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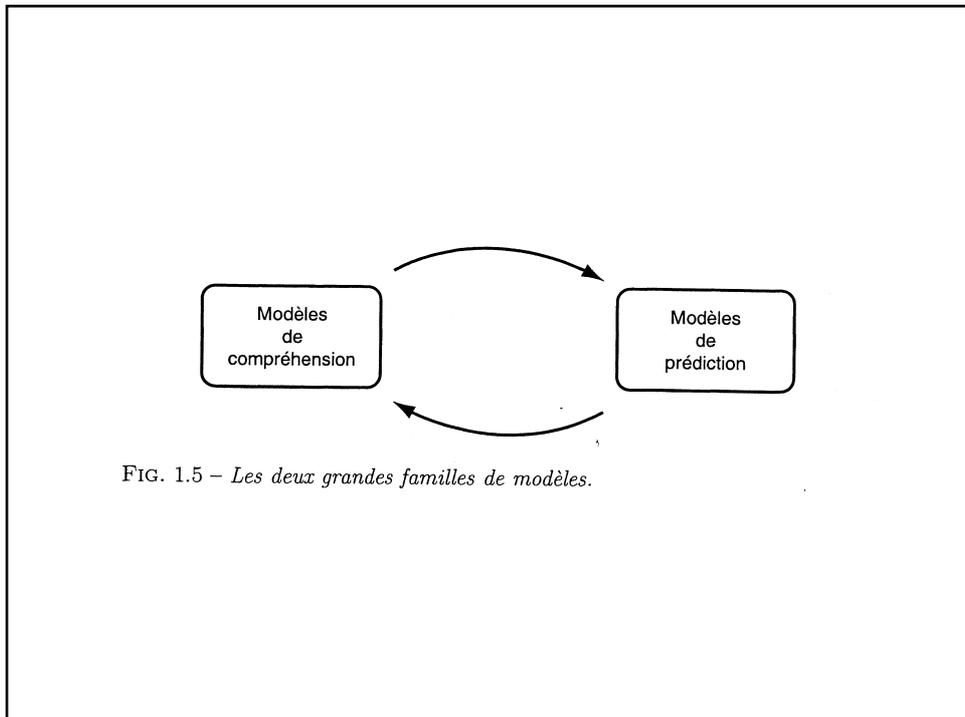


FIG. 1.5 – *Les deux grandes familles de modèles.*

2

## O que é um Modelo?

**Modelo** *s.* Uma descrição esquemática de um sistema, teoria ou fenómeno que contabiliza as suas propriedades conhecidas ou inferidas, e pode ser utilizada para estudos mais aprofundados das suas características.

*-The American Heritage® Dictionary of the English Language: Fourth Edition. 2000.*

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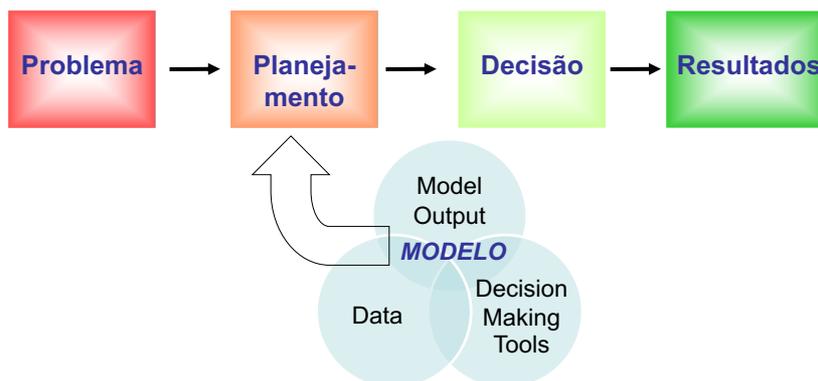
## Porque usamos modelos?



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## Porque usamos modelos?

- Modelo ajuda a responder “E se?”



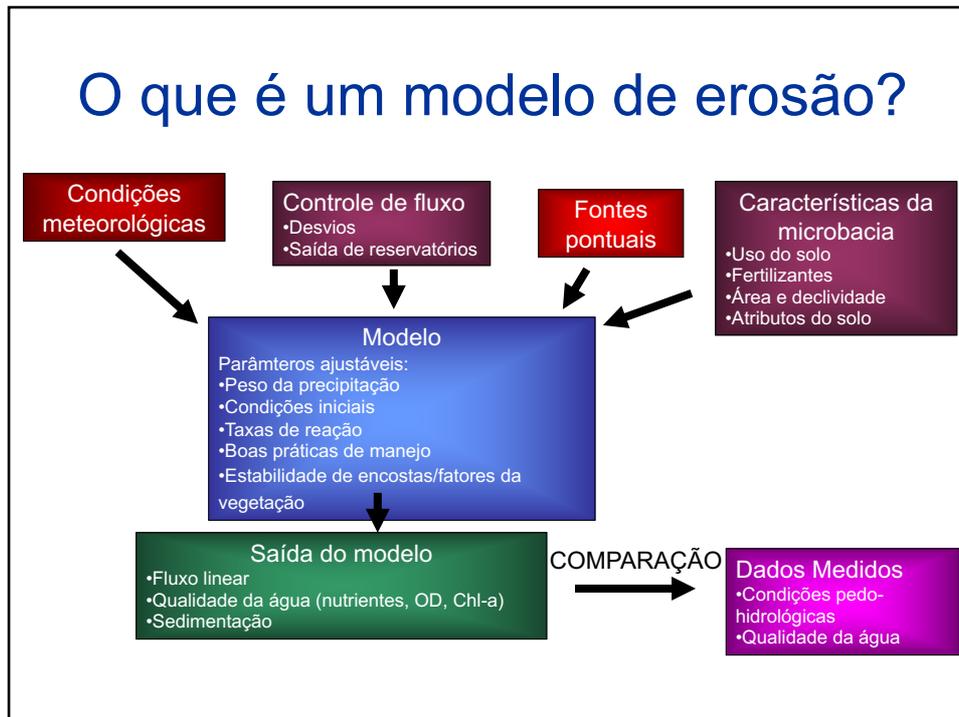
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## Tipos de Modelos de Erosão

- **Avaliação dos Balanços de Massa**
  - Cálculos simplificados, planilhas de cálculo
  - Baixo custo, fácil de implementar, partem de suposições simplificadas
- **Ferramentas baseadas em SIGs**
  - Relacionar modelos de balanço de massa simples a bases de SIG
  - Produzir mapas ressaltando regiões das microbacias de alta sensibilidade
- **Modelos Matemáticos**
  - Ferramentas complexas utilizando equações diferenciais para descrever processos físicos
  - Rigoroso, baseado em processos físicos, fornecem simulações dinâmicas de um sistema

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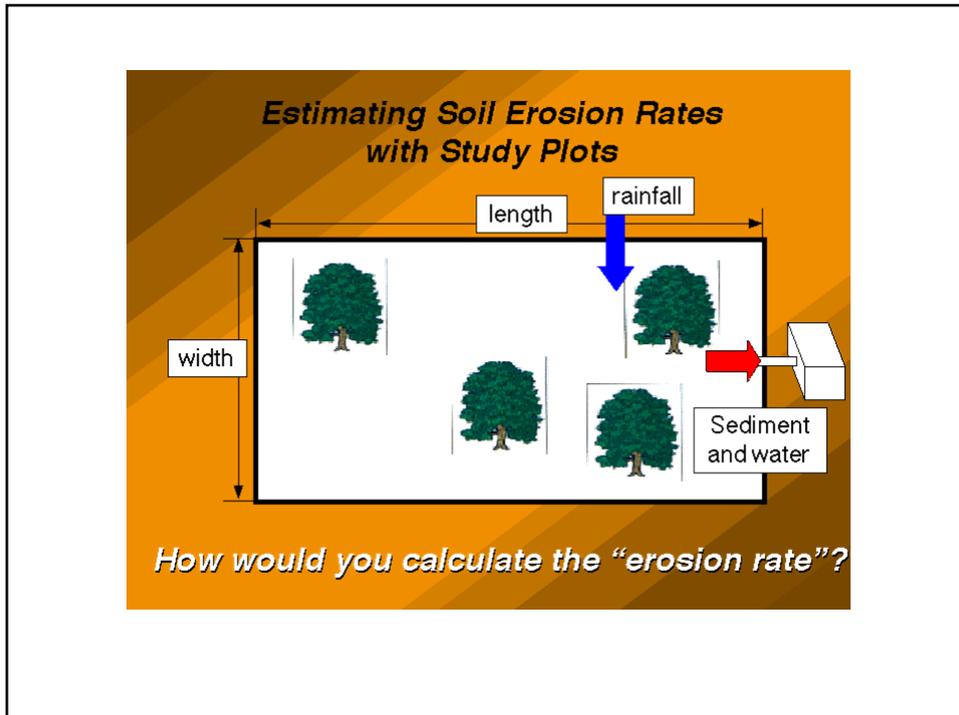
## O que é um modelo de erosão?



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## Quantificando a Erosão do Solo

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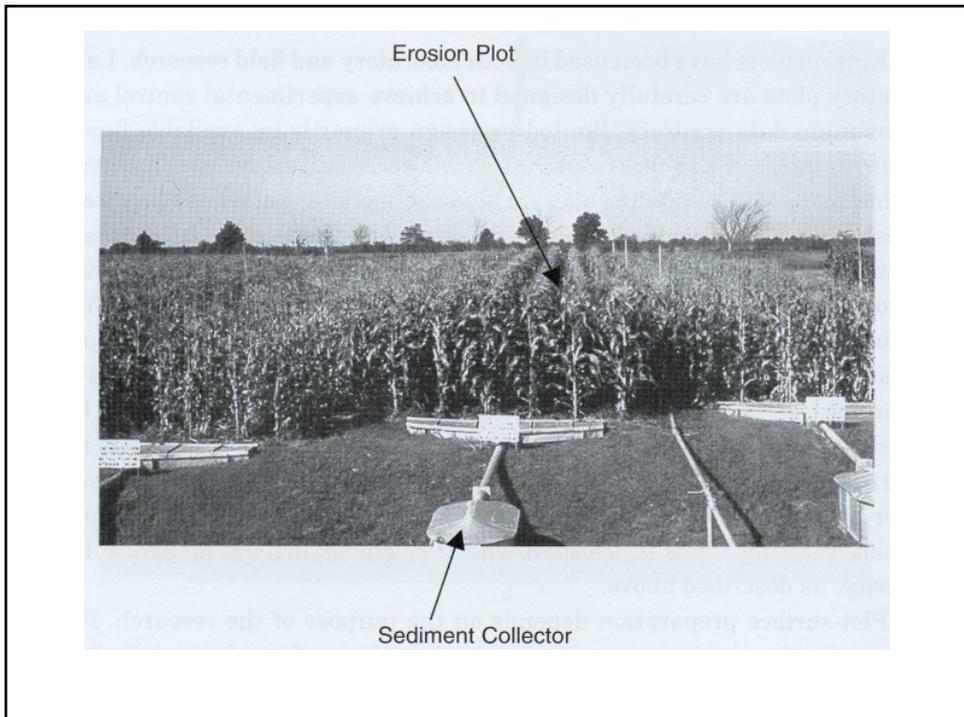
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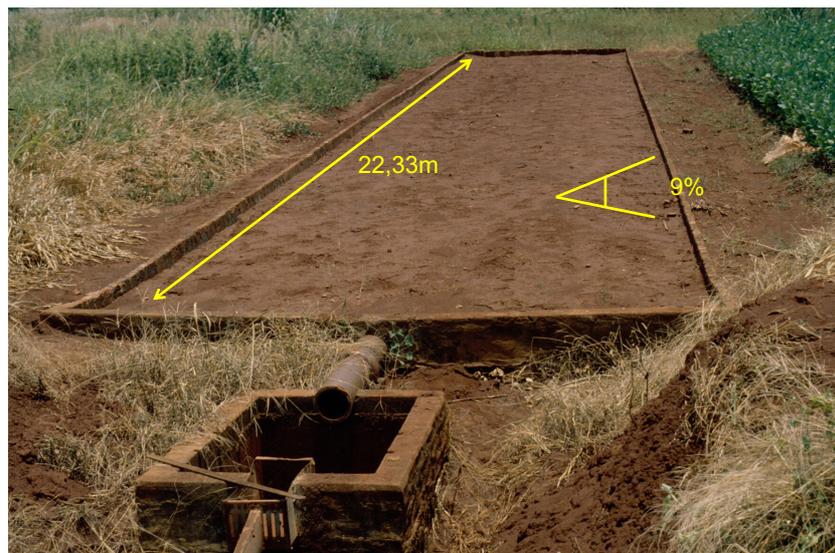
## Canteiro coletor USLE



- Comprimento 22,33m
- Declividade 9%
- Largura 4m.

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## Canteiro coletor USLE (valor padrão)



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# USLE

## Equação Universal de Perda de Solo

- Wischmeier, W.H. and D.D. Smith. 1978. Predicting rainfall erosion losses. USDA Agriculture Handbook 537, U.S. Department of Agriculture.

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- Modelo Empírico:
  - Análise de observações
  - Procura caracterizar respostas destas informações
- Baseado:
  - Padrões de chuva, tipo de solo, topografia, sistema de cultivo e práticas conservacionistas.
- Prediz:
  - Taxas anuais de perda do solo de longo prazo
- Subrotinas em modelos como:
  - SWRRB (Williams, 1975), EPIC (Williams et al., 1980), ANSWERS (Beasley et al., 1980), AGNPS (Young et al., 1989)

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A equação:

$$A = R \times K \times LS \times C \times P$$

- A = perda do solo anual (tons/ha ano)
- R = índice de erosividade
- K = erodibilidade do solo
- L = comprimento de rampa
- S = declividade
- C = fator de cultivo/preparo
- P = fator práticas conservacionistas

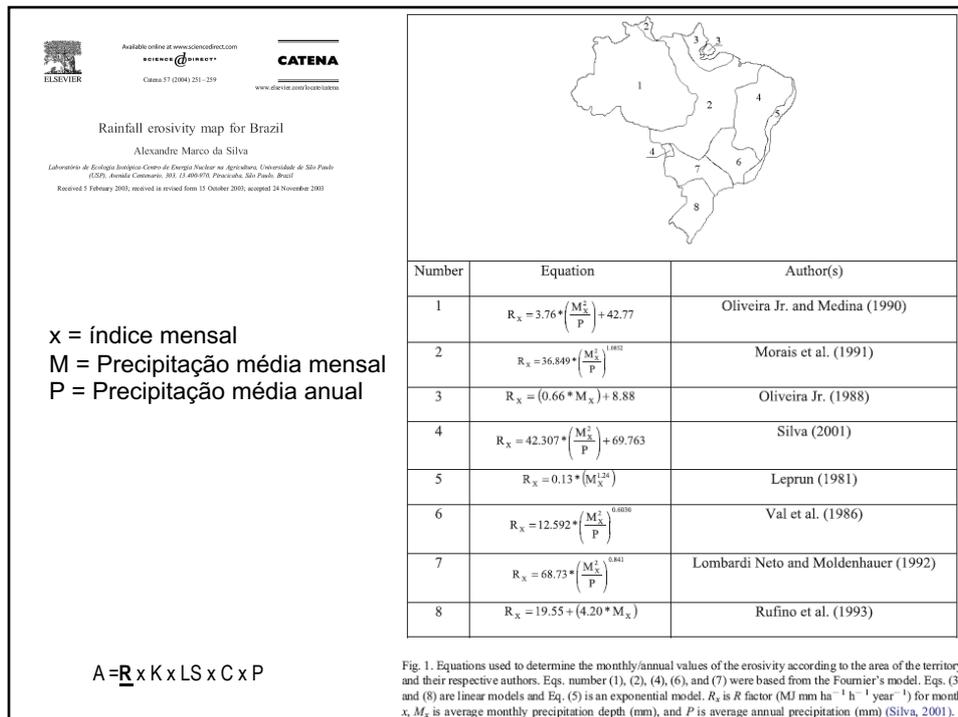
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R (índice de erosividade)

- Índice de erosão (EI) para um evento:
  - Produto da energia cinética das gotas de chuva e a intensidade máxima em 30 minutos.
- Fator  $R = \sum EI$  num ano/100

$$A = R \times K \times LS \times C \times P$$

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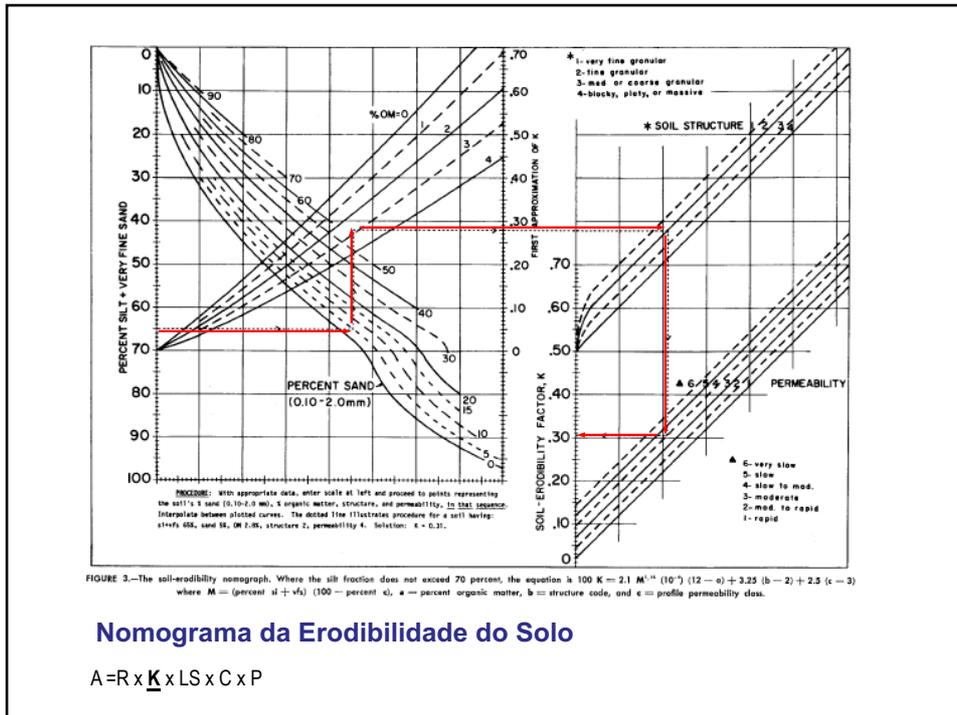
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## K (erodibilidade do solo)

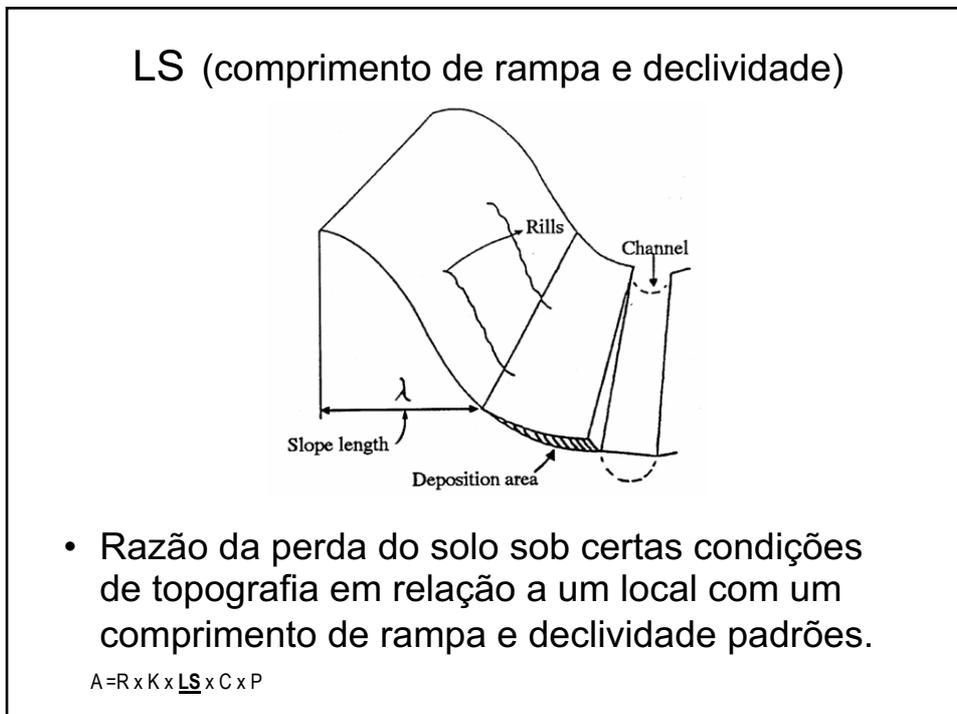
- Susceptibilidade de um solo ao processo erosivo pela água e enxurrada
- Depende de:
  - Textura, estrutura, conteúdo de matéria orgânica, e permeabilidade.

$$A = R \times K \times LS \times C \times P$$

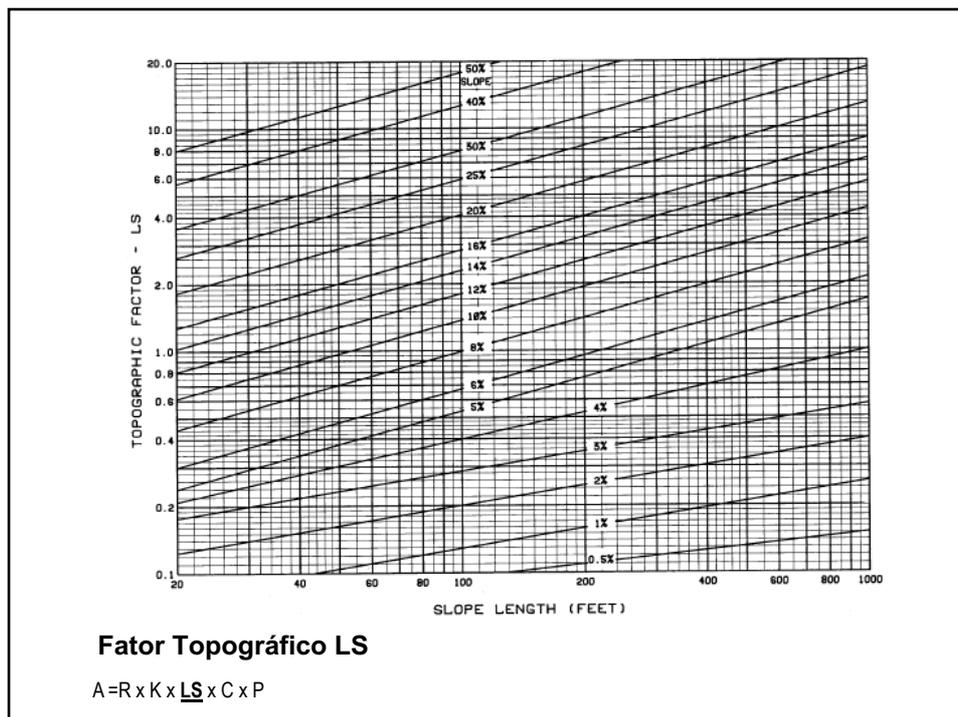
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### C (fator de cultivo/preparo)

- Razão da perda do solo por um uso do solo sob condições específicas em relação à áreas em pousio ou preparo contínuo.

Crop	Fator
Milho grãos	0.40
Milho silagem, Feijão & Canola	0.50
Cereais	0.35
Cultivos hortícolas	0.50
Frutíferas	0.10
Feno e Pastagens	0.02

Preparo	Fator
Aração de outono	1.00
Aração de primavera	0.90
Preparo com mulch	0.60
Preparo em nível	0.35
Preparo em talhões	0.25
Plantio Direto	0.25

$$A = R \times K \times LS \times \underline{C} \times P$$

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### P (práticas conservacionistas)

- Razão da perda do solo de uma prática conservacionista em relação a um preparo morro abaixo.

Prática	Fator P
Morro Abaixo	1.00
Plantio cruzado	0.75
Plantio em nível	0.50
Plantio em faixas, cruzado	0.37
Plantio em faixas, em nível	0.25

$$A = R \times K \times LS \times C \times P$$

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## WEPP Water Erosion Prediction Project

- ☀ Foster, G.R. and L.J. Lane (compilers). 1987. User Requirements. USDA-Water Erosion Prediction Project. NSERL Report #1, USDA-ARS National Soil Erosion Research Laboratory, West Lafayette, IN.

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## Water Erosion Prediction Project (WEPP)

- Desenvolvido em 1987
- Modelo baseado em processos físicos que simula todo o processo de erosão
- Pode prever a distribuição espacial e temporal da perda e deposição líquida do solo

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Process Based Models: Mass balance differential equation

$$\delta(cq)/\delta x + \delta(ch)/\delta t + S = 0$$

c = Sediment concentration (kg/m<sup>3</sup>)  
 q = Runoff discharge (m<sup>2</sup>/s)  
 x = Distance in the direction of flow (m)  
 h = Depth of flow (m)  
 t = Time (s)  
 S = Source/sink term (kg/(m<sup>2</sup>s))

WEPP

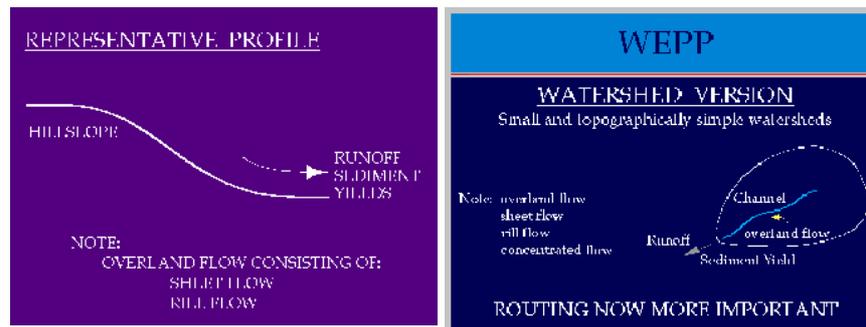
$$dG/dx = Dr + Di$$

G = Sediment load per unit width in the flow (kg/(m s)) = cq  
 Dr = net rill erosion rate per unit area of rill bottom (kg/(m<sup>2</sup> s)) (+ or -)  
 Di = Interrill sediment delivery to rill (kg/(m<sup>2</sup> s))

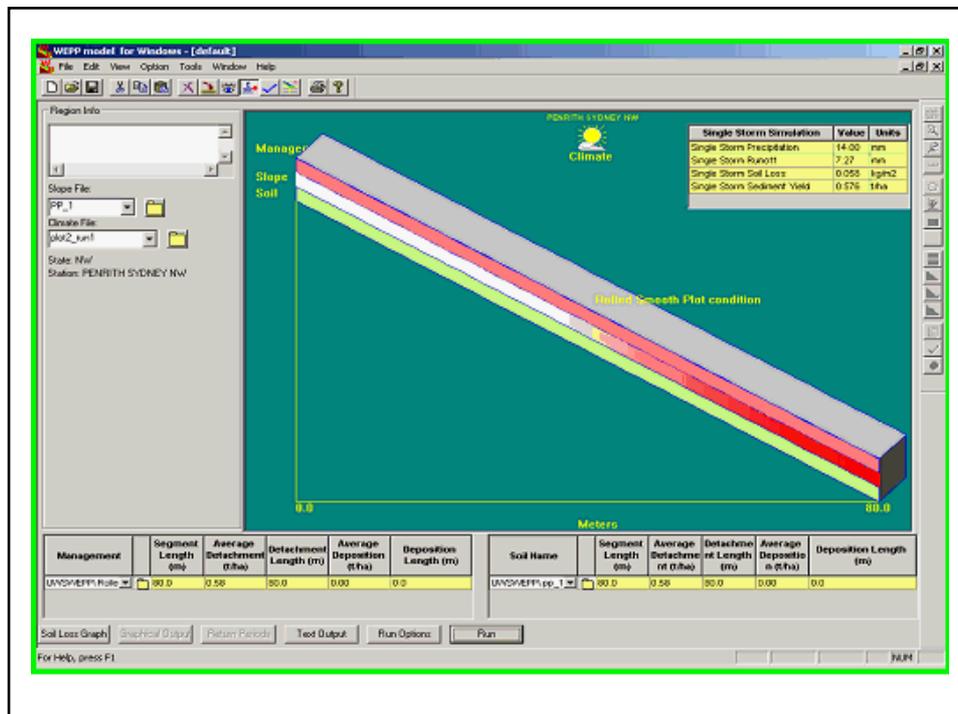
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# Aplicações do modelo WEPP

- Vertente
  - Substituição direta da USLE
  - Pode prever a perda e deposição do solo numa vertente
- Microbacia hidrográfica
  - Desprendimento, transporte e deposição de sedimentos em sistemas fluviais e na vertente



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**Table 9.1.** Comparison of the main model characteristics

Erosion model	Event based	Empirical equation for simulating erosion	Interface to Arc/Info	Simulation of transport, deposition, etc.	Required input data	Maximum number of grid cells	User friendliness
USLE	No	Yes	No	No	+	n.i.	Yes
RUSLE/MUSLE	Yes	Yes	No	No	+	n.i.	Yes
EPIC	No	Yes	No	No	+++	n.i.	No
AGNPS	Yes	Yes	Yes	Yes	++	1 900	Yes
CREAMS	No	Yes	No	Yes	++	n.i.	No
GLEAMS	No	Yes	No	Yes	++	n.i.	No
ANSWERS	Yes	No	No	Yes	++	1 700	Yes
EROSION-2D/3D	Yes	No	Yes	Yes	++	50 000	Yes
KINEROS	Yes	N.I.	No	Yes	+++	n.i.	No
OPUS	Yes	No	No	Yes	+++	n.i.	No
SPUR I/II	Yes	Yes	No	No	+++	n.i.	No
WEPP	Yes	No	Yes	Yes	+++	n.i.	No
EUROSEM	Yes	No	Yes	Yes	+++	n.i.	No

n.i. No information;  
 + Few;  
 ++ Moderate;  
 +++ Many.

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## Modelagem de erosão:

Der Tropenlandwirt, Beiträge zur tropischen Landwirtschaft und Veterinärmedizin,  
 101. Jahrgang, Oktober 2000, S. 107 - 118.

### Comparison of Three Water Erosion Prediction Methods ( $^{137}\text{Cs}$ , WEPP, USLE) in South-East Brazilian Sugarcane Production

G. Sparovek<sup>1</sup>, O.O.S. Bacchi<sup>2</sup>, E. Schnug<sup>3</sup>, S.B.L. Ranieri<sup>4</sup> and I.C. De Maria<sup>5\*\*</sup>

Key words: Erosion prediction,  $^{137}\text{Cs}$ , WEPP, USLE, sugarcane, Brazil.



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Computers & Geosciences 31 (2005) 1270-1276

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Erosion database interface (EDI): a computer program for georeferenced application of erosion prediction models  
 Simone Beatriz Lima Ranieri<sup>6</sup>, Quijrin de Jong van Lier<sup>6\*</sup>, Gerd Sparovek<sup>6</sup>,  
 Dennis C. Flanagan<sup>7</sup>

<sup>6</sup>University of São Paulo, CP 9, 13418-900, Piracicaba (SP), Brazil  
<sup>7</sup>USDA-Agricultural Research Service, National Soil Erosion Research Laboratory, 1100 Building Soil, West Lafayette, IN 47907-1196, USA

Received 3 August 2000; received in revised form 19 April 2001; accepted 12 July 2001

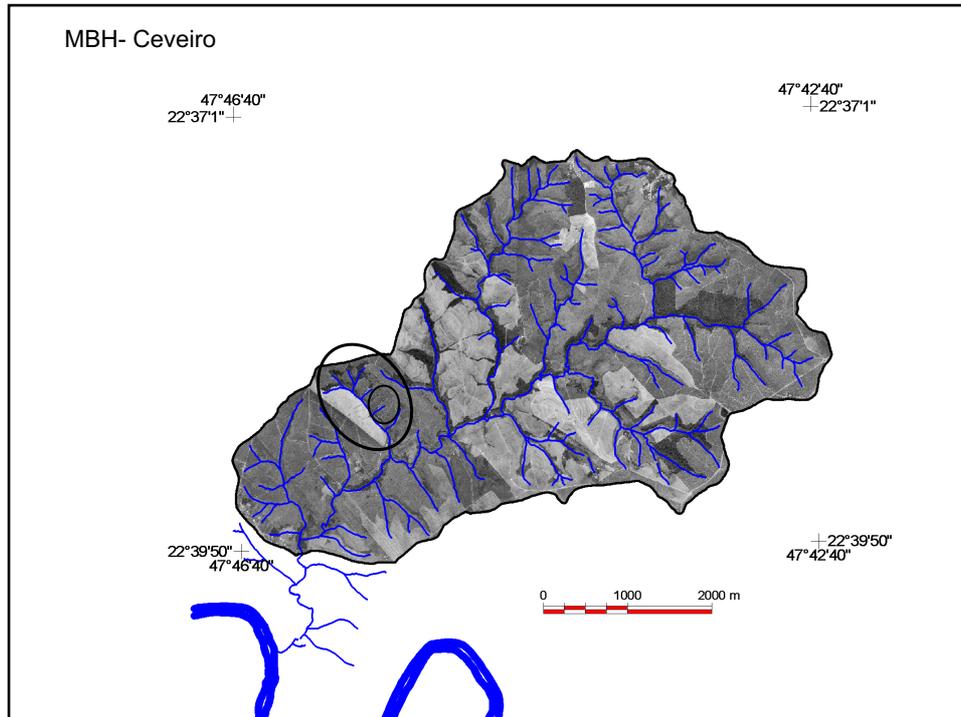
Short note  
 Runoff mapping using WEPP erosion model and GIS tools

Quijrin de Jong van Lier<sup>6\*</sup>, Gerd Sparovek<sup>6</sup>, Dennis C. Flanagan<sup>7</sup>,  
 Elke M. Bloem<sup>8</sup>, Ewald Schnug<sup>9</sup>

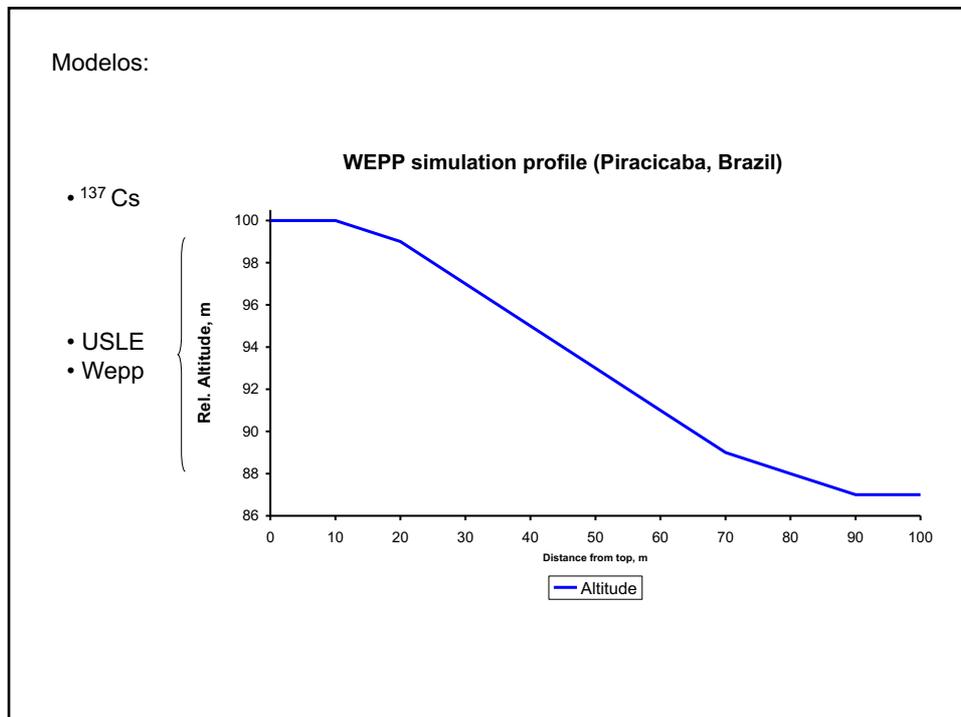
<sup>6</sup>University of São Paulo, CP 9, 13418-900, Piracicaba (SP), Brazil  
<sup>8</sup>USDA-Agricultural Research Service, National Soil Erosion Research Laboratory, 275 S. Russell Street, West Lafayette, IN 47907, USA  
<sup>9</sup>Institute of Plant Nutrition and Soil Science, Federal Agricultural Research Center (FAL), Bundesallee 50, D-38116, Braunschweig, Germany

Received 15 September 2003; received in revised form 22 March 2005; accepted 22 March 2005

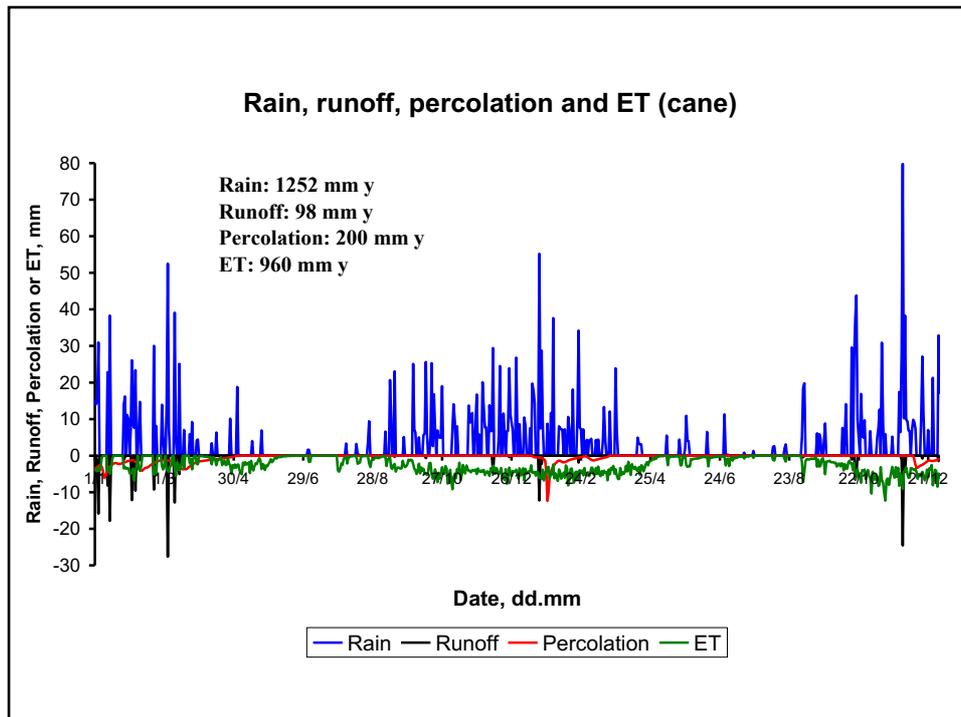
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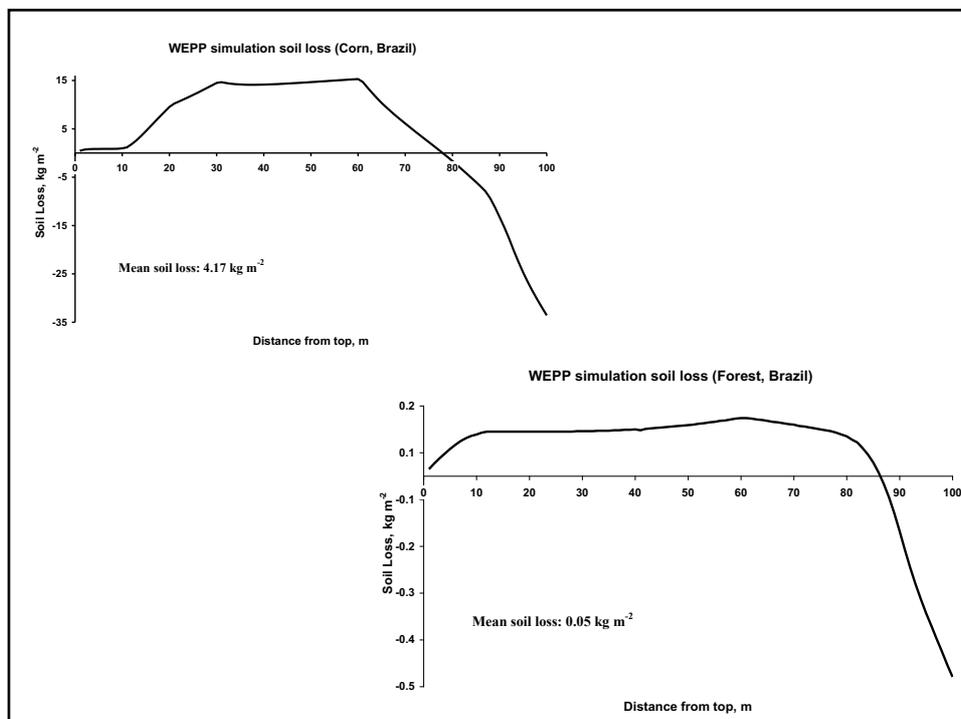
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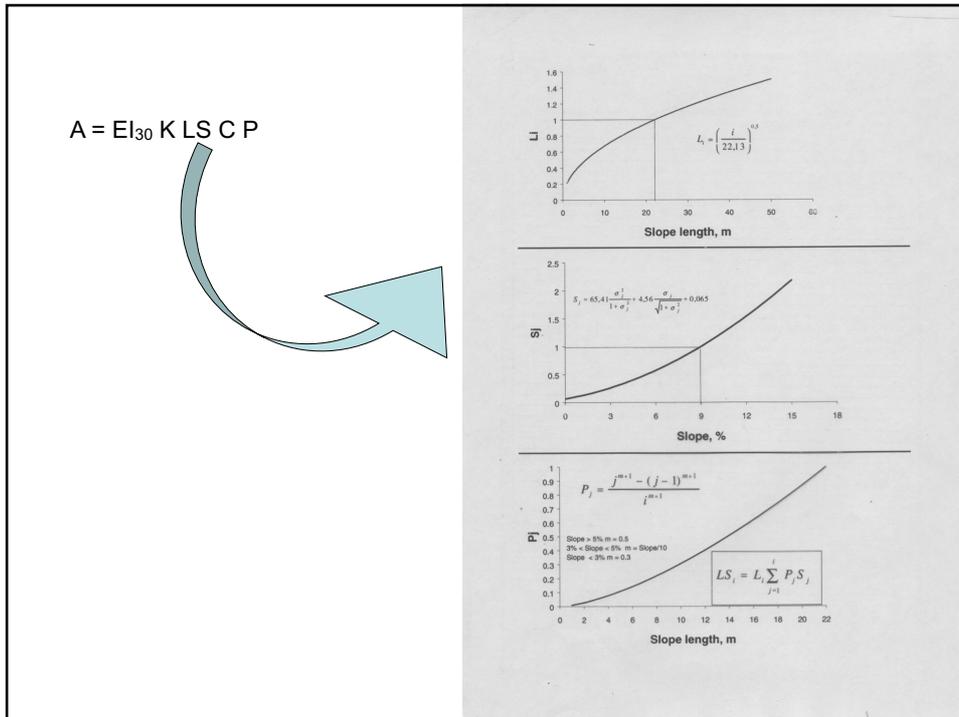
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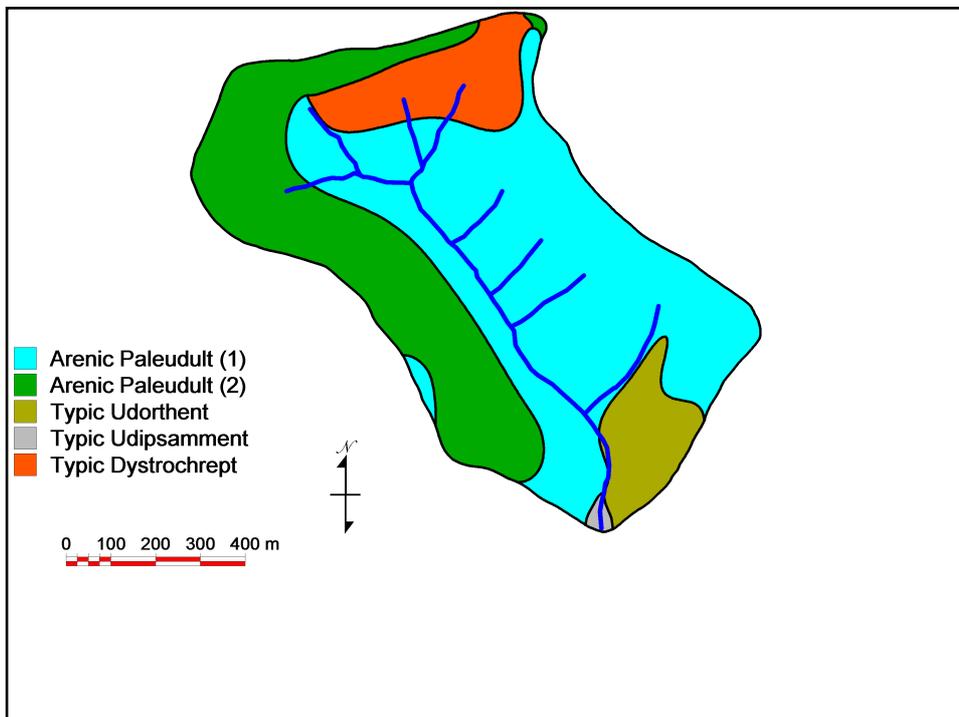
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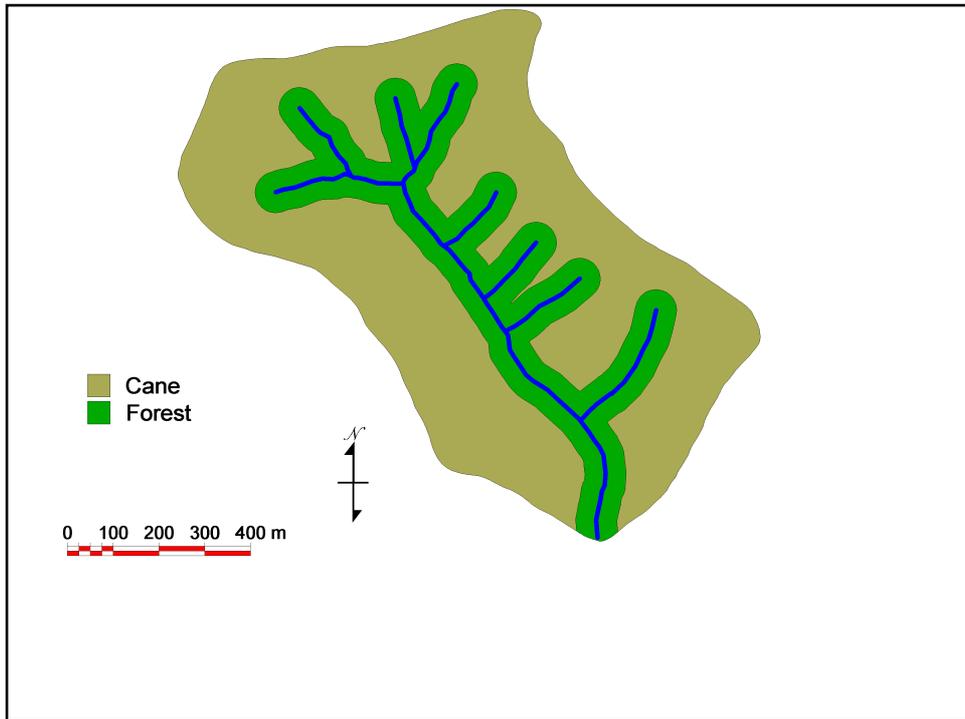
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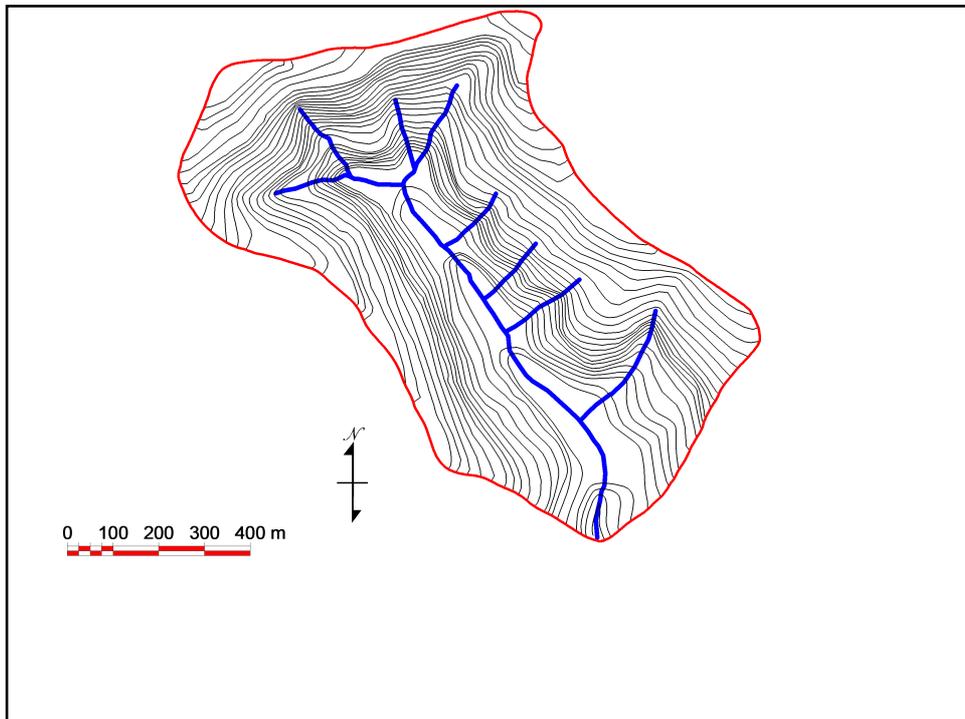
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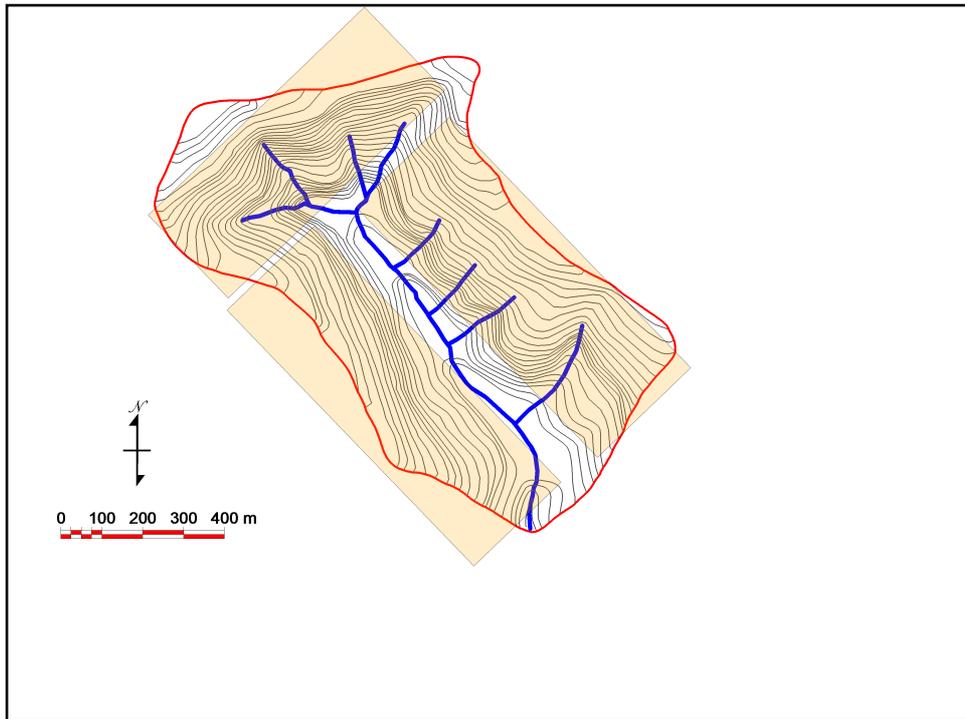
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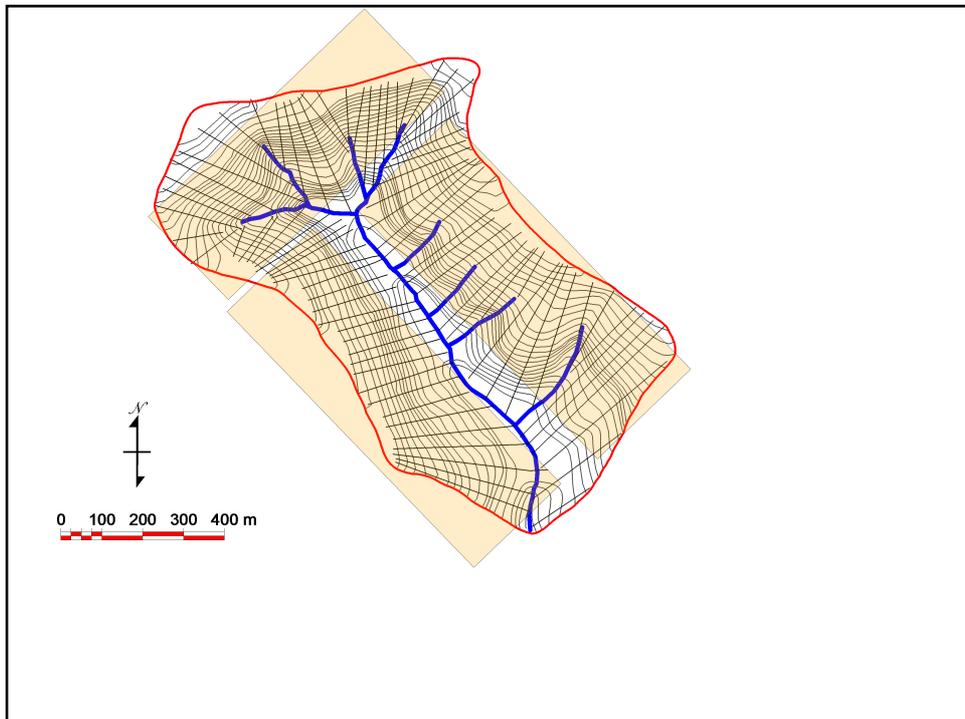
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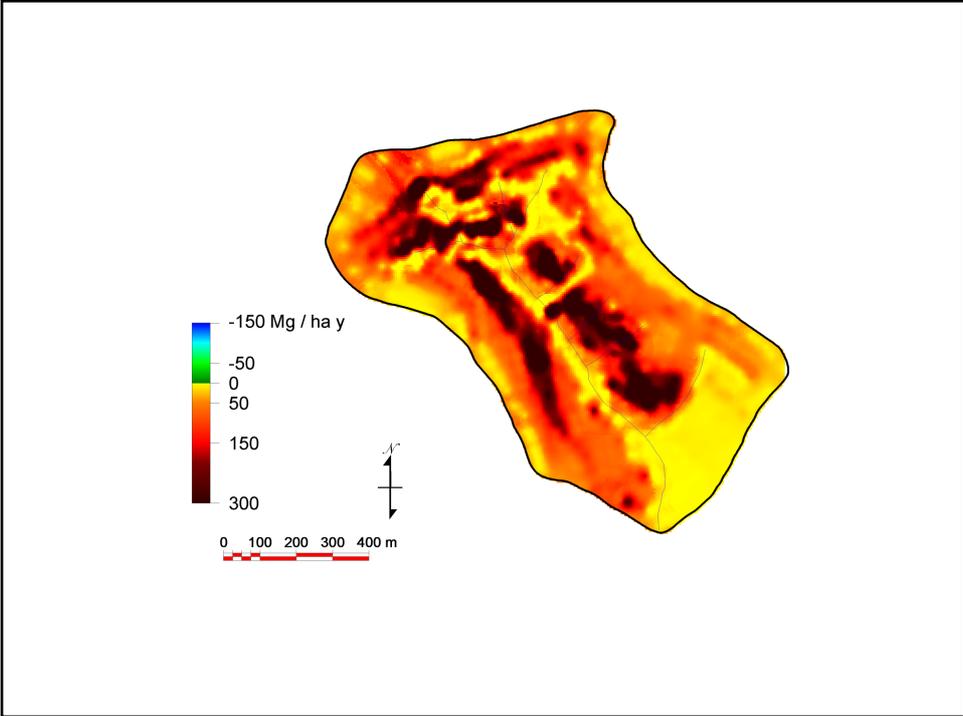
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Table 1  
 Example of input text format database file used for erosion calculations by EDI for WEPP and USLE in Ceuveiro watershed for hillslopes 1 and 2 from a total of 84 hillslopes

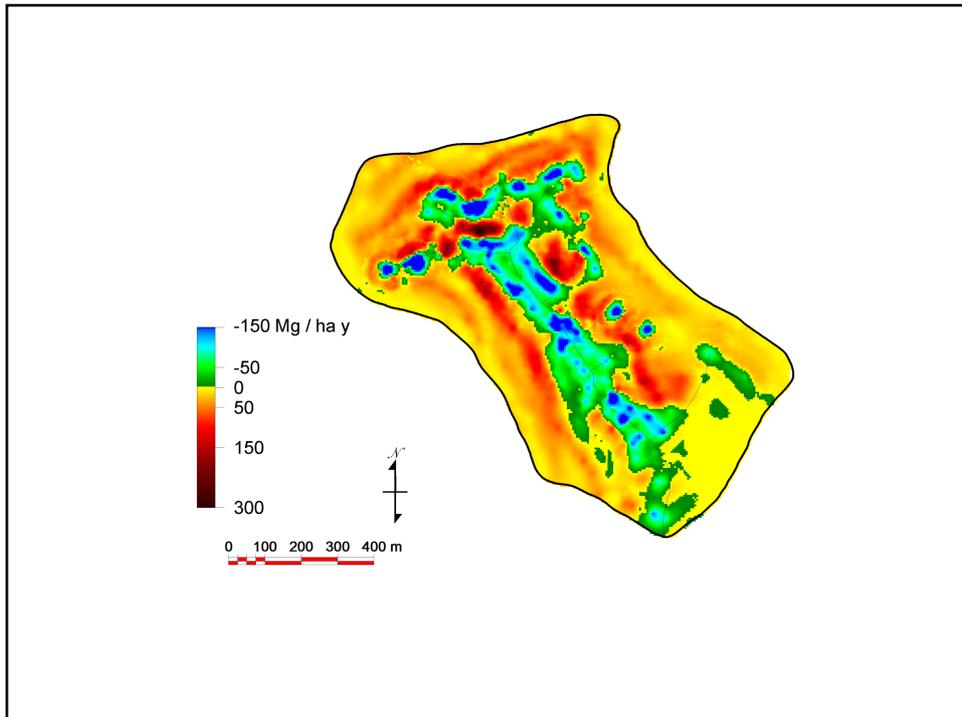
X <sup>a</sup>	Y <sup>b</sup>	Z <sup>c</sup>	Soil <sup>d</sup>	Land use <sup>e</sup>	Hillslope <sup>f</sup>
215972.14	7492357.91	500	5	1	1
215990.84	7492351.37	498	5	1	1
216012.30	7492343.87	496	5	1	1
216036.98	7492335.24	494	5	1	1
216064.13	7492325.75	492	5	1	1
216093.04	7492315.65	490	5	1	1
216109.58	7492309.86	488	5	1	1
216125.73	7492304.22	486	5	1	1
216145.52	7492297.30	484	3	1	1
216168.09	7492289.41	482	3	1	1
216188.68	7492282.21	480	3	1	1
216196.28	7492279.56	478	3	1	1
216204.46	7492276.70	476	3	1	1
216218.54	7492271.77	474	3	1	1
216236.58	7492265.47	472	3	1	1
216253.16	7492259.67	470	3	1	1
216263.90	7492255.92	468	3	1	1
216274.53	7492252.20	466	3	1	1
216288.76	7492247.23	464	23	1	1
215972.28	7492367.25	500	5	1	2
215992.31	7492362.44	498	5	1	2
216010.06	7492358.18	496	5	1	2
216033.34	7492352.59	494	5	1	2
216061.82	7492345.76	492	5	1	2
216091.39	7492338.66	490	5	1	2
216108.31	7492334.60	488	5	1	2
216123.42	7492330.97	486	5	1	2
216143.98	7492326.04	484	5	1	2
216169.89	7492319.82	482	3	1	2
216191.85	7492314.55	480	3	1	2
216204.36	7492311.55	478	3	1	2
216215.97	7492308.76	476	3	1	2
216229.35	7492305.55	474	3	1	2
216249.48	7492300.72	472	3	1	2
216268.06	7492296.26	470	3	1	2
216279.50	7492293.51	468	3	1	2
216291.42	7492290.65	466	3	1	2

<sup>a</sup>Easting in Universal Transverse Mercator (UTM) coordinates (zone 23S, ellipsoid IUGG 1967, datum South American 1969 Brazil).  
<sup>b</sup>Northing in UTM coordinates.  
<sup>c</sup>Altitude (BSL) in metric units extracted from the digital contour line map from the Ceuveiro watershed.  
<sup>d</sup>Soil type, where 3—Arenic Paleudult; 5—Typic Dystrochrept and 23—Typic Udorthent.  
<sup>e</sup>Land use, where 1—sugarcane.  
<sup>f</sup>Hillslope number.

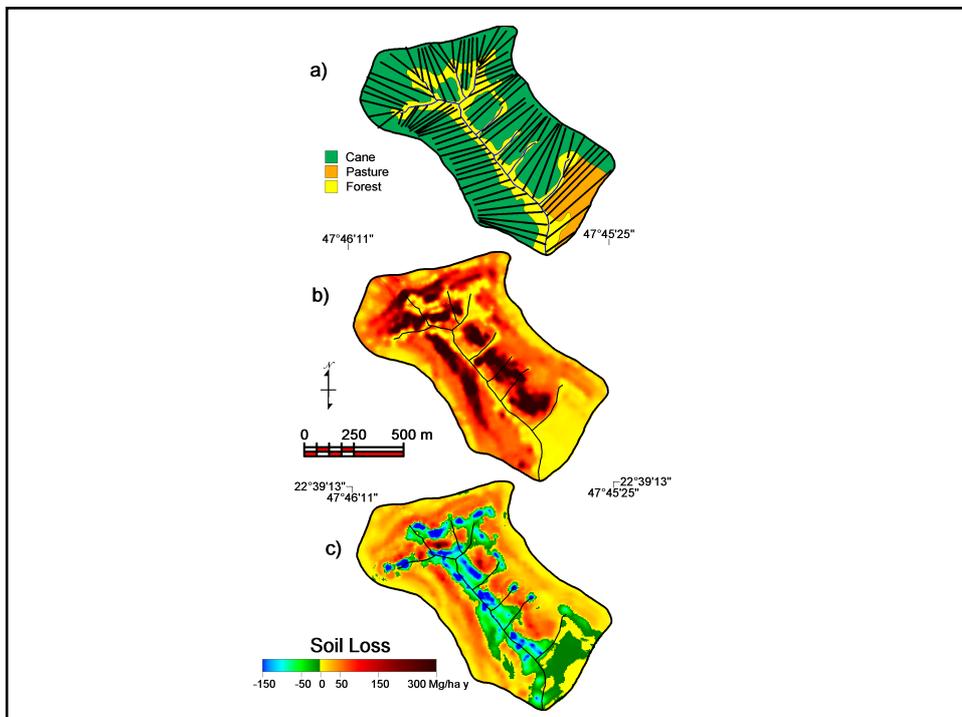
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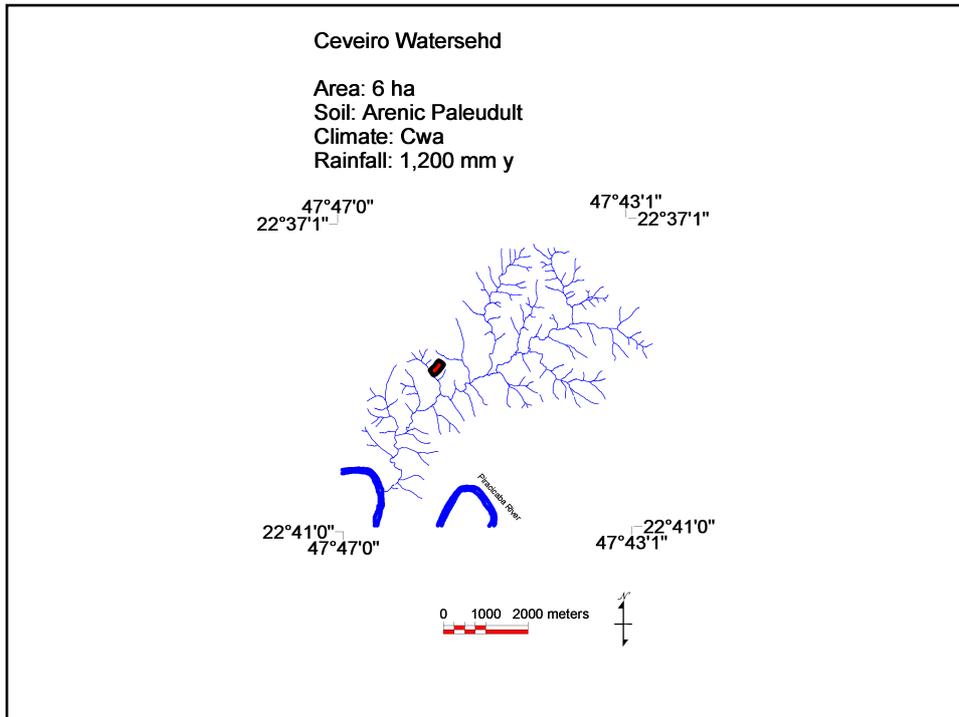
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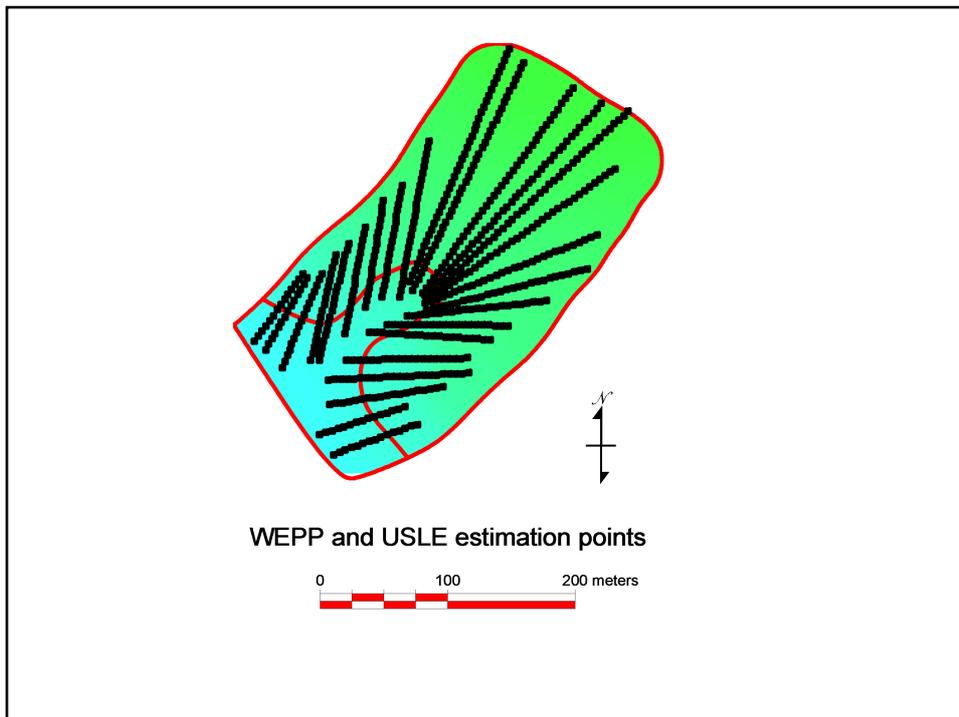
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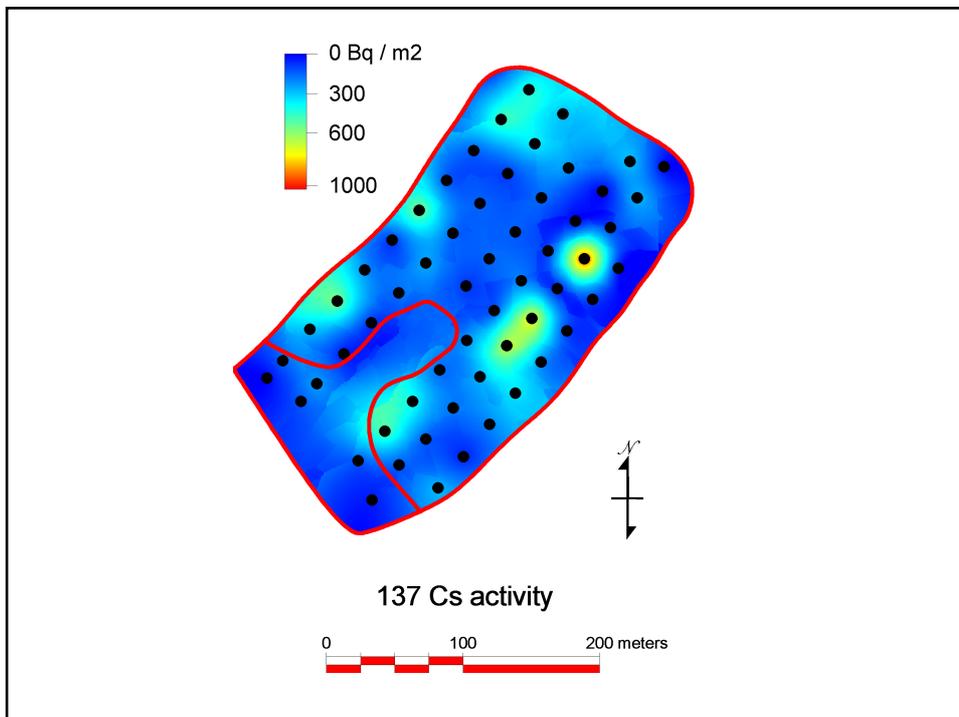
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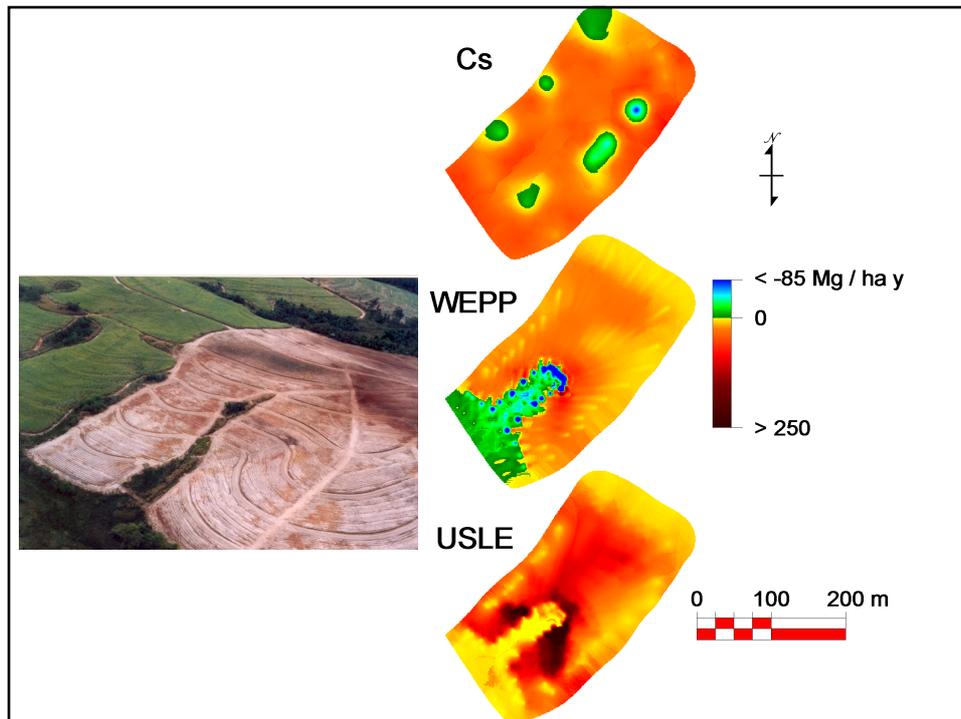
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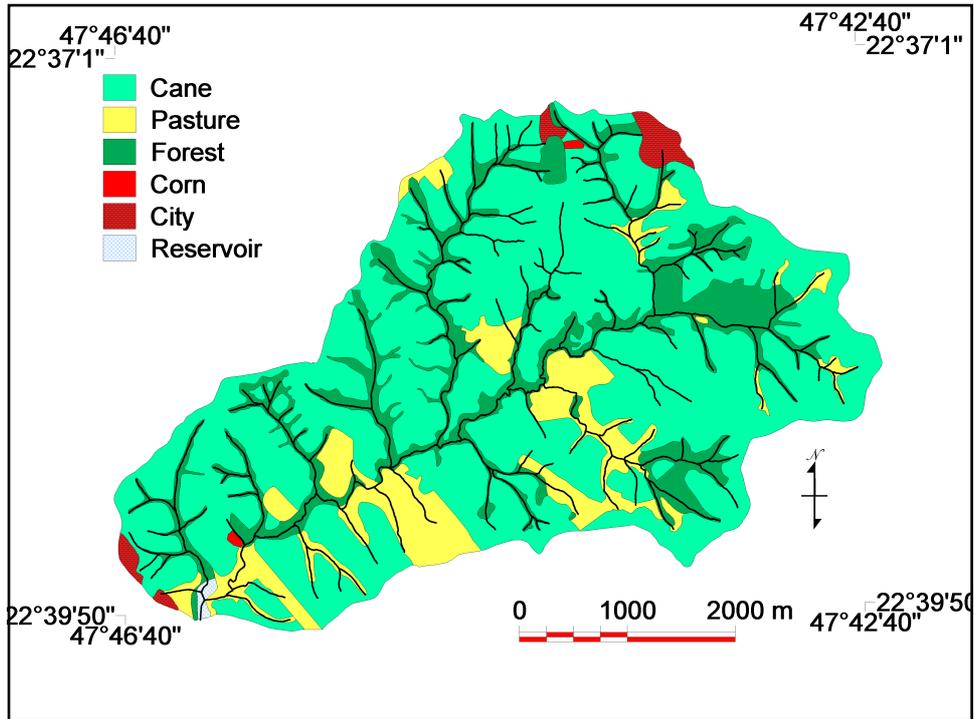
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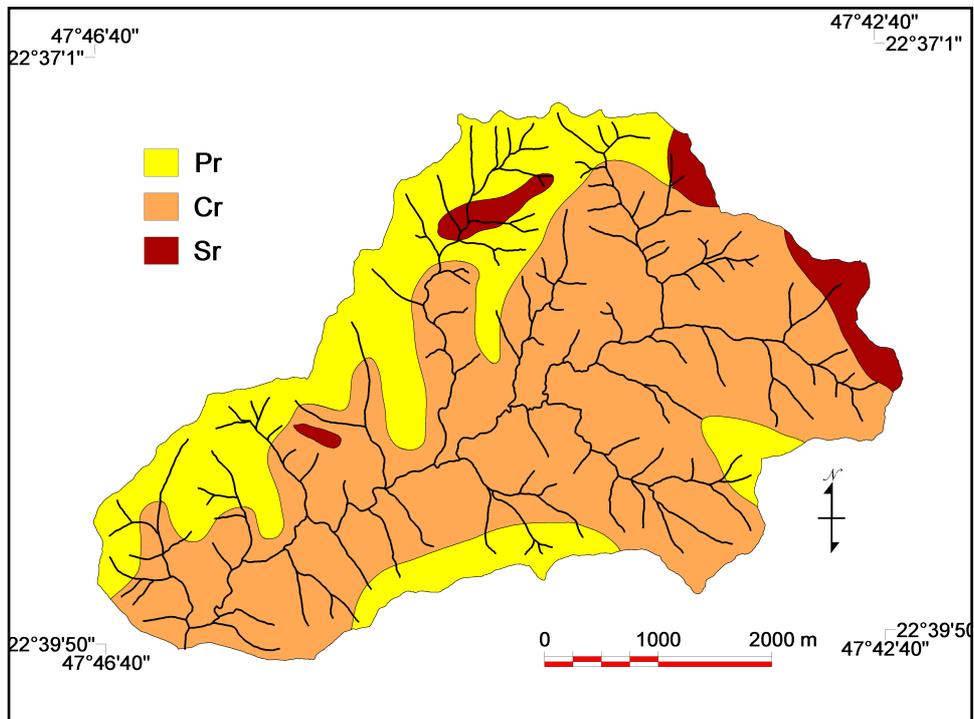
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Order	X	Y	Soil Loss	Runoff
1	218623.1	7495027.6	0.23	17.492
2	218635.2	7495044.9	0.3	18.818
3	218558	7495297.7	0.51	21.247
4	218605	7495182.1	0.79	23.84
5	217093.8	7494673.1	0.87	24.974
6	215438.6	7492096.5	0.91	26.288
7	215386.1	7492204	0.91	26.356
8	218514.1	7495278.6	0.71	27.538
9	218612.8	7495043.8	0.67	27.743
10	215342.7	7492603.4	1.98	32.247
11	217410.8	7494984.7	1.27	34.976
12	217025	7494528.7	2.82	35.833
13	215332.3	7492605.9	2.43	37.158
14	217566.4	7495122.6	1.34	37.971
15	218536.2	7494999	1.48	38.893
16	215366.3	7492602.6	2.47	39.092
17	215363.5	7493013.2	2.83	39.238
18	217018.1	7494509.3	2.95	40.162
19	217024.7	7494524.6	3.14	40.885
20	215353.5	7492601.7	1.92	41.606
21	215375.6	7493012.4	3.24	41.735
22	215380.6	7492605.5	3.15	42.471
23	215973.5	7492327.9	2.92	42.821

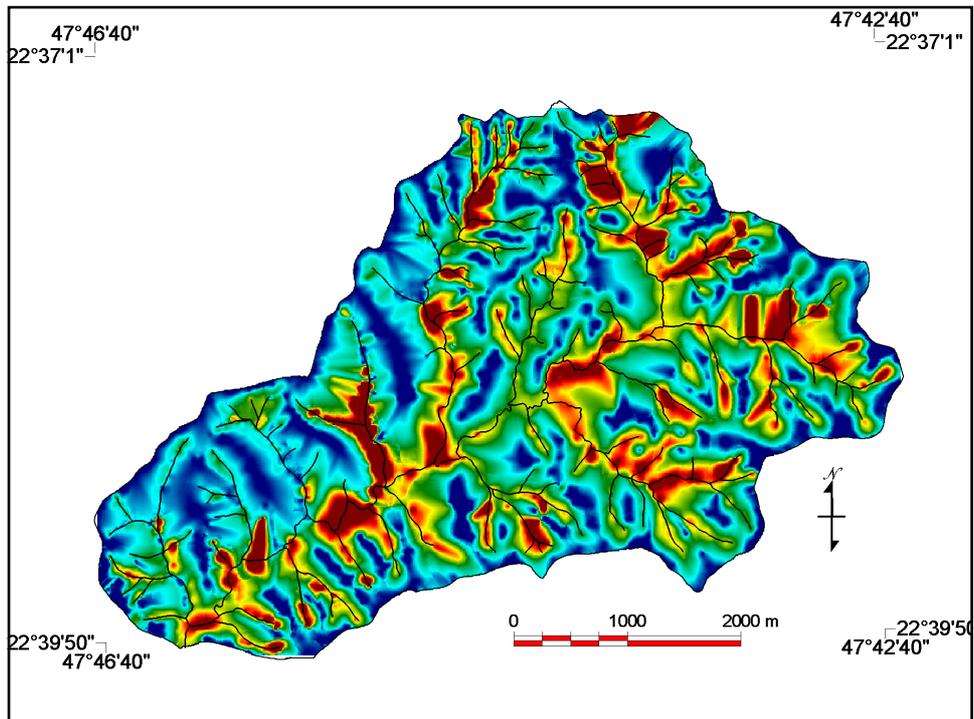
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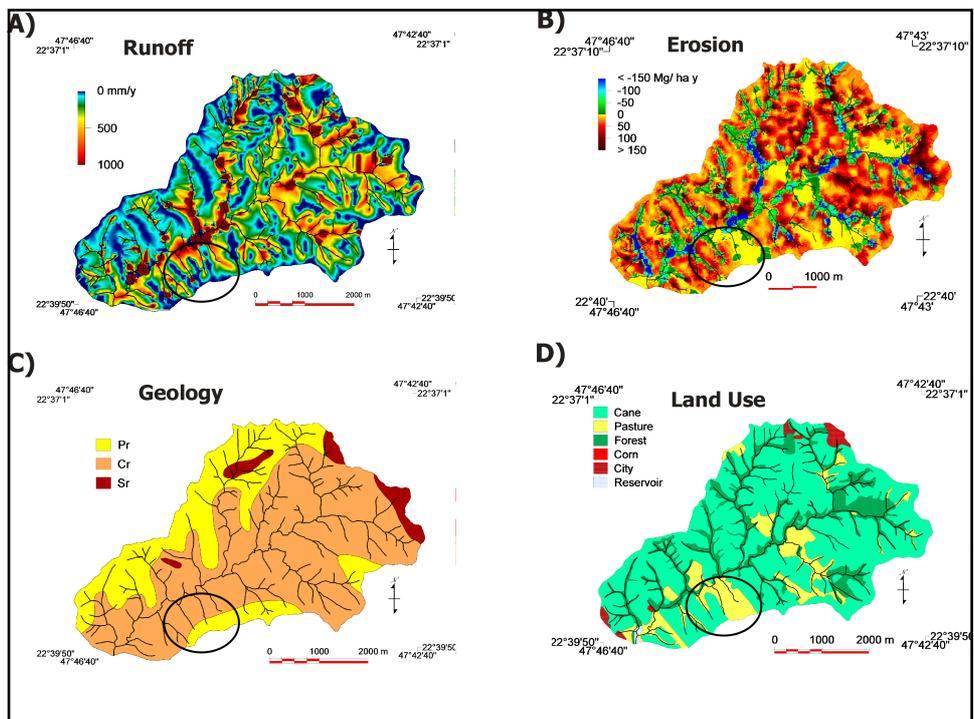
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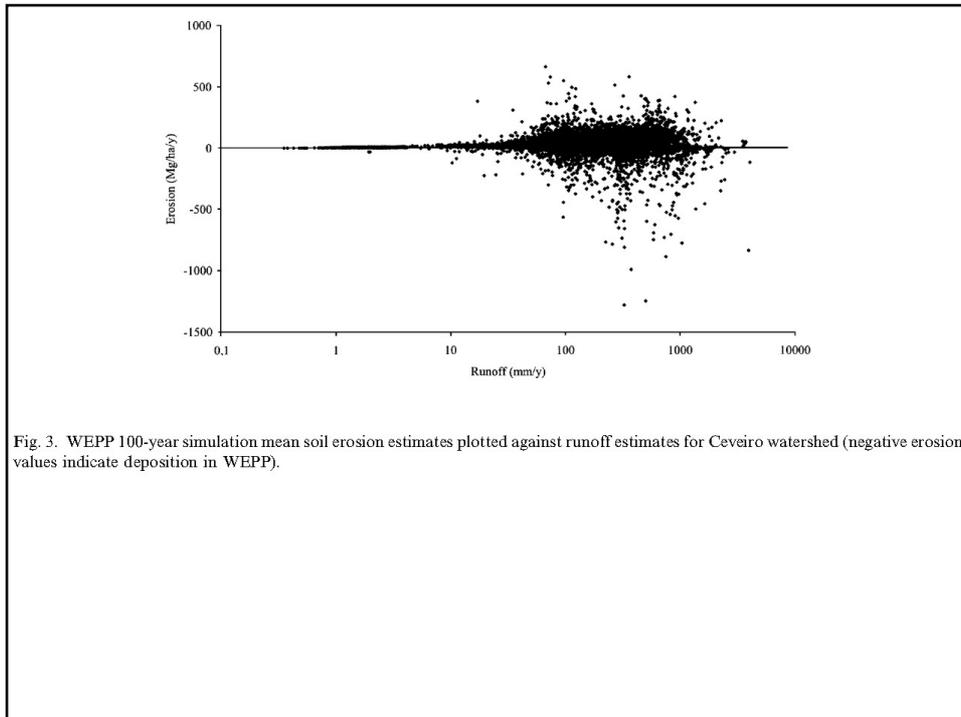


Fig. 3. WEPP 100-year simulation mean soil erosion estimates plotted against runoff estimates for Ceviro watershed (negative erosion values indicate deposition in WEPP).