EUROSEM (2008)
A re-engineered
and restructured software tool for soil erosion scenario analysis and sediment connectivity assessment

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Aims of this presentation

• To Present the new restructured version (2008) of EUROSEM soil erosion model and the works in progress on it, started in he 2004.

• To present the changes made with respect to previous version, and the reasons of these changes

• To Discuss the integration of the Flow Connectivity Approach (FCA) with EUROSEM model For upscaling EUROSEM results to large catchment

• And our plan to distribute freeware, for the scientific community , the EUROSEM future versions

What is EUROSEM

The European Soil Erosion Model (EUROSEM) is a dynamic distributed model, able to **simulate sediment transport, erosion and deposition** by rill and interill processes in single storms for both individual fields and small catchments.
Model **output includes total runoff, total soil loss, the storm hydrograph and storm sediment graph**.

EUROSEM describes the terrain using **cascading planes and channels**, is distributed and physically based. Its hydraulics, despite being **limited to hortonian overland flows**, is based on good mathematics and numerical approximations.
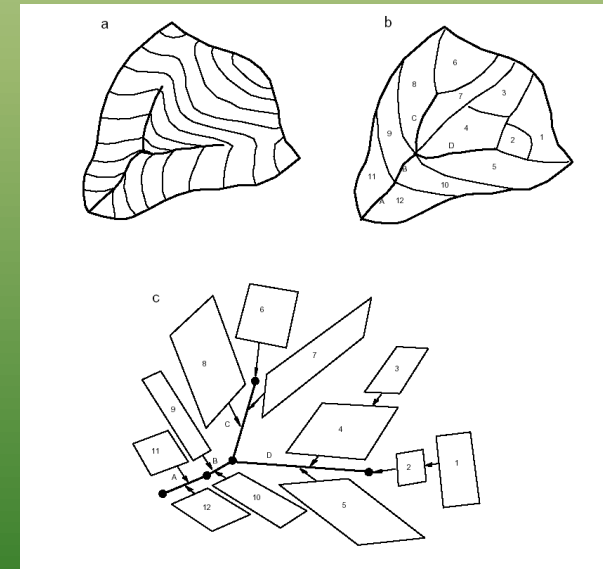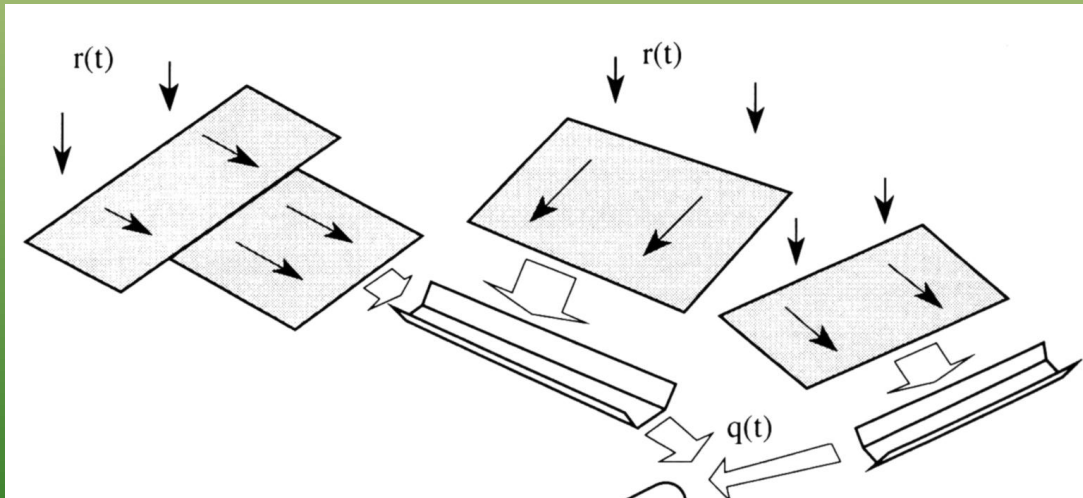
EUROSEM has been developed with Financial support from Directorate General XII and VI of the Commission of the European Communities in the period 1986-2001)

Why EUROSEM ?

The following objectives were set as requirements for an European soil erosion model (Chisci and Morgan, 1988). It should:
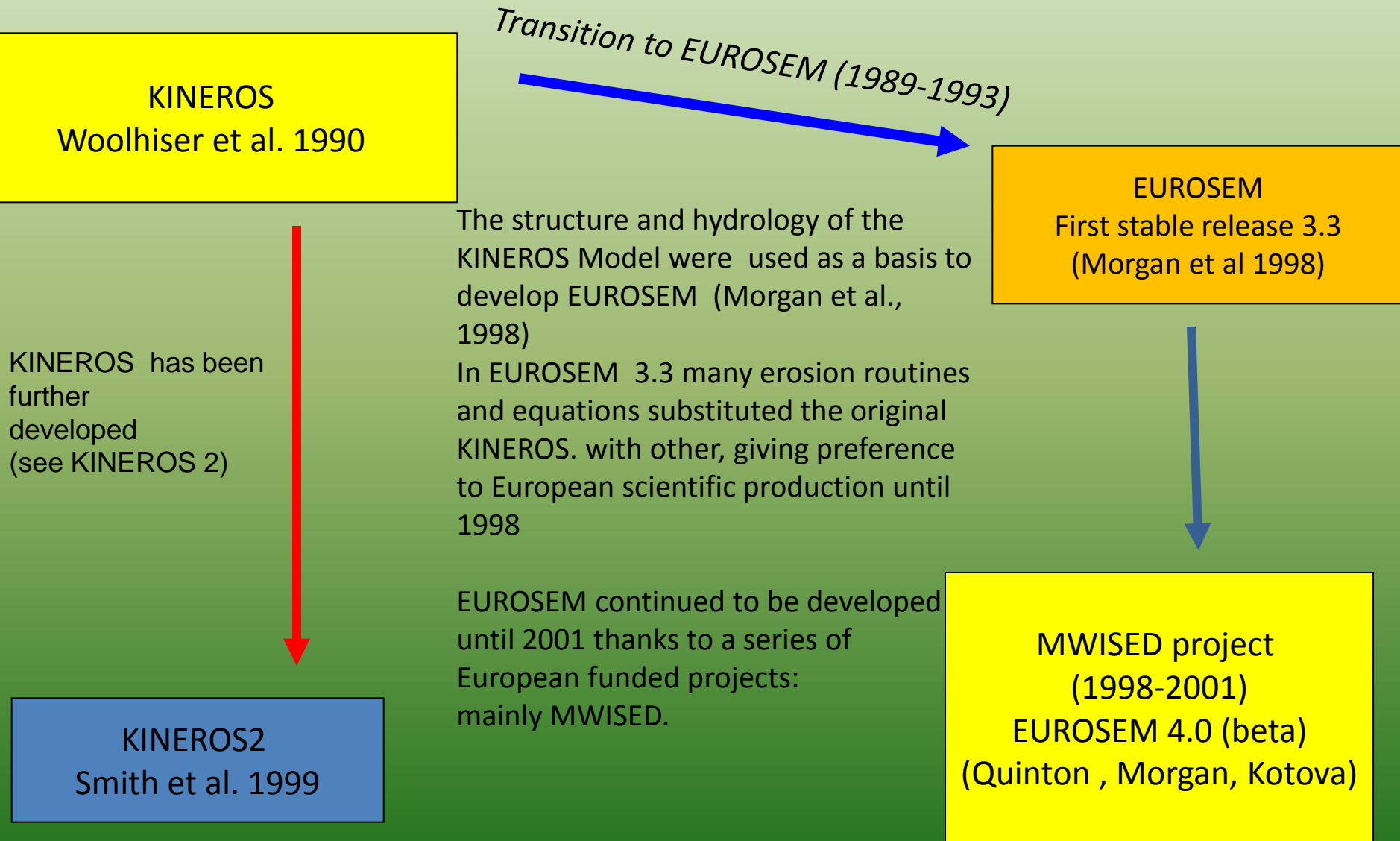
(1) enable the risk of erosion to be assessed;
(2) be applicable to fields and small catchments;
(3) operate on an event basis;

And

(4) be useful as a tool for selecting soil protection measures.

A short hystory of EUROSEM

KINEROS
Woolhiser et al. 1990

Transition to EUROSEM (1989-1993)

EUROSEM
First stable release 3.3
(Morgan et al 1998)

The structure and hydrology of the KINEROS Model were used as a basis to develop EUROSEM (Morgan et al., 1998)
In EUROSEM 3.3 many erosion routines and equations substituted the original KINEROS. with other, giving preference to European scientific production until 1998

KINEROS has been further developed (see KINEROS 2)

EUROSEM continued to be developed until 2001 thanks to a series of European funded projects: mainly MWISED.

KINEROS2
Smith et al. 1999

MWISED project
(1998-2001)
EUROSEM 4.0 (beta)
(Quinton , Morgan, Kotova)

The European Soil Erosion Model (EUROSEM) has been a joint effort of many European scientists (*in INCOMPLETE alphabetical order*):

J. Albaladejo Montoro, V. Andreu, K. Auerswald, P. Bazzoffi, W. Blum, Boiffin, H.R. Bork, P. J. Botterweg, V. Castillo, J.A. Catt, G. Chisci, B. Diekkrüger, W. Everaert, A. Folly, S. Giakoumakis, G. Govers, B. Hasholt, A.J. Johnston, E. Klaghofer, Y. Le Bissonnais, G. Monnier, R.P.C. Morgan, J. Nachtergaele, T. Panini, J.W.A. Poesen, J.N. Quinton, R.J. Rickson, J.L. Rubio, V. Sardo, , <u>R.E. Smith</u>, P. Strauss, M.E. Styczen, D. Torri, G. Tsakiris, R. Webster, M. Vauclin,. .. **…….. And   .. many many others**…

Eurosem 1998 – 2001 during MWISED project

EUROSEM code specific efforts (Quinton , Morgan , Kotova)
Recoding EUROSEM 3.3 procedural language (Fortran 77) in Object
  Oriented language (Object Pascal - Borland) developing a Windows
  graphical interface

MWISED findings and result (not all implemented in eurosem)

1) **Width discharge relationship to start linear erosion in absence of pre-formed rills and gullies (from Nachtergaele et al., 2002)**
2) **Ephemeral gully threshold**
3) **New infiltration routine (with dynamic changes of final infiltration rate linked to sealing processes)**

Item 1) and 2) were implemented into EuroSEM4WIN but
without success 3) was implemented but in its static form

EUROSEM changes, new integrations and first recoding in 2004-2007 (RECONDES project)

1) Search for bugs into EuroSEM4WIN
2) Elimination of the ephemeral gully routine (still unfinished and poorly integrated into the code)
3) Simplification of input data handling and its substitution with and EXCEL input data file.
4) Development of input data integration and of a series of algorithms for building self-consistent scenario analysis.
5) Inclusion of root effects as an increase of cohesion into the input data file (De Baedts at al. 2008)
6) Adoption of Darcy-Weissbach equation instead of Manning's and adoption, with marginal modification, of WEPP algorithms to calculate friction factor
7) Development of a model to transform the parameters of a multi-layered vegetation system into the equivalent (from the point of view of erosion and hydraulics) mono-layer system

EUROSEM re-engineering 2007-2008

1) Mainly code re-organization with restructuring and translation into a freepascal code , Object Pascal (freepascal compiler project FPC - OPEN SOURCE)
2) Elimination of further bugs and improvement of the infiltration routine
3) Integration of disaggregation algorithm for low resolution recorded rainfalls

EUROSEM2008 : CODE STRUCTURE AND DEVELOPMENT TOOLS

The code related to USER INTERFACE is completely separated from the parts that contains the data structure and the libraries with the numerical code.
This structure facilitate the maintenance of the code, the modification, debugging an profiling.

In this phase we choosed to use only **open source** programming and development tools, and In particular :

COMPILER
Freepascal compiler   FPC 2.2.2 (http://www.freepascal.org)

DEVELOPEMENT ENVIRONMENT
Lazarus 0.9.25 IDE   (http://www.lazarus.freepascal.org)

DEBUGGING and PROFILING
Insight 6.3.5 + GDB 6.7 + GPROF (www.mingw.org)

This will facilitate also the distribution freeware of the produced software under LGPL or GPL Licence (....we have to decide).

Graphical user interface

The main user interface is simple and intuitive (e.g no Menus… Like many many Antivirus software now are doing ...

EUROSEM INPUT OUTPUT

INPUT
(watehrshed data related ato plane anc channels and their properties; rainfall event data)
•TABLE (ASCII FILE -TAB,SPACE data separator) as exported from EXCEL data form preparation
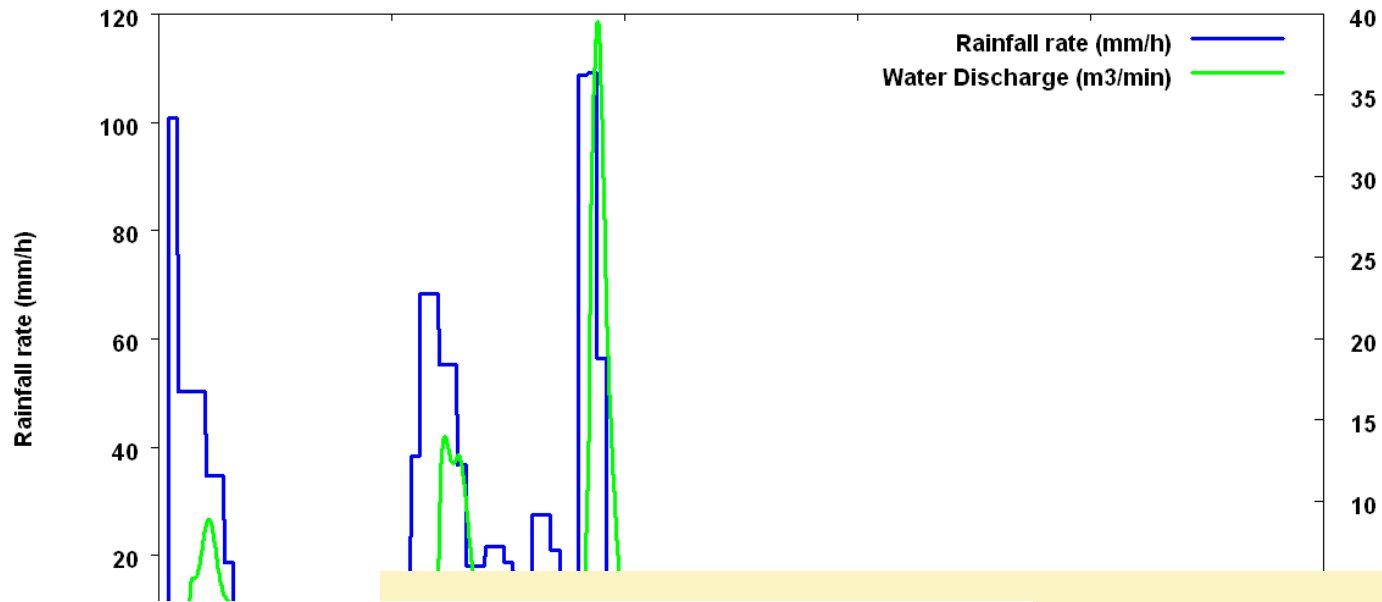•Excel file (XLS) (…. soon)

OUTPUT
Diagnostic: Ascii text file
Results and report : excel files (xls) ;   ASCII file – tabulated
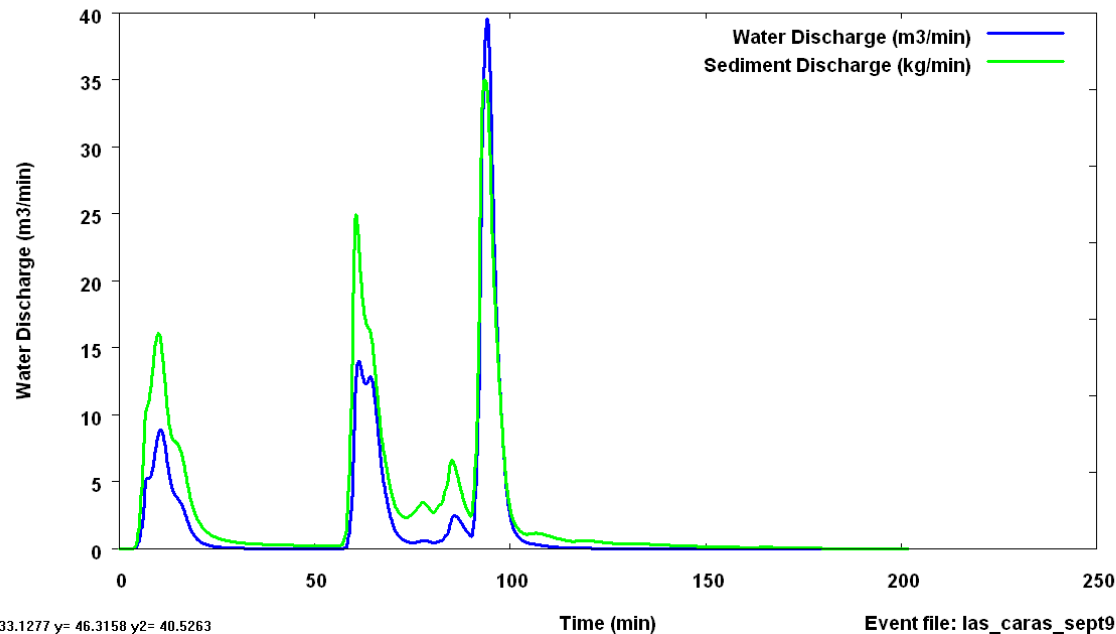
GRAPHIC OUTPUT:
Plotting by calling GNUPLOT (4.3) engine to produce plots or various time series of relevant parameters as (rainfall rate, Infiltration ate, discharge, sediment discharge, sediment concentration) for each element in the watershed.
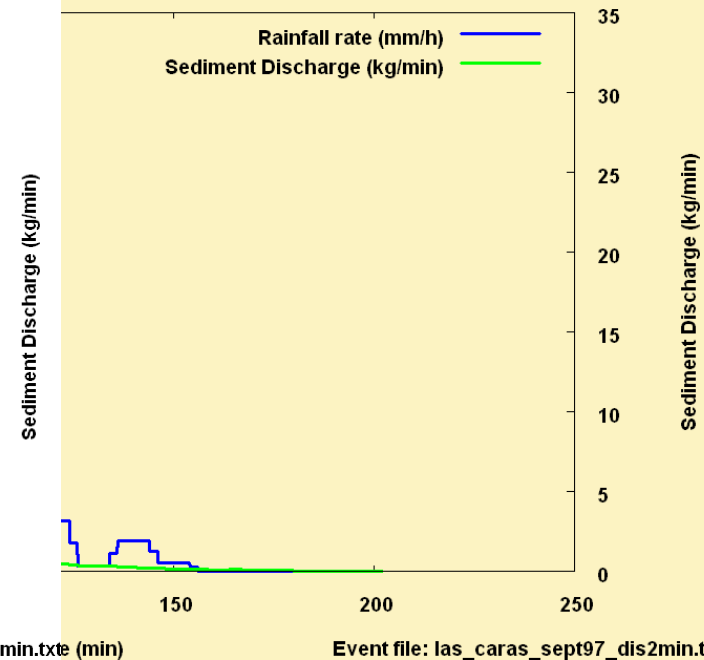
EUROSEM2007 - laherrada_2_highCOH.txt : element10
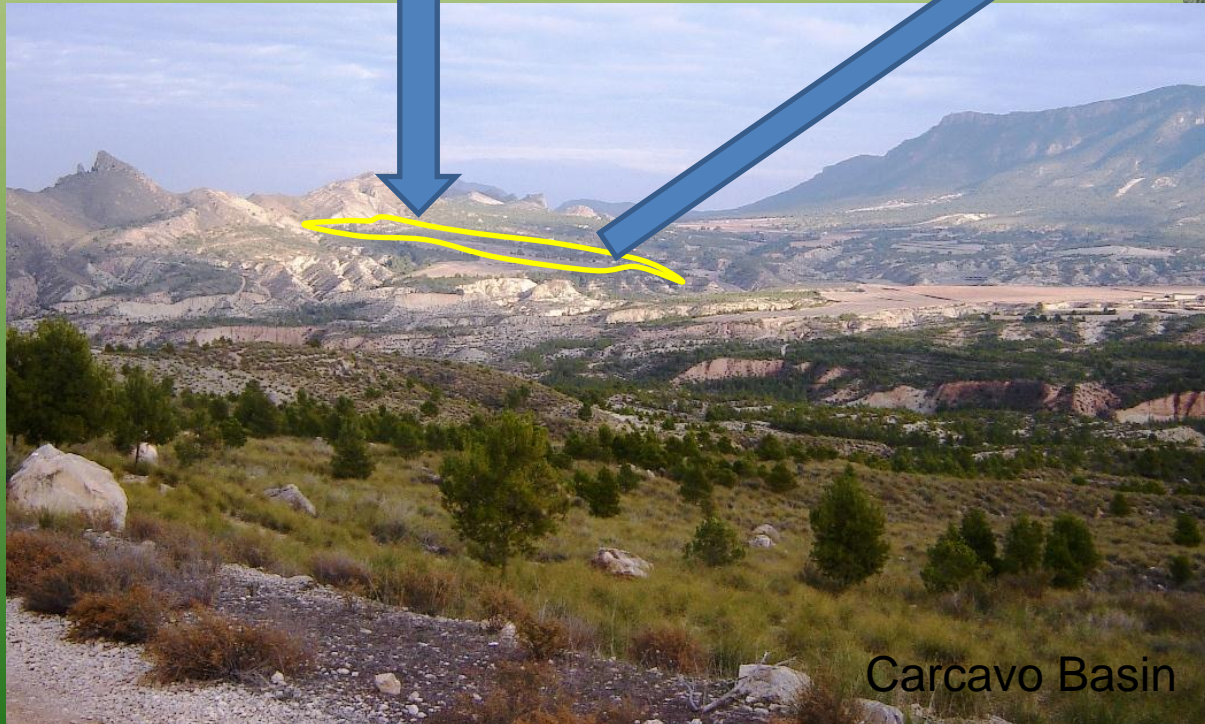

EUROSEM2007 - laherrada_2_highCOH.txt : element10

a_2_highCOH.txt : element10


x=-33.1277 y= 46.3158 y2= 40.5263

EUROSEM 2008 example of application -1

"La Herrada", 22 ha watershed located in the northwest area of the Carcavo basin (MURCIA, Spain). This area, characterized by a slope ranging from 10% to 50%, includes materials of different geologic ages: limestone and dolomite (Muschelkalk, Trias), marl and gypsum (Keuper, Trias), marl limestone and sandstone (Tortonian, Tertiary) and undifferentiated materials (Colluvium, Quaternary). There are four main land uses in Cárcavo catchment: olive/almond, semi natural vegetation, cereals and reforestation.

Carcavo Basin

Eurosem 2008 example of application -2

Land Use

- Cereals
- Olive/almond
- Reforestation
- I vegetation

Slope (%)

- 0-10
- 10-20
- 20-30
- 30-40
- >50
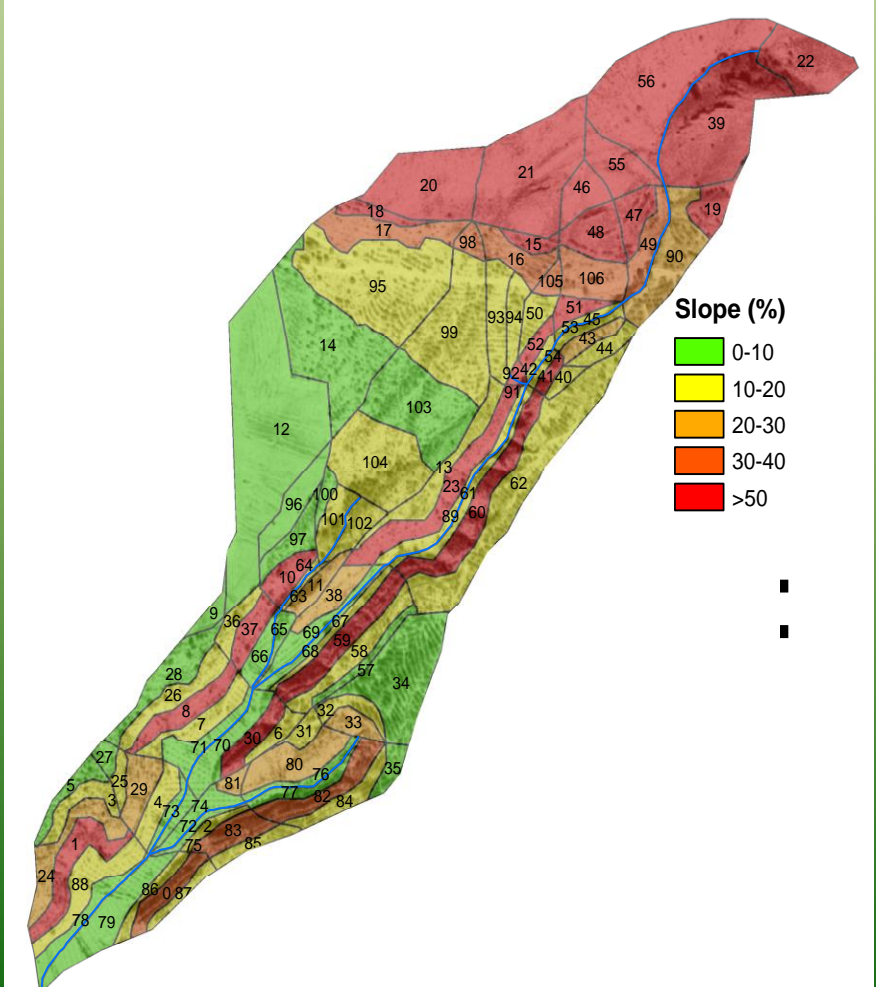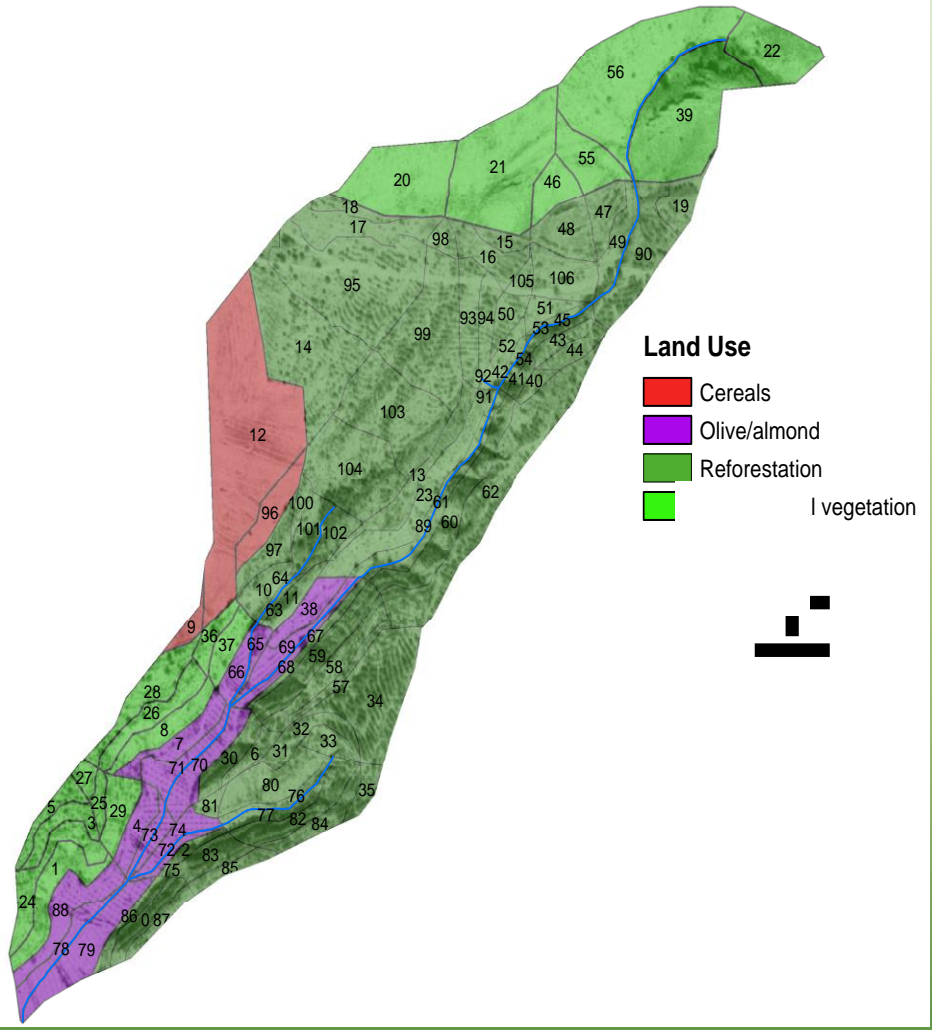
Eurosem 2008 example of application -3

La Herrada basin. Illustration of the decomposition of natural topography (a) into elements (b) for modelling a catchment (c).
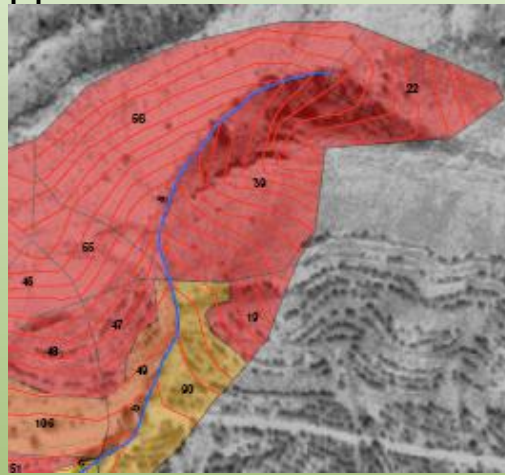
(a)
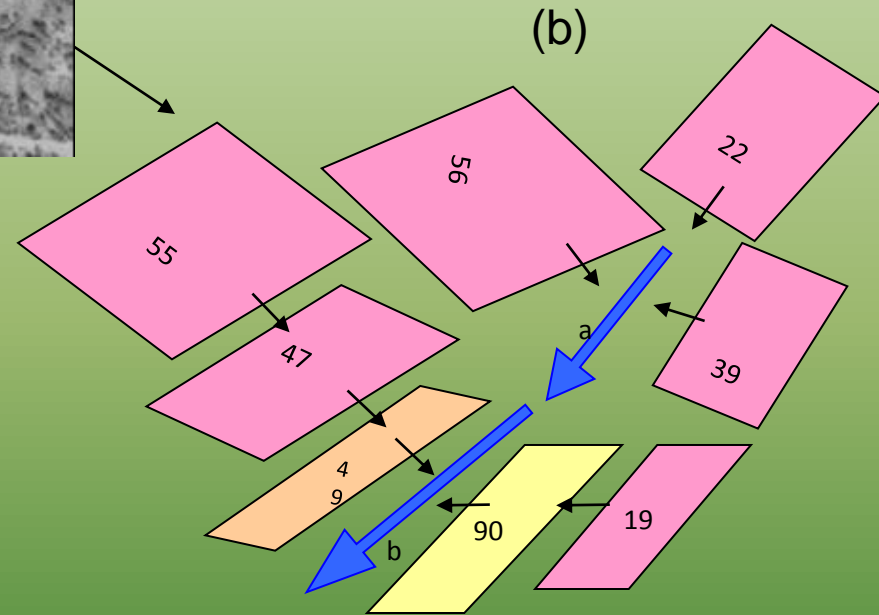
(b)

EUROSEM describes catchments by decomposition into elements which are either **planes or channels**. The method is taken from the KINEROS, and more details and examples can be found in the KINEROS manual (Woolhiser et al, 1990)

(c)

121 elements
(Planes and channels)

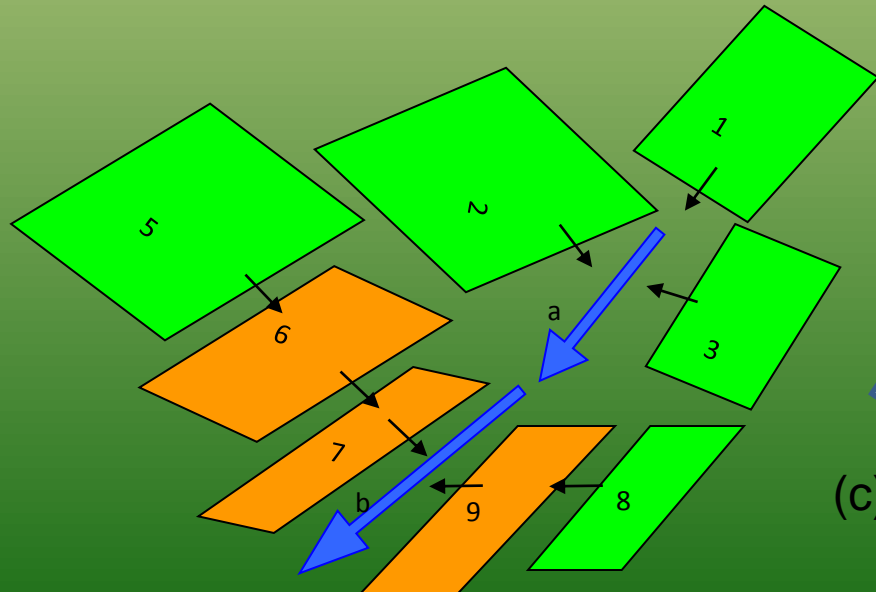# Eurosem 2008 example of application -4

A   ------------->   B   C   D   E   F   ------------->   I   ------------->   AM   -->   AR

Type	Overland Flow Length (m)	Simulation time (min)	Air Temperature (o)				
0	1193.00	600	10				

	Type	Element	Width (m)	Length (m)	Upper element	Bottom Width (m)	First channel number	Right-hand plane number	Second channel number	Left-hand plane number	Right-hand side slope	Left-hand side slope
Poligono												
22	1	1	38	90	0	0	0	0	0	0	0.0	0.0
56	1	2	158	60	0	0	0	0	0	0	0.0	0.0
39	1	3	90	90	0	0	0	0	0	0	0.0	0.0
a	2	4	0	165	1	1	0	2	0	3	0.2	0.2
55	1	5	34	64	0	0	0	0	0	0	0.0	0.0
47	1	6	51	28	5	0	0	0	0	0	0.0	0.0
49	1	7	66	24	6	0	0	0	0	0	0.0	0.0
19	1	8	12	66	0	0	0	0	0	0	0.0	0.0
90	1	9	51	70	8	0	0	0	0	0	0.0	0.0
b	2	10	0	116	4	2	0	7	0	9	0.2	0.2

G   H   ------------->   J   -->   U

Saturated hydraulic conductivity (mm/h)	Effective net capillary drive (mm)	Porosity (fraction)	Moisture content (v/v) initial	Moisture content (v/v) saturation	D50 (µm)	Specific gravity (Mg/m³)	Erodibility (g/J)	Cohesion (kPa)	Depth to non-erodible layer (m)	Position of rocks	Fraction of embedded rocks	Rock fragment cover (fraction)	Rock fragment content (v/v)
20.07	213.29	0.50	0.10	0.46	30	2.65	1.98	3.00	0.60	0.00	0.00	0.18	0.15
20.07	213.29	0.50	0.10	0.46	30	2.65	1.98	3.00	0.60	0.00	0.00	0.18	0.15
20.07	213.29	0.50	0.10	0.46	30	2.65	1.98	3.00	0.60	0.00	0.00	0.18	0.15
28.74	196.13	0.50	0.10	0.46	35	2.65	1.98	3.00	0.60	0.00	0.00	0.30	0.15
20.07	213.29	0.50	0.10	0.46	30	2.65	1.98	3.00	0.60	0.00	0.00	0.18	0.15
25.33	186.73	0.50	0.10	0.46	30	2.65	1.98	3.00	0.60	0.00	0.00	0.18	0.15
26.42	186.73	0.50	0.10	0.46	30	2.65	1.98	3.00	0.60	0.00	0.00	0.18	0.15
26.42	186.73	0.50	0.10	0.46	30	2.65	1.98	3.00	0.60	0.00	0.00	0.18	0.15
26.42	186.73	0.50	0.10	0.46	30	2.65	1.98	3.00	0.60	0.00	0.00	0.18	0.15
29.52	196.13	0.50	0.10	0.46	35	2.65	1.98	3.00	0.60	0.00	0.00	0.30	0.15

# Eurosem 2008 example of application - 5
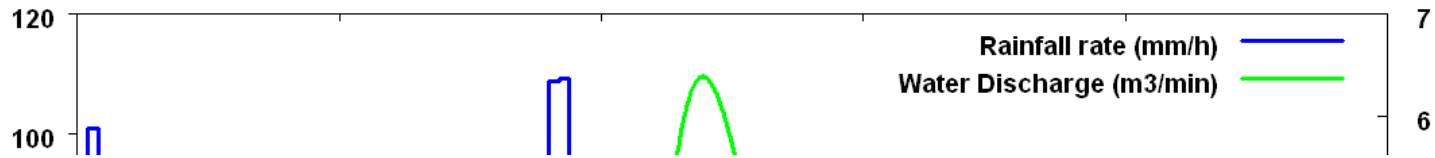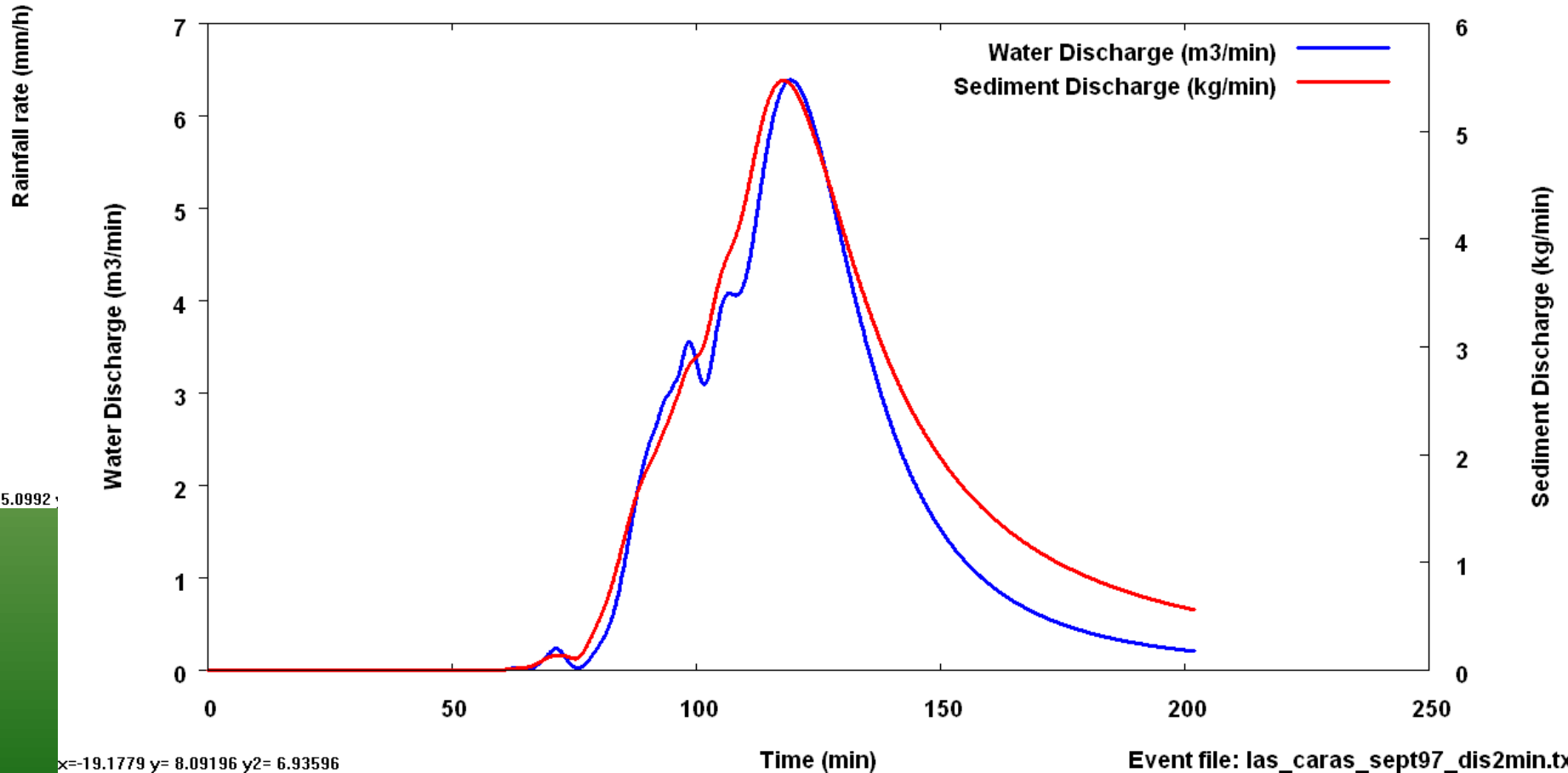
Eurosem 2008-2001x next steps

1) **EROSEM distribution as freeware tool for the scientific community (…we hope to do this in spring 2009)**
2) **Inclusion of the multilayer vegetation description into the model**
3) **Inclusion of some recent (Govers, 1992, Gimenez et al. 2004, Torri and Borselli, 2002; Torri et al., 2006) and less recent (Savat, 1978) research results which will affect flow velocity, erosion and deposition processes**
4) **Development of a series of algorithms for input data estimation and self-consistency evaluation**
5) **Raster based description of the catchment (as an alternative to the plane and segment representation)**
6) **Integration of EuroSEM with Flow Connectivity Approach (FCA)**

EUROSEM 2008 and connectivity assessment

Connectivity is defined as chances that a particle has to reach the nearest sink
It depends on: **distance to the sink ; characteristics of the route ; water available to transport from upslope ; water that is gained/lost along the downslope route.**

The characteristics above are defined, or are used, by many soil erosion distributed models like EUROSEM for modelling and computation.

The *Buffalo jump*
A Native Americans' Hunting technique
That Have some similitude with soil erosion /runoff processes
e.g. The chance of each buffulo to fall …. and die.

Buffalo Flow rate,   Compression and storage ,   Driving force

Distance to cliff
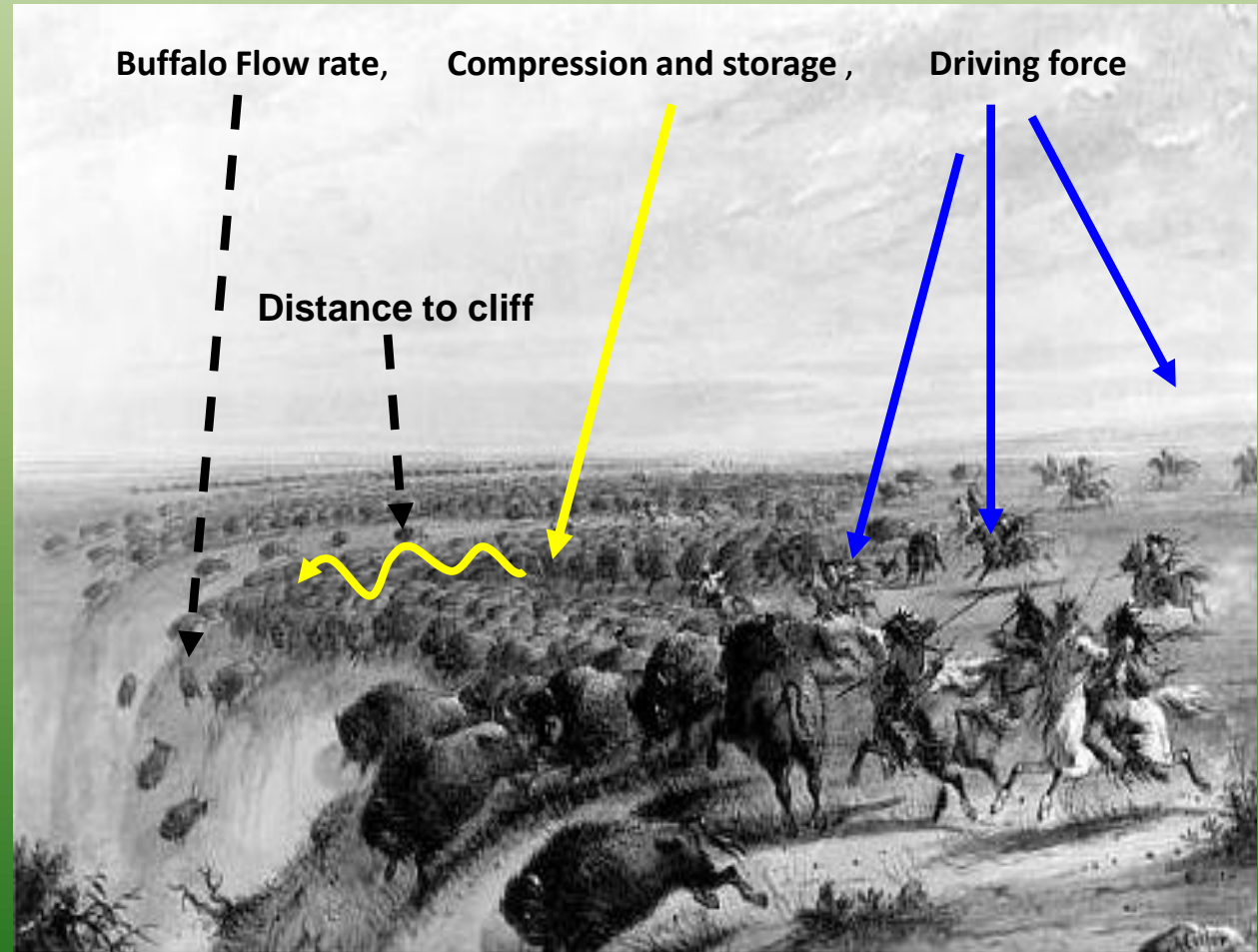
Source: Alfred J. Miller 1887   from National Archives of Canada

Connectivity index model – IC

Borselli et al. (2005) *Flow connectivity and sediment delivery at field scale, within a watershed context – COST 634 conference Lublin (PL) -2005*
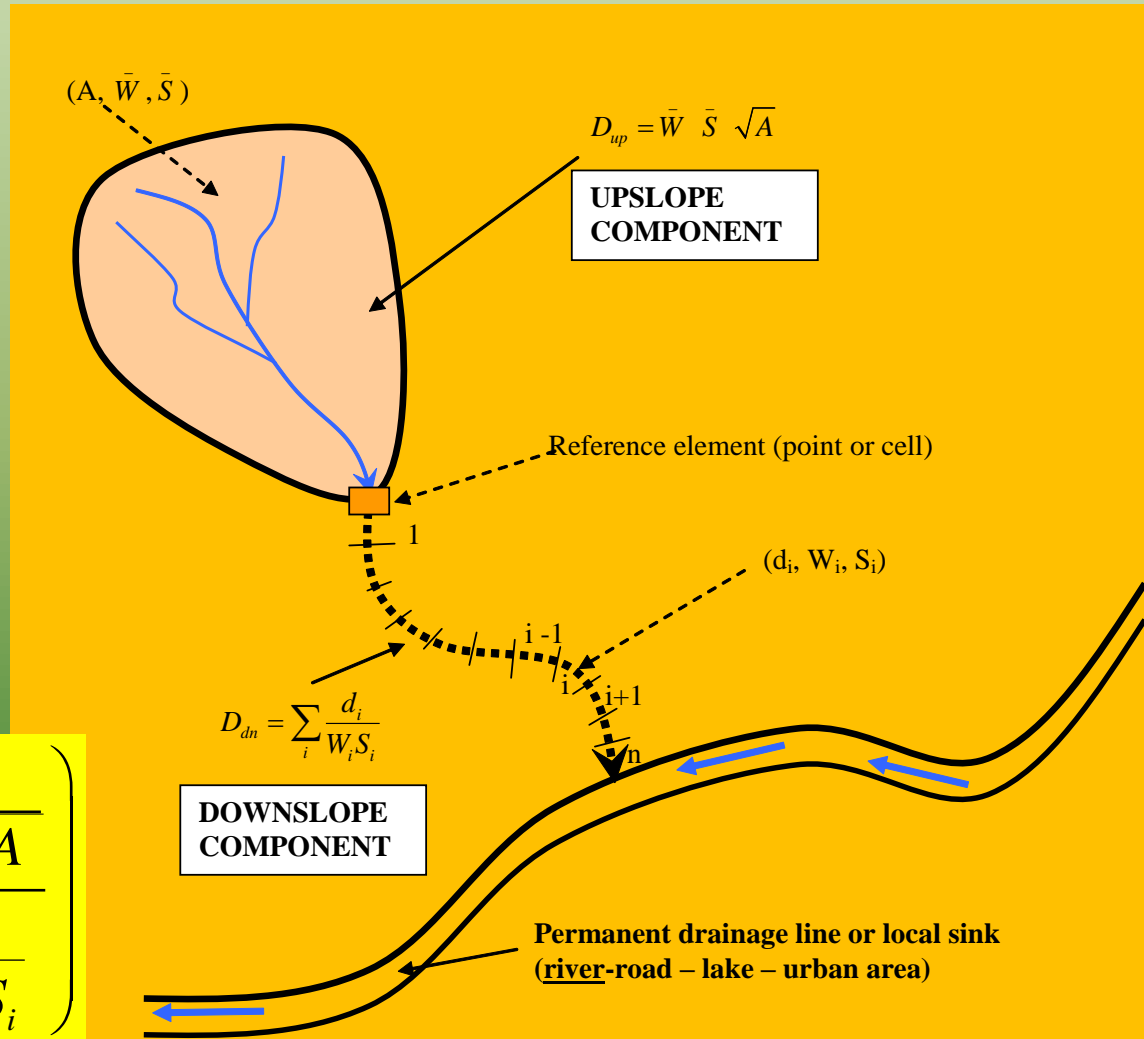Cassl et al. (2007) . *Flux connectivity index as a tool for soil erosion scenario analysis: anthropic impact assessment in Bilancino Watershed (Tuscany) . COST 634 conference – Florence (IT) -2007*
Borselli et al. (2008). **Prolegomena to Sediment and flows connectivity in the landscape: a GIS and field numerical assessment . CATENA (accepted)**

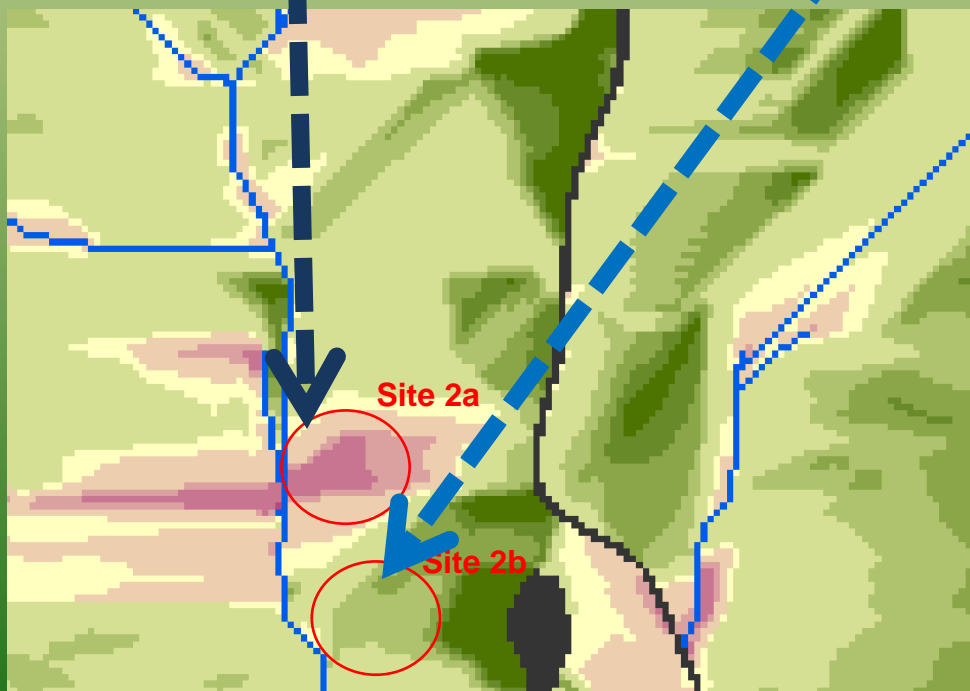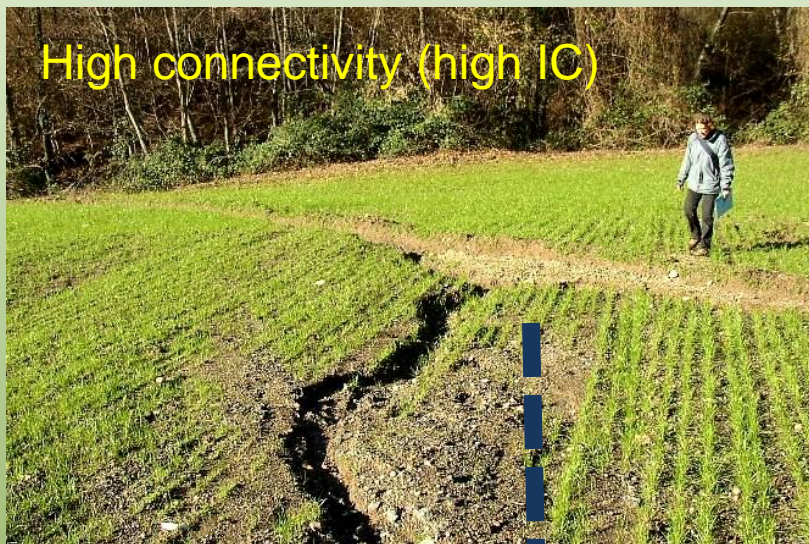**The Connectivity Index (IC) value is computed using two components:**

•**Downslope component**: is the sinking potential due to the path length, land use and slope along the downslope route.

•**Upslope component**: is the potential for down routing due to upslope catchment's areas, mean upslope and land use.
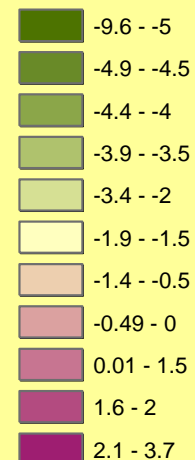
$(A, \bar{W}, \bar{S})$

$D_{up} = \bar{W}\ \bar{S}\ \sqrt{A}$

UPSLOPE COMPONENT

Reference element (point or cell)

(d_i, W_i, S_i)

$D_{dn} = \sum_i \dfrac{d_i}{W_i S_i}$

DOWNSLOPE COMPONENT

Permanent drainage line or local sink
(**river**-road – lake – urban area)

$$IC = \log_{10}\left(\frac{D_{up}}{D_{dn}}\right) = \log_{10}\left(\frac{\bar{W}\,\bar{S}\,\sqrt{A}}{\displaystyle\sum_i \frac{d_i}{W_i S_i}}\right)$$
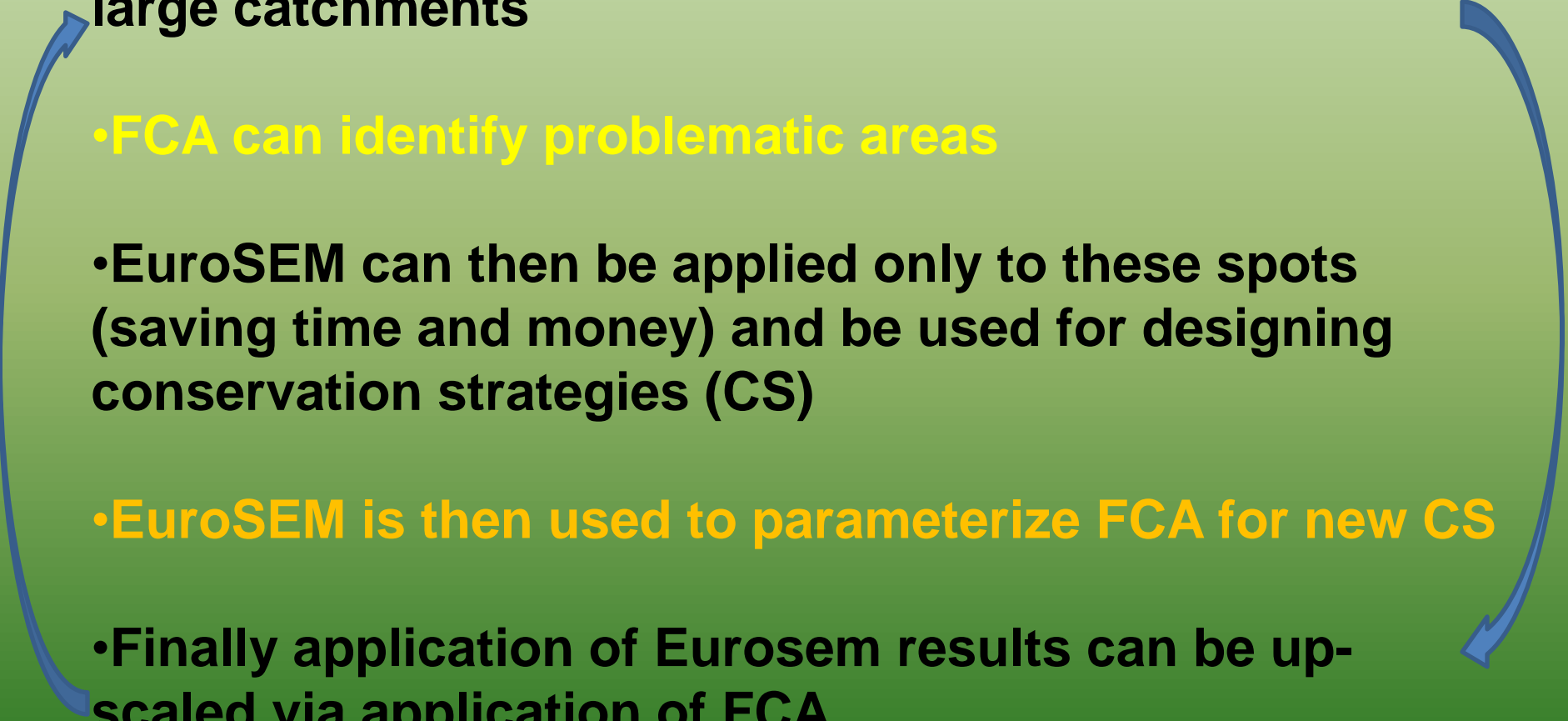
Connectivity index model (Borselli et al. 2005,2008): applications to Bilancino watersheed

High connectivity (high IC)

Low connectivity (negative IC)

Connectivity fluxes index

	-9.6 - -5
	-4.9 - -4.5
	-4.4 - -4
	-3.9 - -3.5
	-3.4 - -2
	-1.9 - -1.5
	-1.4 - -0.5
	-0.49 - 0
	0.01 - 1.5
	1.6 - 2
	2.1 - 3.7

Site 2a

Site 2b

Possible integration between soil erosion and connectivity assessment models

- **Flow connectivity approach (FCA) is easy to apply to large catchments**

- **FCA can identify problematic areas**

- **EuroSEM can then be applied only to these spots (saving time and money) and be used for designing conservation strategies (CS)**

- **EuroSEM is then used to parameterize FCA for new CS**

- **Finally application of Eurosem results can be up-scaled via application of FCA**

Acknowledgements:

To All the soil erosion Scientists which contributed to the previous versions of EUROSEM

Many tanks for your attention