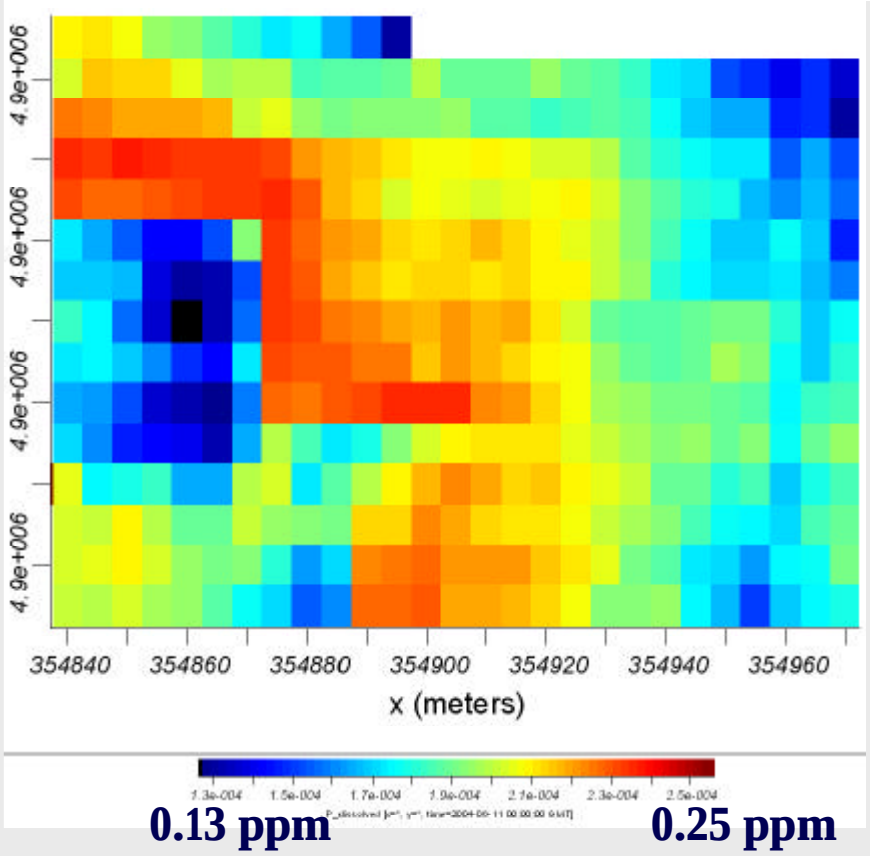
Dissolved-P Loss

Runoff and Dissolved P-loss measured and predicted with PALMS

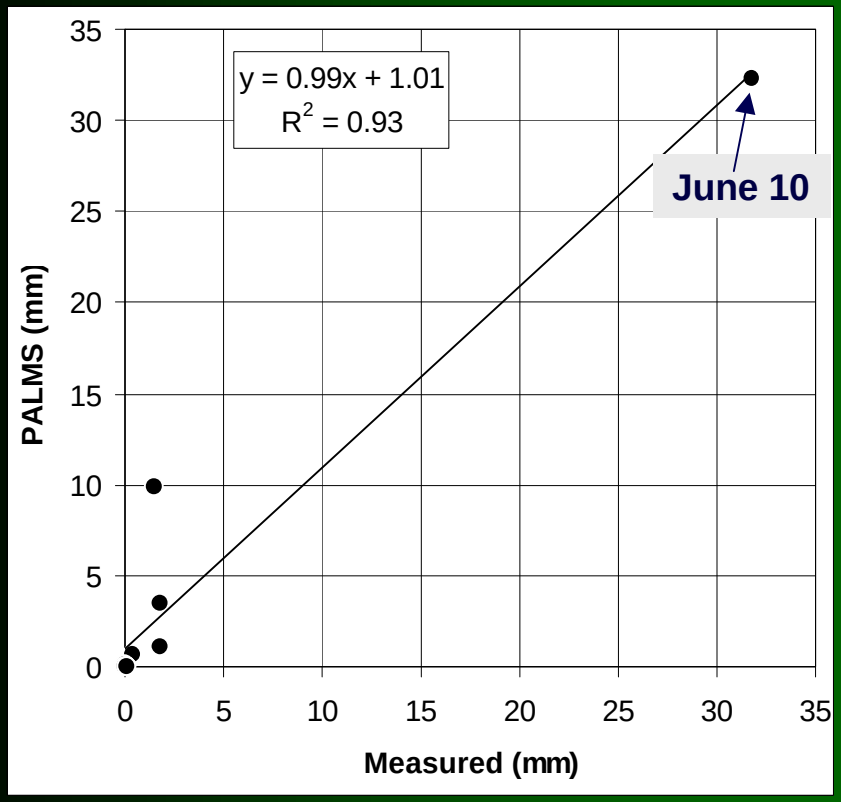
	Measured	PALMS
Runoff (mm)	31.8	32.3
Dissolved P (kg/ha)	0.071	0.078



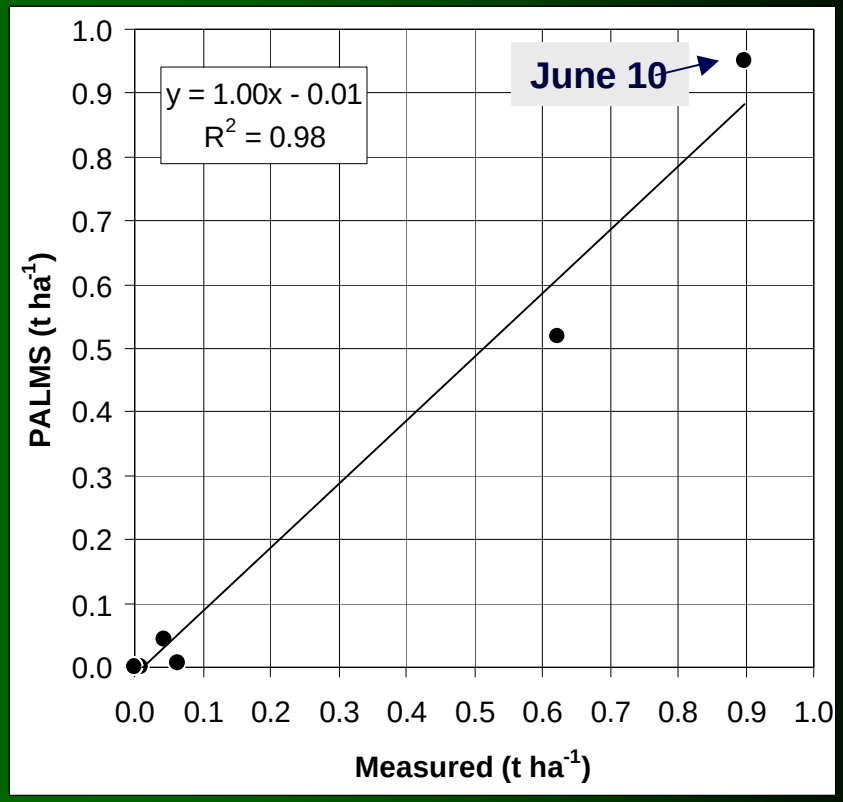
Dissolved P Concentration June 10



Measured and estimated runoff events



Measured and estimated soil losses

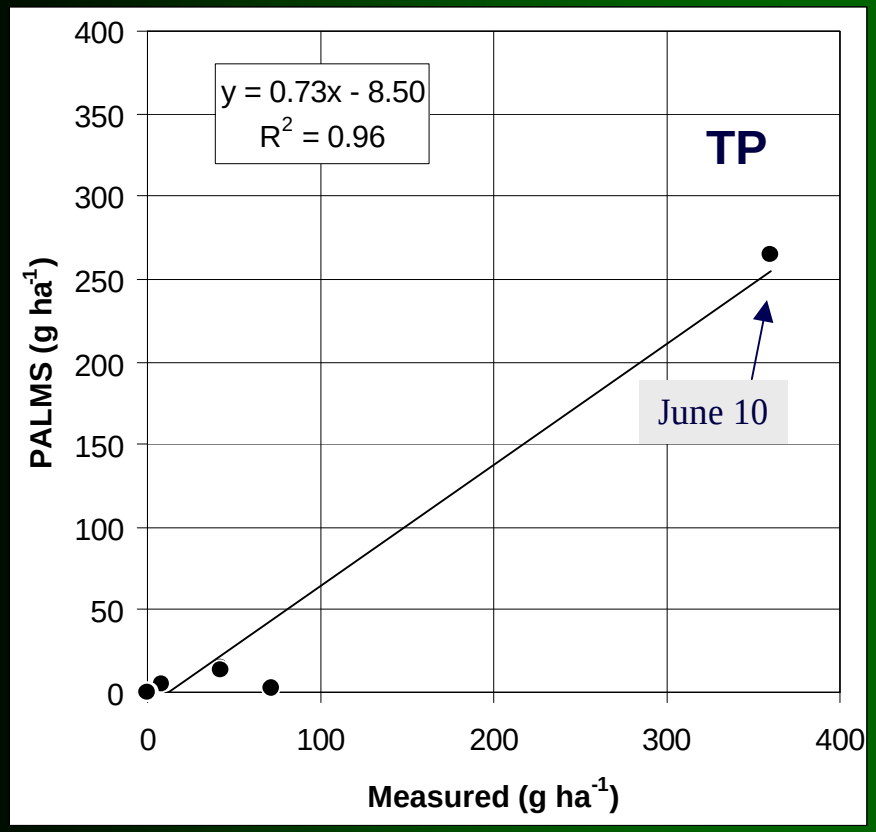


10 runoff events

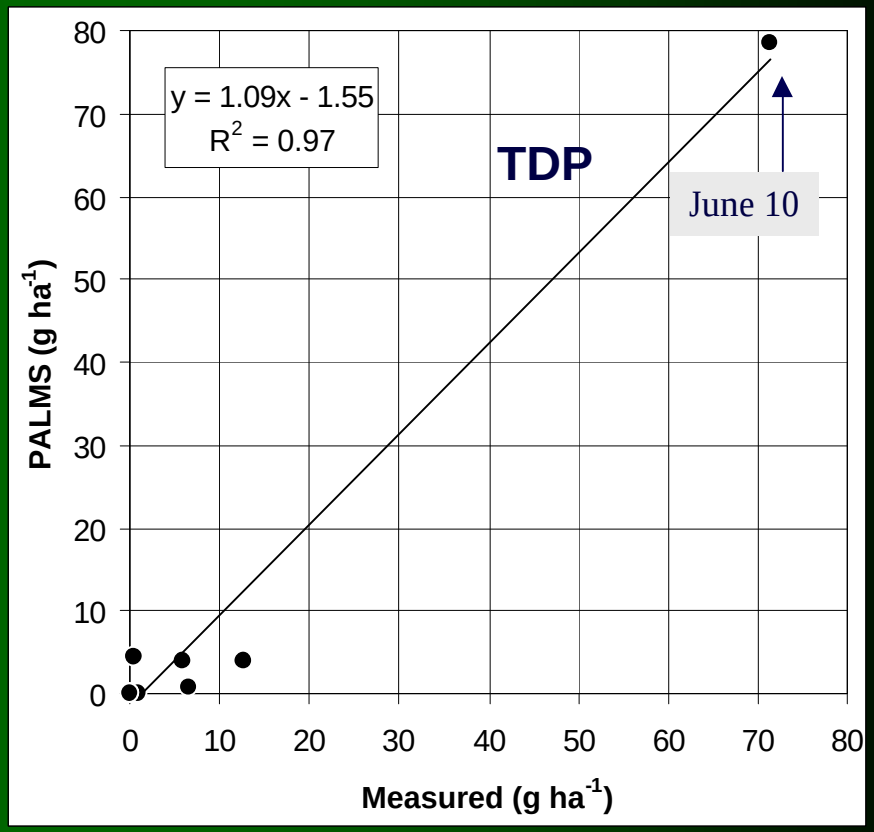
Statistics for the runoff and soil losses measured and predicted with PALMS

	Runoff (mm)		Soil loss (t ha^{-1})	
	RMSE	R^2	RMSE	R^2
Entire set	2.70	0.93	0.041	0.98
w/o June 10 event	2.84	0.42	0.040	0.99

Measured and estimated total phosphorus loss



Measured and estimated total dissolved phosphorus loss



Statistics for the total and total dissolved phosphorus losses measured and predicted with PALMS

	TP (g ha^{-1})		TDP (g ha^{-1})	
	RMSE	R^2	RMSE	R^2
Entire set	39.5	0.96	4.2	0.97
w/o June 10 event	26.9	0.31	3.8	0.34

Conclusions

- PALMS agrees with WEPP in the test cases and provides runoff and sediment loss estimates for complex topographies
- PALMS estimates of runoff, sediment loss and P loss agree reasonably with one example of field measurements made on a cultivated farm field

Acknowledgments

- Funding:
  - USDA Cooperative State Research, Education, and Extension Service's Water Quality Program
  - Wisconsin Department of Natural Resources
  - Natural Resource Conservation Service
  - The Non-Point Pollution Project, Arlington Agricultural Research Station, University of Wisconsin – Madison

- Dr. George Foster provided insights into measurement and modeling approaches, Dr. Dennis Flanagan and Dr. Mark Nearing (USDA/NSERL) assisted with interpretation of WEPP, Dr. Daniel Yoder (U. Tenn.) assisted with instrumentation.