Scaling riparian buffer capacity of nitrogen: a synthesis of numerical experiments

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Riparian Hot Spot for NO_3^-

Biogeochemical and transport processes

- Anaerobic condition, High OM and NO_3^-

---controlled by water table, soil and vegetation types, and nutrient loads, etc

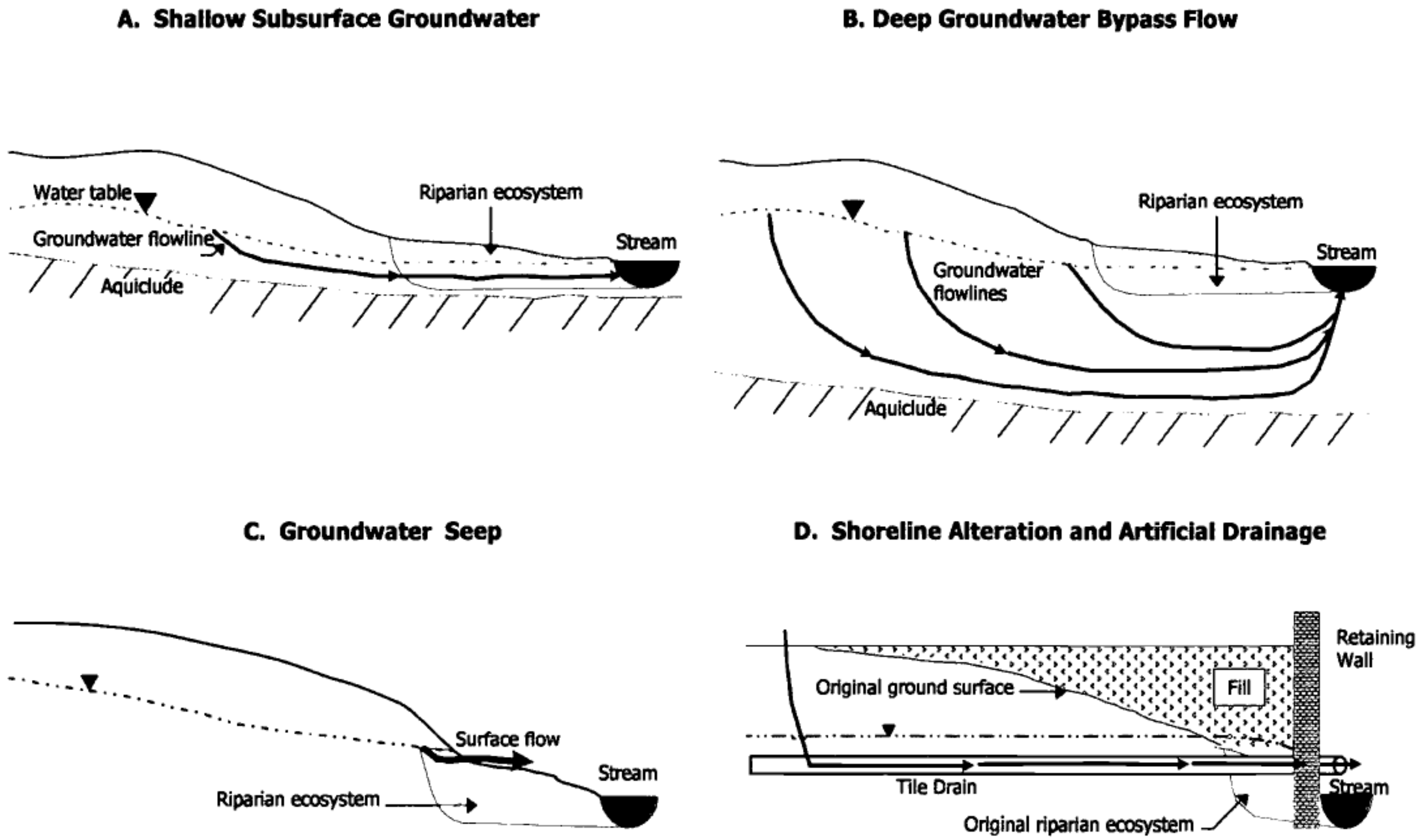
- Large water fluxes (thus nutrient fluxes)

---determined by topography and hydrogeology

it is challenging to assess buffering capacity across varying systems

McClain et al., 2003; Vidon et al.,2010

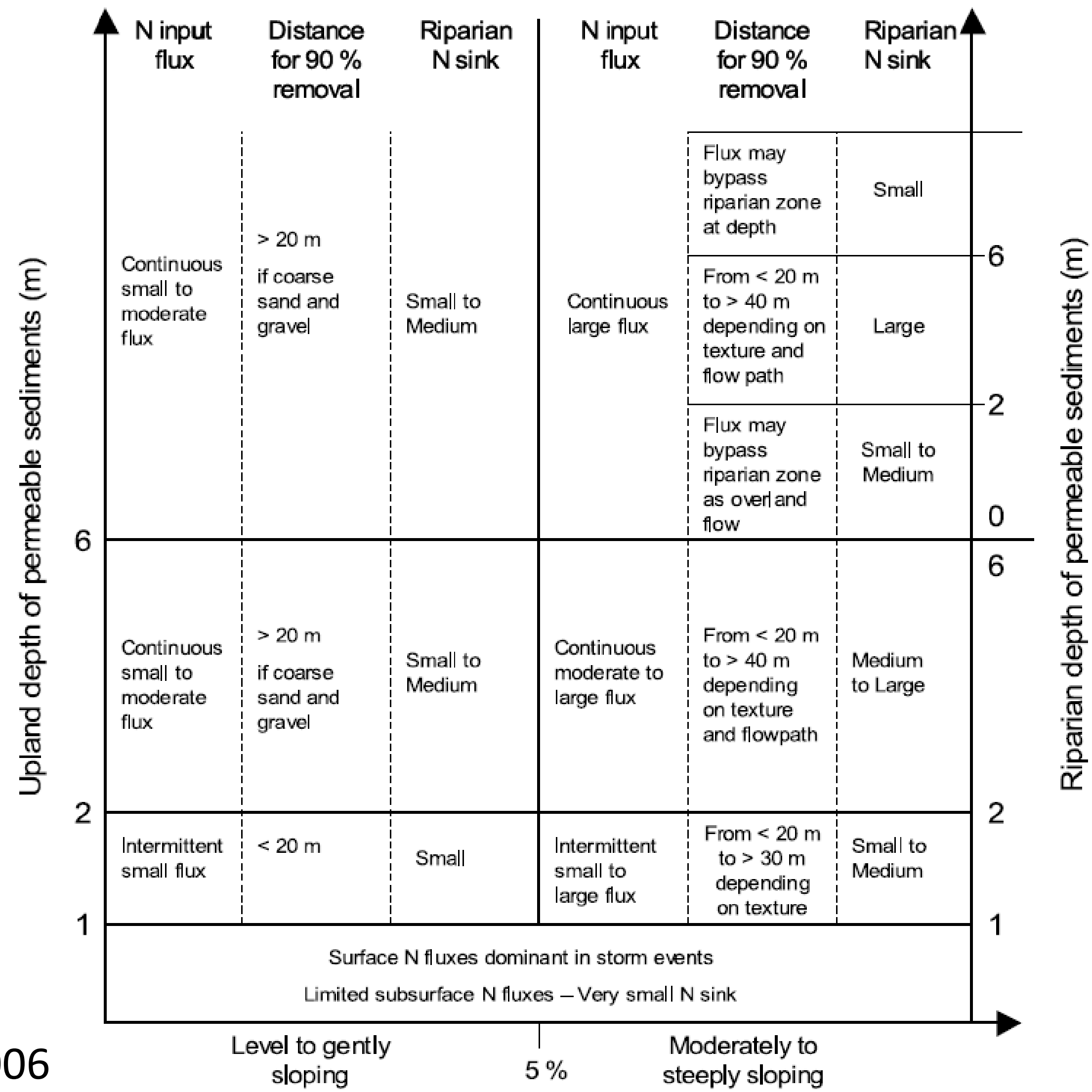
Riparian zones display wide variation in their buffering capacity



Hydrological flow pathways across the upland-riparian continuum (from Gold et al., 2001)

A unifying conceptual model

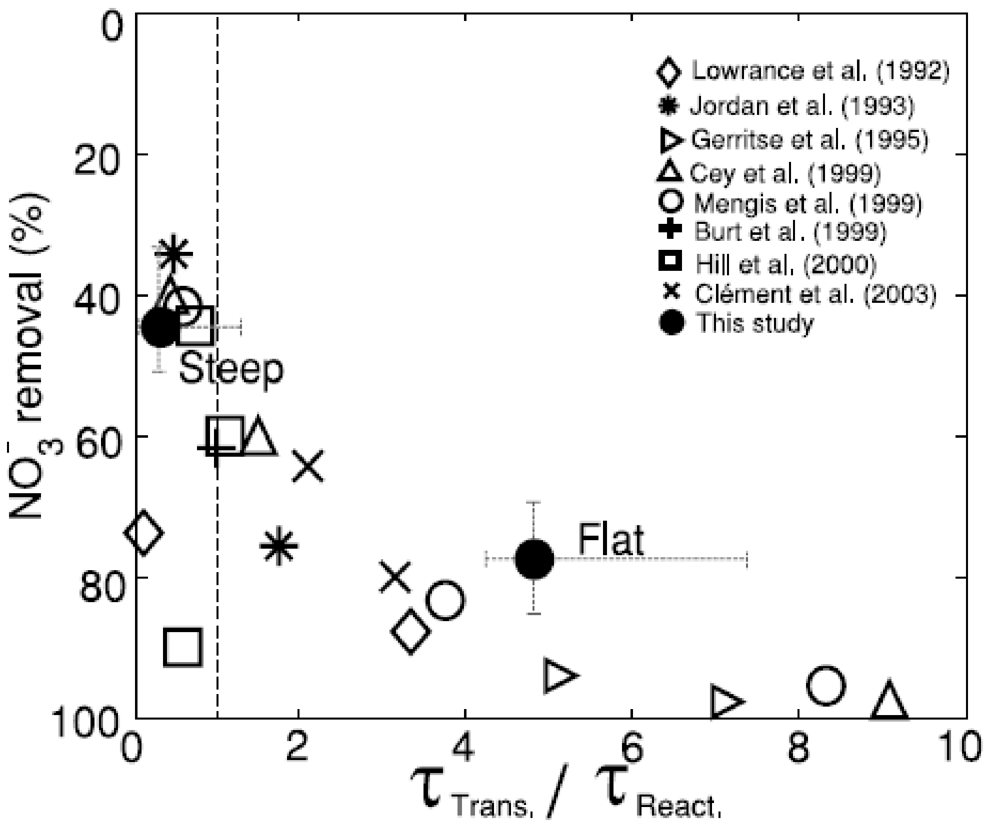
- helpful in watershed management
- qualitative only



Vidon and Hill, 2006

A scaling index, Damkohler number, for riparian buffering capacity

- Quantitative
- But the index is not easy to measure
- Limited application to real-world watershed management



Ocampo et al., 2006

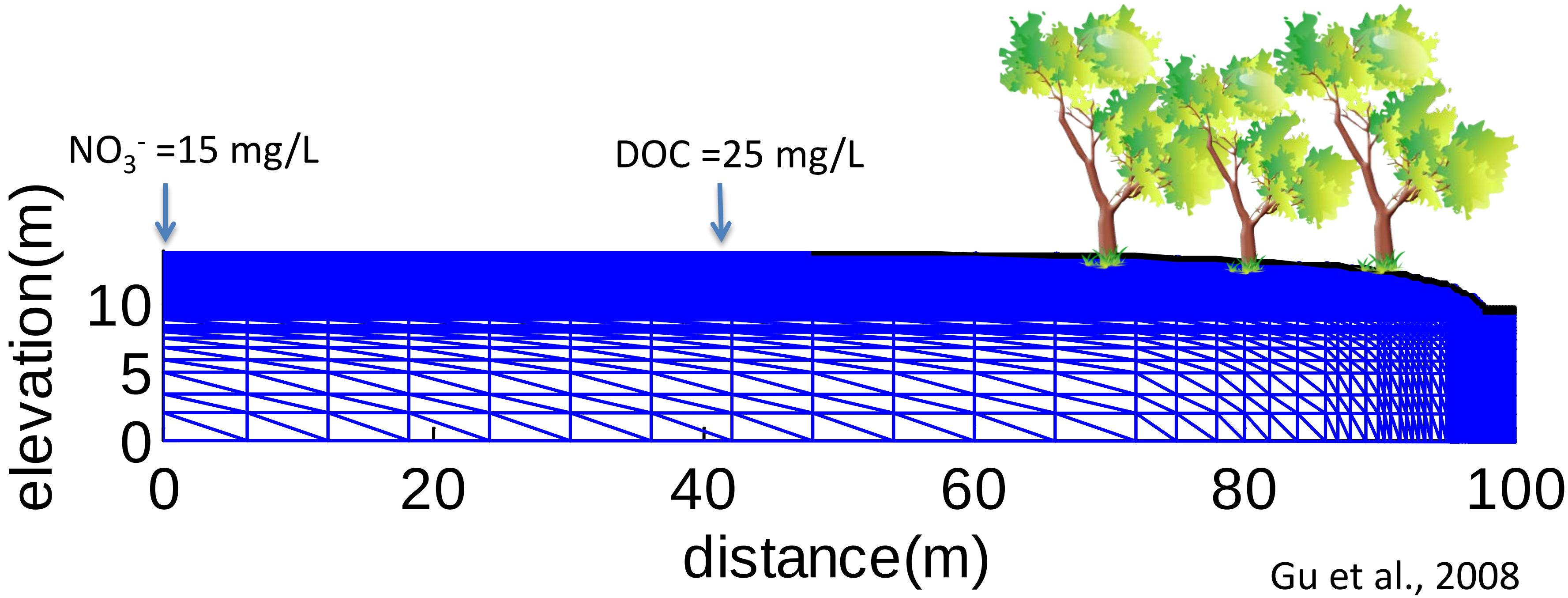
Need a quantitative scaling model with easily measurable characteristics

- a simple yet robust scaling relationship to quantify riparian buffering capacity
- Field comparative studies at multiple sites are expensive and impractical.
- Numerical experiments using computer models are cheap and feasible.



2D Riparian Model

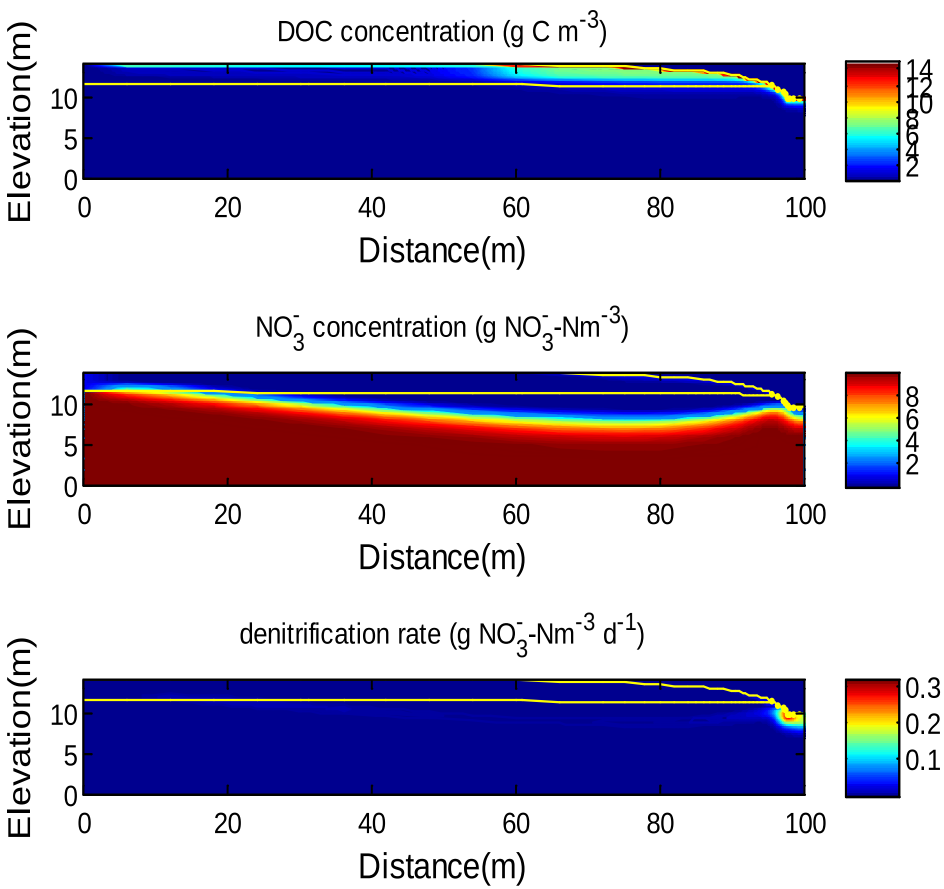
numerical experiments were conducted to examine the effects of varying physical and biogeochemical conditions on N retention in riparian zones.



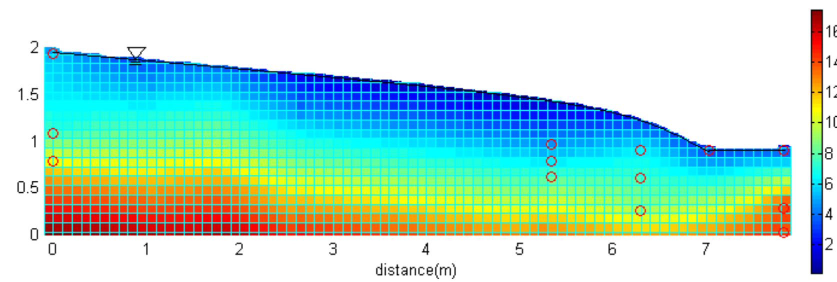
Gu et al., 2008

Model Testing

- Simulation results



Field observation



Observed groundwater NO_3^- concentration in the riparian zone (Gu et al., 2008)

Buckingham's pi theorem

To generate dimensionless groups for total NO_3^- removal rate, *M*, including the following steps:

(1) selecting the minimum number of sensitive variables that describe *M*,

(2) generating dimensionless groups of the controlling variables, and

(3) using the numerical experiment data to determine a power law scaling relationship for *M*.

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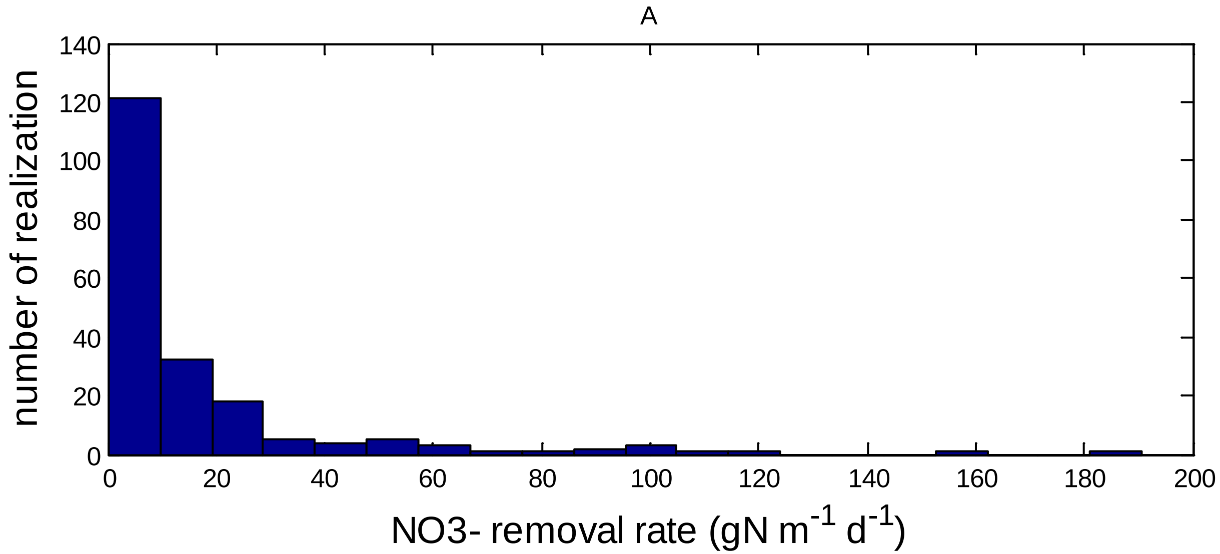
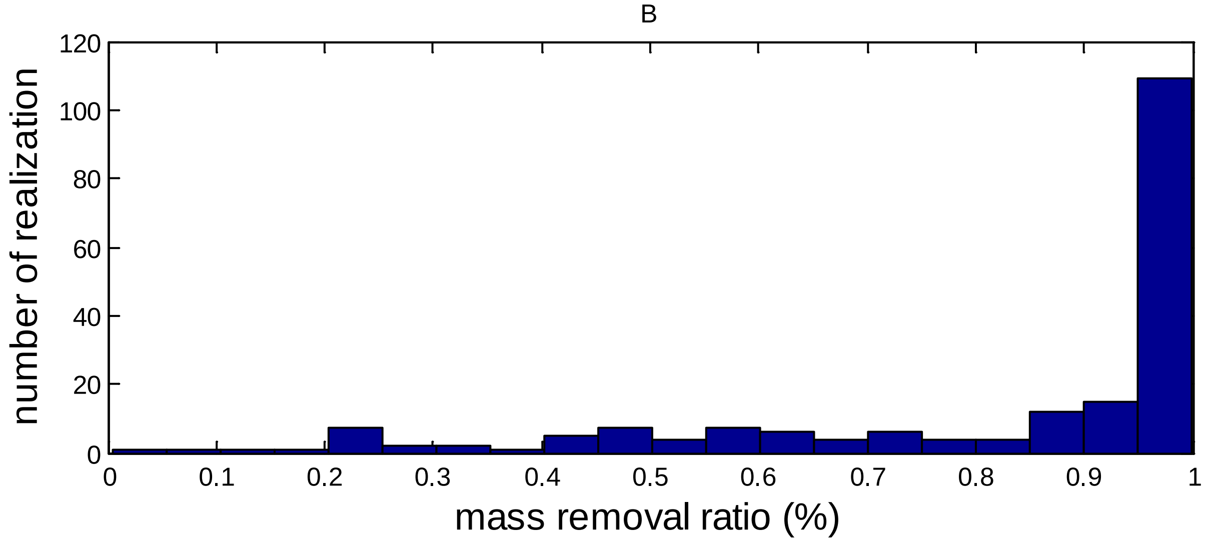
Table. Dimensional Analysis variables.

Variable	Description	Dimensions
K	Hydraulic conductivity	LT^{-1}
H	Aquifer thickness	L
WT	Water table depth	L
i	Hydraulic gradient	-
Alpha	Dispersivity	L
DOC	DOC relative concentration	-
NO_3^-	NO_3^- relative concentration	-
u	Reaction rate	$ML^{-3}T^{-1}$
M	Total mass removal rate per unit length of river	$ML^{-1}T^{-1}$

$$M = f\,(K, WT, H, I, alpha, DOC, NO_3^-, u)$$

Monte Carlo Simulation Results





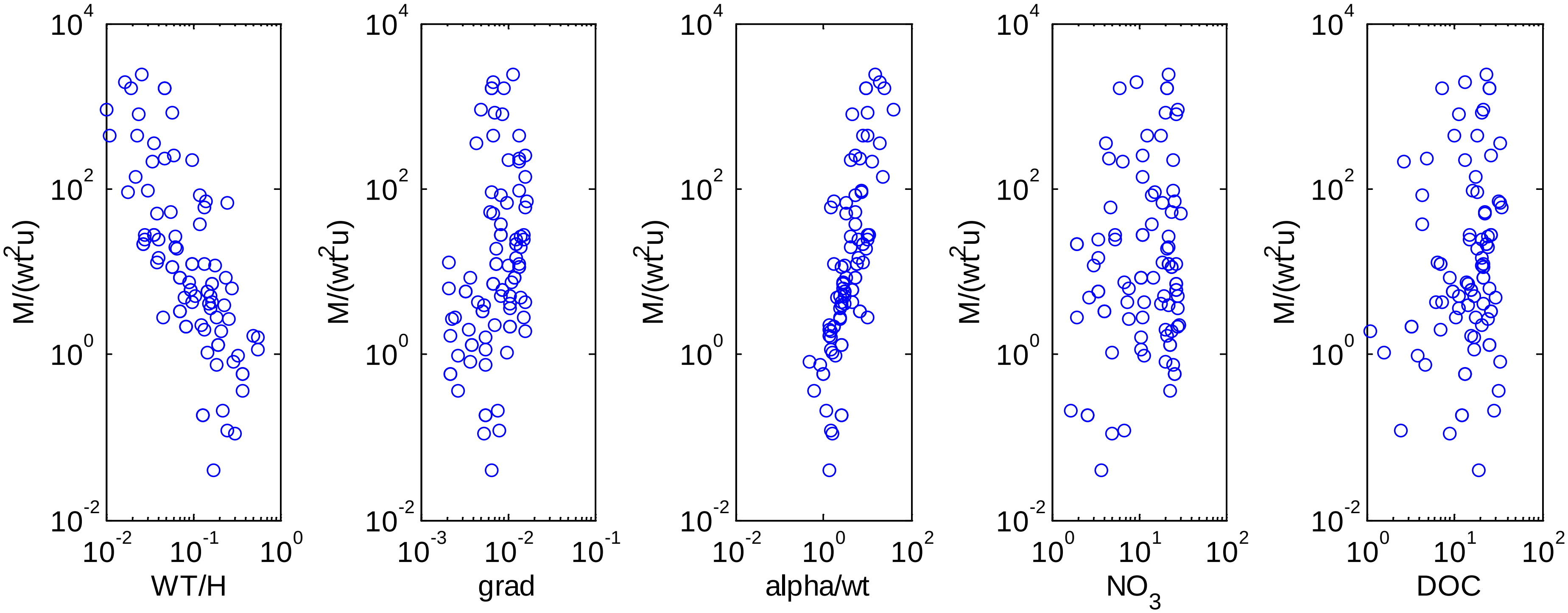
Identify dimensionless groups

- There are three dimensions and nine environmental variables were included, which resulted in 9-3=6 possible dimensionless groups.

$$\frac{M}{WT^2u} = (\frac{H}{WT})^a(\frac{\alpha}{WT})^b(i)^c(DOC)^d(NO_3{}^-)^e$$

The exponents *a, b, c, d, e, and f* were determined from multiple regression between the individual dimensionless group and the dimensionless mass removal rate (M/WT^2u).

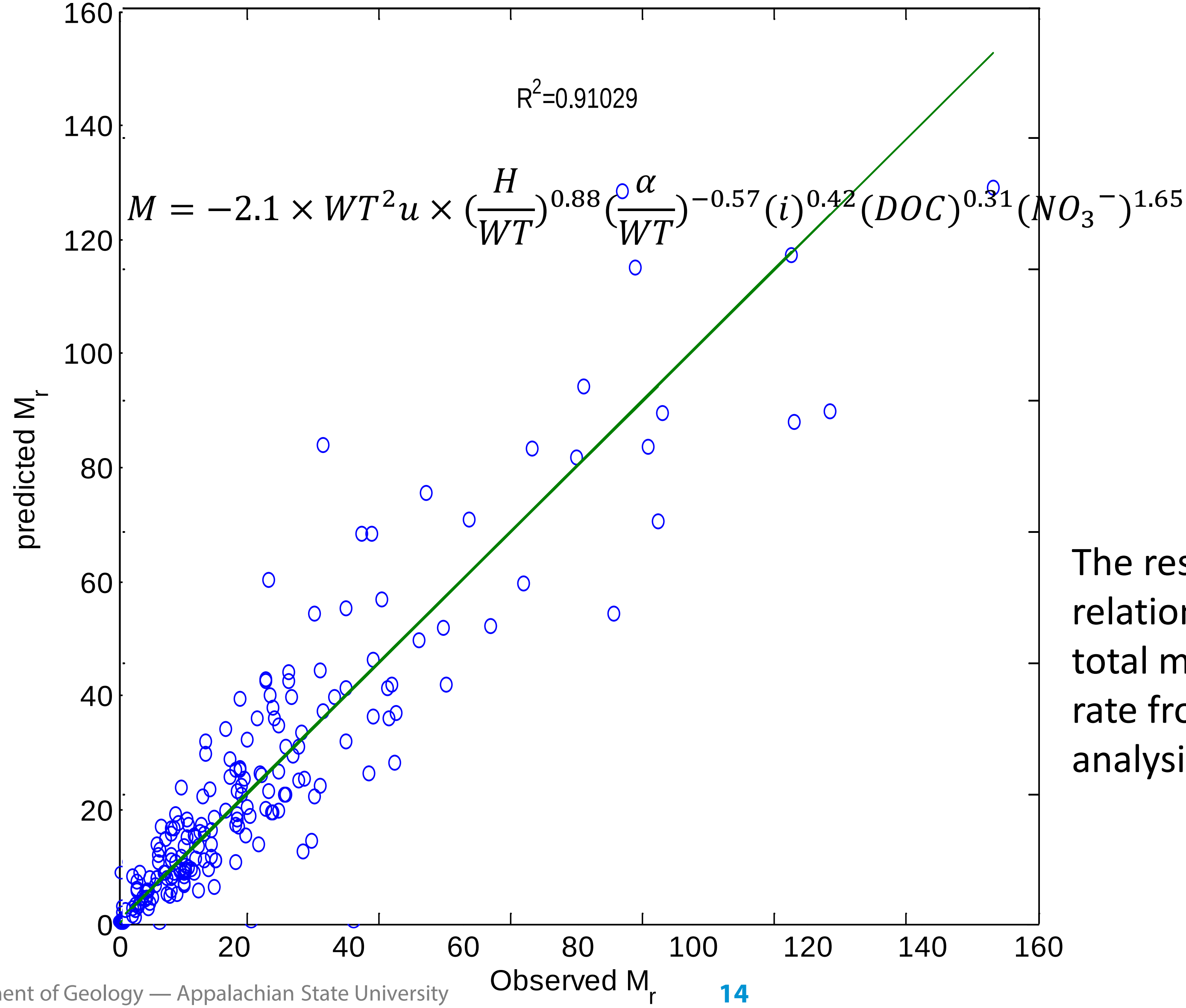
Correlation between M/(wt^2u) and the dimensionless groups



Correlations between the dimensionless mass removal M/(wt^2u), and the dimensionless groups. The scaling coefficients a, b, c, d, and e are the slope of the individual plots.

The final scaling equation:

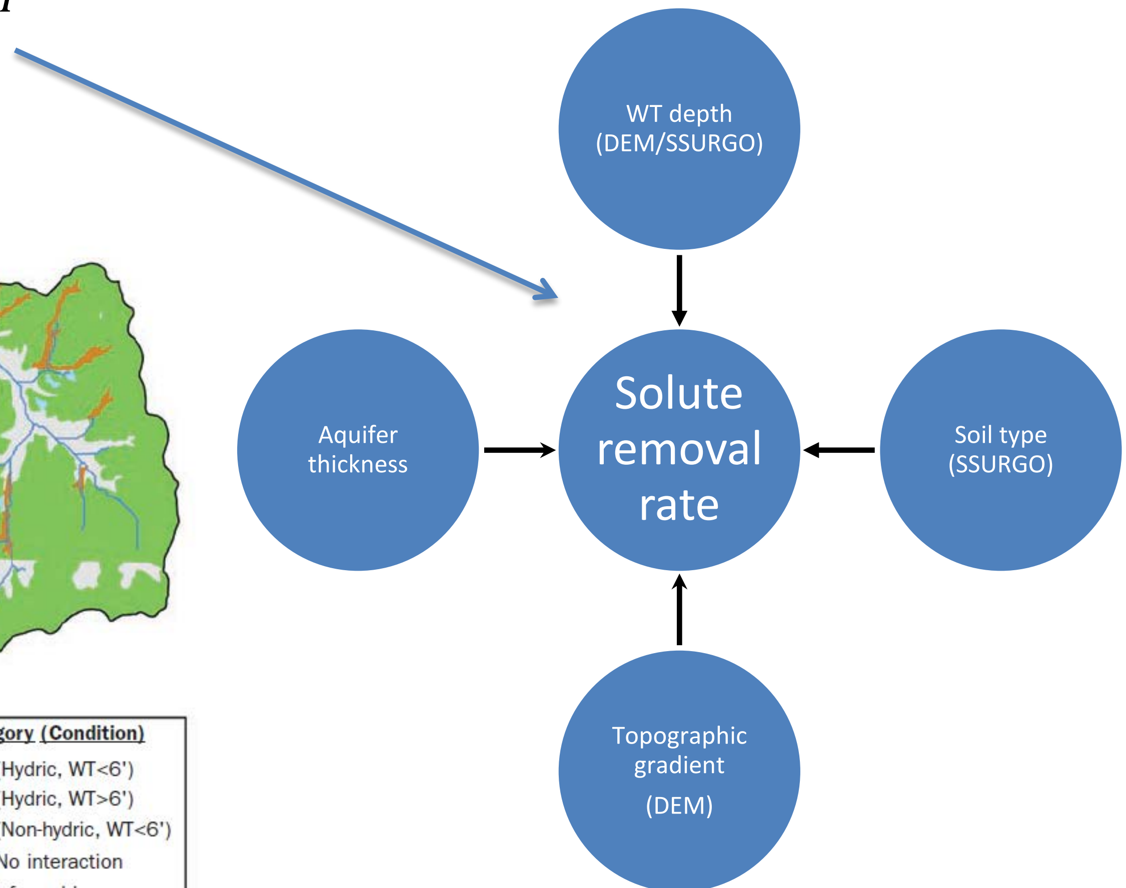
$$\frac{M}{WT^2u} = -2.1\left(\frac{H}{WT}\right)^{0.88}\left(\frac{\alpha}{WT}\right)^{-0.57}(i)^{0.42}(DOC)^{0.31}(NO_3^{\ -})^{1.65}$$

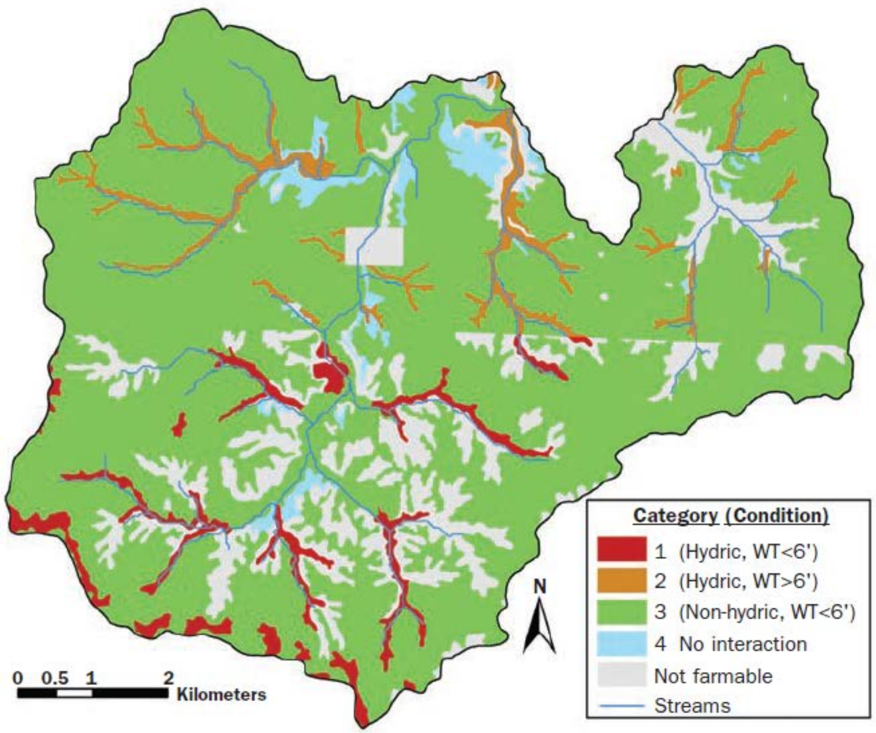


The resulting scaling relationship of the total mass removal rate from dimensional analysis.

Future work: A landscape index for watershed modeling

$$M = -2.1 \times WT^2 u \times \left(\frac{H}{WT}\right)^{0.88}\left(\frac{\alpha}{WT}\right)^{-0.57}(i)^{0.42}(DOC)^{0.31}(NO_3{}^{-})^{1.65}$$





Dosskey et al_2006

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Future work:

Need more testing of the scaling equation against field observations with varying landscape settings.