MODELLING WITHIN-STORM SOIL EROSION DYNAMICS

Contract ENV4-CT97-687

final report

1/4/1998 – 30/6/2001

Coordinator:	**CNR - Istituto per la Genesi e l'Ecologia del Suolo (CNR-IGES)**
Resp. scientist:	**Dr. Dino Torri**
Address:	Istituto per la Genesi e l'Ecologia del Suolo Piazzale delle Cascine 15-28 - I-50144 Firenze, Italia
Telephone:	+39 055 3288290
Fax:	+39 055 321148
email:	dbtorri@iges.fi.cnr.it
Contractor:	**Katholieke Universiteit Leuven (KULEUVEN)**
Resp. scientist:	**Prof. Dr. Jean Poesen**
Address:	Laboratory for Experimental Geomorphology Redingenstraat 16 - B-3000 Leuven, Belgium
Telephone:	+32 16 32 64 25/26
Fax:	+32 16 32 64 00
email:	jean.poesen@geo.kuleuven.ac.be
Contractor:	**Cranfield University, Silsoe (CRANFIELD)**
Resp. scientist:	**Prof. Roy Morgan**
Address:	Silsoe College, Silsoe Bedfordshire MK45 4DT - United Kingdom
Telephone:	+44 (0)1525 863059
Fax:	+44 (0)1525 863099
e-mail:	r.morgan@cranfield.ac.uk (Prof. Roy Morgan)
Contractor:	**Consejo Superior de Investigaciones Científicas (CSIC-CEBAS)**
Resp. scientist:	**Dr. Juan Albaladejo**
Address:	Centro de Edafología y Biología Aplicada del Segura Av. Fama. Apartado 4195 - E30080 Murcia. España
Telephone:	+34-968-215717
Fax:	+34-968-266613
email:	jalba@natura.cebas.csic.es
Contractor:	**Istituto di Idraulica Agraria (IIA)**
Resp. scientist:	**Vito Sardo**
Address:	via Valdisavoia, 5 - 95123 Catania - Italia
Telephone :	++ 39 - 095 - 350401
Fax:	++ 39 - 095 - 7311992
email :	sardo@mbox-fa.gr.unict.it
Contractor:	**Institut für Bodenforschung, Universität für Bodenkultur (BOKU)**
Responsible Scientist:	**Dr. Peter Strauss**
Address:	Gregor-Mendelstrasse 33 A-1180 Wien, Austria
Telephone:	+43 1 7416 52108 17
Fax:	+43 1 7416 52108 3
E-mail:	peter.strauss@baw.at
Contractor:	**Istituto Sperimentale per lo Studio e la Difesa del Suolo (ISSDS)**
Resp. scientist:	**Dr. Paolo Bazzoffi**
Address:	Piazza D'Azeglio, 30 - 50121 Firenze - Italia
Telephone:	+39 55 2491211
Fax:	+39 55 241485
email:	bazzoffi.paolo@iol.it
Contractor:	**Faculty of Geographical Sciences, Utrecht University (UU)**
Resp. scientist:	**Dr. Victor Jetten**
Address:	Heidelberglaan 8 POBOX 80115 - 3508 TC Utrecht, The Netherlands
Telephone:	+31 2535773
email:	v.jetten@geog.uu.nl
EU responsible:	**Denis Peter - DG Research, Brussels, Belgium**

Contents

I Project Executive summary

Abstract

Objectives

The projects aims were:

1) description of the within-storm dynamics of soil surface roughness, sealing, soil aggregates and infiltration
2) prediction of ephemeral gully generation and development during erosive storms
3) production of a generator of synthetic erosive rainstorms
4) development of a fully dynamic model taking into account point 1 and 2
5) development of a pedo-algorithm package for model users.

Results

All the goals have been addressed. Scientific achievements regarding 1, 2 and 3 have been obtained and now a description of interrill dynamics is available: surface roughness behaviour, sealing and infiltration dynamics have been investigated and original results obtained. They include the dynamics of ponded areas, saturated hydraulic conductivity and soil detachability (by splash). Gully generation is now clearly described in empirical and theoretical terms. A rainfall generator, suitable for this within-storm erosion modelling, has been produced. A set of pedo-algorithms has been developed, based on foreground knowledge and on original acquisition within this project. Two models (EUROSEM and EUROWISE) contain part of the developed knowledge. In particular they contain a routine for generating ephemeral gullies and an improved infiltration equation.

Introduction

The scope of the project was substantially that of producing one or more models describing soil erosion during extreme rainfall events allowing for surface modifications and for ephemeral gully generations (surface modifications explored in WP1, ephemeral gully in WP2). This led to the decision to modify two models, namely EUROSEM and LISEM, which are substantially based on the same type of mathematical representation of the physics of soil erosion but which differ in one extremely important aspect, i.e. The way they represent the landscape (the former being a conceptual representation - through a cascade of planes, the latter raster). Also different types of difficulty are encountered when generating ephemeral channels that were not already given as an input at the time of the preparation of the input tables and maps. WP4 was used for the coding of the new algorithms, and the validation of the new models.

When presenting a model, one of the most important elements is indeed the input data needed to make it run. Data collection is expensive, sometimes impossible, hence techniques helping experts to make good guesses at the input values are always needed. This brings in the problem of pedotransfer functions, of meteo data, etc. The part regarding a generator of synthetic rainfall was dealt with using WP3 where the model RAINGEN was further developed and improved. Better tables and algorithms for estimating appropriate soil characteristics were developed partly within WP4 and partly within WP1 and 2.

The results obtained by the project can be subdivided into 3 categories: 1) new knowledge developed into new routines in the two models; 2) new knowledge that was not possible to incorporate into the models and 3) new methodologies.

These achievements have been publicised through scientific publications, many still only at the

submitted but not yet published stage, presentations at scientific conferences, presentations at disseminating conferences. Some material is already accessible as freeware downloadable from several web-sites, others will soon be so.
The following chapters are organised as follows: 1) summary of the activity ; 2) achievements grouped in the 3 said categories; 3) results and their diffusion ; 5) detailed summary of each partner's activity; 4) technical implementation plans.

Summary of project activities

Surface conditions are relevant for several processes affecting soil erosion, the main ones being surface roughness, which affects splash detachment and flow transport capacity, and sealing/crusting, which affects runoff generation and soil detachability.
Before discussing the various results obtained by the project, attention must be drawn to the effect of dispersion and of water quality in rainfall simulation (because most of the reported experiments were made in the laboratory with simulated rainfall). It was found (see CNR report) that tap water usually completely depresses dispersion differently from good quality water (electrical conductivity between 10-40 S/cm) and rain water. This causes a slowing down of many processes linked to sealing and soil loss. In particular, soil loss can be 3 times greater when rain-water is used instead of tap water. This means that most of the interrill splash tables, equations or nomographs (usually based on rainfall simulation data) cannot be used and must be substituted by new ones.
Collected data have clearly indicated that Smith and Parlange (1978) equation usually fails when the soil has strong aggregates which slow down sealing processes (CNR report). Another equation has been tested (Morel-Seytoux and Verdin, 1981) which usually compares favourably with Smith and Parlange. The intense dynamics of seed-bed surfaces suggest that none of these equations really adhere to reality. This is because the geometry of aggregates and particles changes fast during the first phases of clod destruction. Hence parameters taken as constant in the said equations must vary. When this is done it is possible to perfectly describe observed behaviours. Unfortunately, the equations describing the time-dependence of the hydraulic characteristics of the first layer is not analytical and many empirical equations can do the job equally well. This leads to an important uncertainty that was not solved within the project.
Surface roughness effects on maximum depression storage and on detention storage (see Cranfield report) were examined and data were collected using stereo photo and photogrammetric techniques. This led to some critique of the equations already suggested in EUROSEM manual for evaluation surface storage. Another set of experiments (CNR report) has led to the construction of a nomograph with simple and clear indication of the behaviour of roughness (relative standard deviation or relative random roughness index) in relation to rain impact energy and soil characteristics (permanent and transient). The nomograph describes well the results obtained in an independent set of experiments in the field with rainfall simulation (CEBAS report). Also the data collected in the field (under natural rainfall) can be easily located in the nomograph (ISSDS report). This result is not included explicitly within the models but will give indications for assigning initial roughness values in the tables of model input data.
The variation during the time that the area was effectively ponded (through series of images taken using a CCD camera connected to a computer) led to the identification of the relative importance of zones sealed by direct drop impact (erosion crust) and those sealed by deposition of splashed particles (CNR report). The results allowed for a completely different approach to soil detachability determination. Actually an inverse procedure for calculating soil detachability was devised. It is based on a splash detachability model proposed by Torri et al. (1998), and takes into account the expansion of ponded areas and the destruction of roughness elements (or their generation in case of excessive soil loss). The application of this procedure to a series of laboratory experiments has led to a new set of erodibility values. As erodibility is also variable with time (or better, with rainfall characterised through its kinetic energy) the new erodibility table will also give indications concerning this.

Aggregate resistance is a characteristic which was explored in relation to several experiments (CEBAS and CNR reports). Results indicate that aggregate behaviour can be used to infer soil erodibility as well as soil propensity to sealing (and consequently to soil hydraulic properties). Nevertheless results did not allow the determination of any clear and reliable relationship between aggregate stability indices and the said characteristics. At present aggregate stability can be used only as an index that can help in identifying reasonable input values for the models.

Ephemeral gully generation has been studied extensively in the field (see KULeuven report mainly, IIA and ISSDS reports). Relationships identifying morphological threshold conditions for gully generation (0.1 m^2 of gully cross section) and for gully fan formation have been studied at length. This has allowed the identification of areas in the landscape where gully erosion can take place.
Collection of data from the literature, some experimental data and data simulated using existing models has allowed the identification of a relationship linking total discharge to channel width, which is one of the basic parameters needed for calculating flow aggressiveness. All this has been reflected into one of the models (EUROWISE, which is a derivation of LISEM, see UU report).
A series of experiments conducted in the laboratory have clearly demonstrated that flow shear stress is the key parameter representing flow aggressiveness (KULeuven and CNR reports). This brings soil shear strength and soil resistance characteristics to the fore: their variation during the year and the differences in soil resistance between successive soil horizons can explain the differences between winter and summer gullies, between gullies entrenching different types of soil horizon (KULeuven report).
Other experiments conducted in the field (CEBAS, ISSDS and CNR reports) and in the laboratory (ISSDS and CNR reports) confirmed an original theoretical model (CNR report). The model was then used to verify the basis of the empirical relationships used within EUROWISE. This control gave a very positive outcome as shown in the CNR report. These experiments also pointed out that Manning's equation, which states that velocity depends on discharge, slope and roughness, does not work during channel erosion: only discharge seems to be related to velocity in agreement with previous findings of Govers (1992).

Regarding the problem of **model development** it was decided to expand LISEM into EUROWISE. The latter model is able to deal with gully generation. As already stated, it incorporates the empirical relationships already mentioned. The philosophy is simple: when there is a substantial flow in the area that is prone to gullying then a gully can be excavated. Hence the more suitable form of the threshold equation for gully initiation was chosen on the basis of its more or less correct identification of the prone area. Then the channel was allowed to increase following discharge. Deepening of the channel was then adjusted using estimated soil detachment and distributing it over the already calculated width. The results were compared with gully data measured in the field (UU and KULeuven reports).
While it was possible to include and test this in EUROWISE it was not so in EUROSEM (Cranfield report) because it had to be first translated from FORTRAN77 into Delphi Pascal (which means the program was restructured). This effort has produced a much better version of the model but bugs (inevitable in these cases) prevented any validation of the gully algorithm.
Both the models include Morel-Seytoux and Verdin infiltration equation. It appears that the water balance (EUROSEM, Cranfield Report) is better with this equation than with Smith and Parlange's.
An evaluation of how the models worked outside the range of conditions in which they have been created was also made (ISSDS report). Here one version of EUROSEM was tested with obvious difficulties due to the still untested Delphi code together with LISEM (it was impossible to test EUROWISE as it was under coding until the end of the project). It was found that the hydrologic part of both models does not cope well with clay rich soil in typical subhumid Mediterranean conditions.
This part of the project was preceded by a careful study concerning soil moisture (ISSDS report)

which made it possible to estimate conditions for presence or absence of cracks. With this at hand it is possible to state that both models fail largely in presence of cracks and to a lesser extent when the soil is close to field capacity. Failure when cracks are present is due to the fact that none of the models incorporate any routine for cracks and flow through macropores. The fact that cracks are open most of the time strongly limits the applicability of EUROSEM and LISEM to Mediterranean condition on clay rich soils.

In order to make a **synthetic rainfall generator** (RAINGEN) capable of producing precipitation causing soil losses similar to the corresponding natural rains (BOKU report) it was decided to proceed by examining a series of alternatives (design storm; markov chain methodology based on wet day/dry day probabilities;Bartlett-Lewis-type models; scaling models).
The scaling model was the only one giving an acceptable correspondence between soil losses simulated with synthetic rain and those simulated with the corresponding natural rains. The basic assumption of the scaling approach is that actual rainfall intensity of storm events is a self-similar stochastic process which can be described with a scaling coefficient and a series of 3 parameters. To further complicate the model it was found that the scaling coefficient was usually time dependant. Hence, it was necessary to fit H using piecewise linear regressions. Rainfalls are generated supposing: 1) their duration to be Weibull distributed; 2) their total depths to be hyperexponentially distributed; 3) incremental depths to be Gamma distributed and 4) rainfall intensity within a storm to be a self-similar (simple scaling) process.
While exploring erosion behaviour using similar simulated rainfall but with different storm intensity patterns (BOKU report) it appeared that erosion varies with intensity pattern but in different ways for different soils. This indicated that the erodibility/detachability dynamics has an important role to play.
Independently from the Boku' study, another investigation (ISSDS report) showed that, in the short term – about 10 years, rain characteristics have evolved in Tuscany towards larger aggressiveness (drying up of climate in the short period with increasing rain kinetic energy, higher rain maximum intensity in 30 minutes and longer average lag between successive events). This indicates that models such as RAINGEN will soon need further refinements in order to cope with a shifting climate (in short periods).
The two erosion models and the rain generator have sufficiently developed interfaces which should cause little difficulty to skilled users. Each model contains simple tools for helping users in selecting input values of the various parameters.

A more sophisticated system of **pedotransfer functions and algorithms** has been organised in the form of a Java applet (Soil Equation Interface – SEI; CNR report). Presently it is completely operational with respect to the calculation of parameters such as soil water potential, saturated soil-matrix hydraulic conductivity and net capillary drive. Suggestions on how to evaluate soil interrill detachability are also given together with estimation of soil surface roughness (and its value at different times after seed bed preparation), and sealing intensity.
In order to make the applet useful where soil roughness estimation is concerned, a series of pictures of sites at different degrees of surface roughness was made while at each site roughness was measured.
This was done in two areas (Murcia and Tuscany, see ISSDS and CEBAS reports). The series of pictures is completed by a short discussion regarding roughness and a quick method for estimating degree of roughness decay, based on estimated soil resistance class (CNR report).

Achievements

•***Models:***

1.EUROSEM4win: erosion model (Delphi environment)
2.EUROWISE: erosion model (PCRaster environment)
3.RAINGEN 1: rainfall generator (C++, Fortran 90)
4.SEI: pedo-algorithms for estimating soil characteristics (JAVA applet)

•***New parts implemented in models:***

in erosion models:
1.Morel-Seytoux and Verdin infiltration equation
2.Ephemeral gully generation
3.Ephemeral gully erosion

in RAINGEN 1
1.scaling model with time dependent scaling factor

in SEI
1.water retention curves
2.saturated hydraulic conductivity
3.net capillary drive
4.soil detachability (and its time variation)
5.roughness estimates and time dependant behaviour
6.gully wall/bed erodibility in wet and dry conditions
7.seal thickness

•***Contribution to know-how***

Major achievements are those related to ephemeral gully erosion. They include: 1) a series of relationships between discharge and channel width, bridging between the already known trends for rills and rivers; 2) a better understanding of the processes driving gully erosion; 3) a theoretical set of equations describing periods of high intensities, i.e. those relevant for shaping new channels; 4) certainty that Manning's equation is not valid during erosion peaks.

Regarding interrill processes, the dynamics of ponded areas within single-rainstorms and over several rainfalls has been studied and related to rainfall kinetic energy. This has allowed the construction of an interrill model which can be used for calculating soil detachability and its dynamics taking into account all the factors known to interfere with it. In particular, sealing thickness can be predicted. Even if this part has not yet been included into any of the models it may greatly improve data collection and analysis, when used as an inverse procedure. The project has also clearly shown that infiltration equations must be modified taking into account a variable hydraulic conductivity or, more generally, taking into account pore system variations. On this account, an existing model linking porosity variations to rainfall impacting energy has been confirmed and improved.

Other important achievements are those linked to rainfall. The best way of synthetically representing rainfall for erosion prediction is by means of a scaling model with a time dependent scaling exponent. Also the fact that in ten years it has been possible to appreciate a significative change in rain erosivity patterns points to an extremely important conclusion: short term scenario analysis related to soil erosion should be able to cope with local trends of climatic variations.

•***New and improved methodologies***

The following new methodologies and/or existing methodologies have been developed/improved and successfully tested :

- *measuring saturated hydraulic conductivity in crusts;*
- *measuring depression storage using stereo photos;*
- *calculating soil detachment by inverse procedure;*
- *calculating saturated hydraulic conductivity in rainfall simulation tests using an inverse procedure (and assuming valid an infiltration equation)*
- *measuring soil susceptibility to rill and gully incision through field and laboratory experimental procedures*
- *synthesising rainfall characteristics for RAINGEN*
- *neural network analysis for predicting periods of maximum occurrence of extreme events.*

Publicizing project results

List of papers (published, in press and submitted):

Borselli L., (2001). “Capacità di invaso idrico superficiale: dinamica, misura e stima”. Riv. Di Irr. E Dren. 48(2):13-20

Borselli L., M.P. Salvador Sanchis, M.S. Yanez, D. Torri. “La dinamica degli orizzonti di superficie nel bilancio idrologico del suolo”, http://www.regione.emilia-romagna.it/sigeografici/testi/**car_suoli/doc_tecn/sina**.**htm#seminario**.

Borselli, L., Torri, D., Poesen, J., Sanchis, P.S., 2001. Effects of water quality on infiltration, runoff and interrill erosion processes during simulated rainfall. Earth Surface Processes and Landforms, 26: 329-342.

FOLLY, A. QUINTON, J.N & SMITH, R.E. 1999. Evaluation of the EUROSEM model for the Catsop watershed, The Netherlands. Catena 37, 507-519.

Martinez-Mena , M., Castillo, V, and Albaladejo, J. Hydrological and erosional response to natural rainfall in a degraded semi-arid area of Southeast Spain. *Hydrological Processes, 15, 557-571. 2001*

Martinez-Mena , M., Garcia Rogel, P, Albaladejo, J. and Castillo, V. Influence of vegetal cover on sediment size particle distribution under natural rainfall in a semiarid environment.*Catena* 38, 175-190. 2000.

Martínez-Mena, M.; Abadía, R., Castillo, V, and Albaladejo, J. “Diseño experimental mediante lluvia simulada para el estudio de los cambios en la erosión del suelo durante la tormenta”. *Cuaternario y Geomorfología* (accepted Marzo 2001).

Martínez-Mena, M.; Castillo, V, y Albaladejo, J. Validation of process-based soil erosion models: a field experimental design *Land degradation and Development* (in press)

Martínez-Mena, M.; Castillo, V, y Albaladejo, J. “Relations between erosion processes and sediment particle size distribution in a semiarid area of SE of Spain” *Geomorphology* (in press)

Nachtergaele J, Poesen J, Vandekerckhove L, Oostwoud Wijdenes D, Roxo M. 2001. Testing the Ephemeral Gully Erosion Model (EGEM) for two Mediterranean environments. Earth Surface Processes and Landforms, 26 (1): 17-30.

Nachtergaele J., Poesen J., 2000. EGEM, a potential prediction tool for soil losses by ephemeral gully erosion in the Belgian loess belt?. Gabriels, D., Schiettecatte, W. (Eds.), Proc. Erosion contact group-meeting, March 11th, 1999, International Center for Eremology, Ghent Univeristy, Belgium. I.C.E. Special report No. 2/2000: 55-60.

Nachtergaele J., Poesen J., Steegen A., Takken I., Beuselinck L., Vandekerckhove L., Govers G., 2001. The value of a physically-based model versus an empirical approach in the prediction of ephemeral gully erosion for loess-derived soils. Accepted for publication in Geomorphology.

Nachtergaele, J., Poesen, J., 1999. Assessment of soil losses by ephemeral gully erosion using high-altitude (stereo) aerial photographs. Earth Surface Processes and Landforms, 24: 693-706.

Nachtergaele, J., Poesen, J., Oostwoud Wijdenes, D., Vandekerckhove, L., 2000. From ephemeral to permanent gully: the medium-term evolution of the Kinderveld gully. In: Verstraeten, G. (ed.), Historical and present-day soil erosion processes in central Belgium. Guide of the annual excursion of the Belgian soil science society, June, 14, 2000. Pedologie –Themata, 9: 60-65/81-87.

Nachtergaele, J., Poesen, J., Oostwoud Wijdenes, D., Vandekerckhove, L., submitted. Medium-term evolution of a gully developed in a loess-derived soil. Geomorphology.

Nachtergaele, J., Poesen, J., Sidorchuk, A., Torri, D., submitted. Flow width – discharge relations for rills and (ephemeral) gullies. Hydrological Processes.

Nachtergaele, J., Poesen, J., Steegen, A., Takken, I., Beuselinck, B., Govers, G., 2000. Ephemeral gully erosion in the Belgian loess belt. In: Verstraeten, G. (ed.), Historical and present-day soil erosion processes in central Belgium. Guide of the annual excursion of the Belgian soil science society, June, 14, 2000. Pedologie –Themata, 9: 56-59/77-80.

Nachtergaele, J., Poesen, J., Steegen, A., Takken, I., Beuselinck, L., Vandekerckhove, L., Govers, G., 1999. Prediction of soil losses by ephemeral gully erosion using EGEM (ephemeral gully erosion model). Pedologie-Themata, 6: 76-85.

Nachtergaele, J., Poesen, J., submitted. Spatial and temporal variations in resistance of loess-derived soils to ephemeral gully erosion. European Journal of Soil Science.

Nachtergaele, J., Poesen, J., Vandekerckhove, L., Oostwoud Wijdenes, D., Roxo, M., in press. Testing the Ephemeral Gully Erosion Model (EGEM) in Mediterranean environments. Proc. 10th International Soil Conservation Organization (ISCO) Conference: Sustaining the Global Farm. Local Action for Land Stewardship. Purdue University, West Lafayette, Indiana, USA, 23-28 May, 1999.

Poesen, J., de Luna, E., Franca, A., Nachtergaele, J., Govers, G., 1999. Concentrated flow erosion rates as affected by rock fragment cover and initial soil moisture content. Catena, 36: 315-329.

Poesen, J., Nachtergaele, J., Deckers, J., 2000. Gullies in the Tersaart forest (Huldenberg): climatic or antropogenic cause? In: Verstraeten, G. (ed.), Historical and present-day soil erosion processes in central Belgium. Guide of the annual excursion of the Belgian soil science society, June, 14, 2000. Pedologie –Themata, 9: 40-51.

Quinton, J.N. & Rodriguez, F. 1999. Modelling the impact of live barriers on soil erosion in the Pairumani sub-catchment, Bolivia. Mountain Research and Development 19: 292-299.

Regüés, D., Torri, D. Efecto de las Tormentas sobre la Dinámica Superficial del Suelo y su Relación Con La Formación de Cárcavas en Ambiente Mediterráneo. Cuaternario y Geomorfologia (submitted).

Rogel Á. , J.; Martinez-Mena, M.; Albaladejo, J. and Castillo, V. Organic carbon and nitrogen influenced by vegetation removal in a semiarid Mediterranean soil. *Biogeochemistry* (in press).

Rousseva S., D.Torri, M.Pagliai. Effect of rain on the macroporosity at the soil surface. European Journal of Soil Science (accepted).

Stalpaert, L., Poesen, J., Nachtergaele, J., 1999. Gevoeligheid van drie lemige bodemhorizonten voor erosie door geconcentreerde afvoer. De Aardrijkskunde, 3: 11-18

Strauss P. , A. Mentler: Phosphorus transport with sediment particles as affected by the location of rainstorm peak intensity. Proceedings of the OECD workshop on „Practical and innovative measures for the control of agricultural phosphorus losses to water“. Greenmount College of Agriculture and Horticulture, Northern Ireland, 1998.

Strauss P. , A. Mentler: Phosphorus transport with sediment particles as affected by the location of rainstorm peak intensity. Proceedings of the OECD workshop on „Practical and innovative measures for the control of agricultural phosphorus losses to water“. Greenmount College of Agriculture and Horticulture, Northern Ireland, 1998.

Strauss P. , F. Sancho, Ch. Prat, G. Arevalo (accepted for TERRA): Diseño de un sistema de generación de lluvias para la Introducción de datos en el modelo EUROSEM. In press.

Strauss P., F. Konecny, S. Zach: Simulation zeitlich hochaufgelöster Niederschläge für hydrologische Modelle am Beispiel von EUROSEM (European Soil Erosion Model). Mitteilungen der Deutschen Bodenkundlichen Gesellschaft. Submitted

Strauss P., F. Konecny: Using a simple scaling model to generate synthetic rainfall input data for EUROSEM. In preparation.

Strauss P., F.Konecny, W.E.H. Blum: A rainfall generation procedure for the European Soil Erosion model (EUROSEM). Hydrology and Earth System Sciences, 3, 2, 213-222, 1999.

Strauss P., J.Pitty, M.Pfeffer, A. Mentler: Rainfall Simulation for Outdoor Experiments. In: P. Jamet, J. Cornejo (eds.): Current research methods to assess the environmental fate of pesticides. pp. 329-333, INRA Editions, 2000.

Strauss P., J.Pitty, M.Pfeffer, A. Mentler: Rainfall Simulation for Outdoor Experiments. In: P. Jamet, J. Cornejo (eds.): Current research methods to assess the environmental fate of pesticides. pp. 329-333, INRA Editions, 2000.

Strauss P.: Raingen – A scaling model to generate event based rainfall. Concepts and technical description. Institut fuer Kulturtechnik und Bodenwasserhaushalt, Bundesamt fuer Wasserwirtschaft, Petzenkirchen 2001.

Strauss P.: Raingen – A scaling model to generate event based rainfall. Concepts and technical description. Institut fuer Kulturtechnik und Bodenwasserhaushalt, Bundesamt fuer Wasserwirtschaft, Petzenkirchen 2001.

Torri D. and Morgan R..P.C., Modelling within-storm soil erosion dynamics. Presented at European Climate Science Conference, Vienna, 19-23 Oct. 1998, on CDROM.

Torri D., L. Borselli (2001). “Equations for high rate gully erosion”, Catena, (submitted)

Torri D., Regues Munoz D., Pellegrini S. and Bazzoffi P. Within-Storm Soil Surface Dynamics and Erosive Effects of Rainstorms, Catena, 32, 8, 131-150.

Veihe, A. & J.N. Quinton 2000. Sensitivity analysis of EUROSEM using monte carlo simulation: I hydrologic, soil and vegetation parameters. Hydrological Processes 14 (5):915-926.

Veihe, A. Quinton, J.N. & Poesen, J.A. 2000. Sensitivity Analysis of EUROSEM using Monte Carlo simulation: II the effects of rills and rock fragments. Hydrological Processes 927-939.

Zach S., P. Strauss, F. Konecny, W.E.H. Blum (Mitteilungen des hydrographischen Dienstes): Erzeugung von Niederschlagsereignissen für das Europäische Bodenerosionsmodell EUROSEM unter der Verwendung des Bartlett-Lewis-Hybrid-Modells.In press.

paper presentations at conferences

Borselli L., M. Pilar Salvador Sanchis, Marta S. Yañez and D. Torri Dynamics and Properties of Ponding Areas International Symposium “The significance of Soil Surface charcateristic in soil erosion”. 20-22 sept. 2001. Strasbourg

Martínez-Mena, M.; Castillo, V. y Albaladejo, J. “Change in soil and surface properties within-storm in a Mediterranean area of Southeast Spain”. Geographical perspectives on environmental management in Iberia Session. RGS-IBG Annual Conference. Plymouth. England. 2001. Oral Comunication.

Martínez-Mena, M.; Castillo, V. y Albaladejo, J. “Modelling changes in soil erosion parameters during the storm” Third International Conference on Land Degradation Rio de Janeiro 2001. Oral Comunication.

Martínez-Mena, M.; Castillo, V. y Albaladejo, J. "Within storm erosion dynamics in Mediterranean agricultural lands: an experimental design." Third International Congress of The European Society for Soil Conservation. Valencia, España. 2000. Oral Communication

Nachtergaele, J., Poesen, J., 1998. Ephemeral Gully Erosion Assessment for the last 50 Years via High Altitude Stereo Aerial Photographs. Case Study: The Belgian Loess Belt. ESSC-workshop: Long-term Effects of Land Use on Soil Erosion In a historical perspective, Müncheberg, Germany, Sept. 11-13, 1998.

Nachtergaele, J., Poesen, J., 1999. Ravijnerosie en ravijnerosie-onderzoek in de Belgische Leemstreek. Bijeenkomst contactgroep erosie, March 11, 1999. Universiteit Gent, centrum voor eremologie, Gent, België.

Nachtergaele, J., Poesen, J., Oostwoud Wijdenes, D., Vandekerckhove, L. and Roxo, M., 1999. Testing and evaluating the Ephemeral Gully Erosion Model (EGEM) in Southern Europe (SE-Spain and SE-Portugal) and the loess belt (Belgium). Ephemeral gully erosion studies, possibilities of joint research. USDA-NRCS, National Sedimentation Laboratory - Oxford Mississippi, 23-25 August, 1999.

Nachtergaele, J., Poesen, J., Sidorchuk, A., Torri, D., 2001. Flow width prediction for concentrated flow on agricultural fields. Cost 623: 'Snowmelt erosion and related problems'. The Norwegian State Pollution Control Authority (Jordfrosk), Oslo, Norway, 28-30 March, 2001.

Nachtergaele, J., Poesen, J., Steegen, A., Takken, I., Beuselinck, L. and Govers, G., 1999. Ephemeral gully erosion in the Belgian Loess Belt. 2nd Int. Symposium on Tillage Erosion and Tillage Translocation. K.U. Leuven, Belgium, 12-14 April 1999.

Nachtergaele, J., Poesen, J., Steegen, A., Takken, I., Beuselinck, L., Govers, G., 2000. Ephemeral gully erosion in the Belgian loess belt. International symposium on Gully erosion under Global Change, K.U. Leuven, 16-19 April, 2000.

Nachtergaele, J., Poesen, J., Steegen, A., Takken, I., Beuselinck, L., Vandekerckhove, L., Govers, G., 1998. Prediction of soil losses by ephemeral gully erosion using EGEM (ephemeral gully erosion model). Gemeenschappelijke studiedag van de Belgische verenigingen voor bodemkunde en landelijk genie "Studie van bodem en duurzame ontwikkeling". Centre de Recherches Agronomiques, Gembloux, Belgium, November 25, 1998.

Nachtergaele, J., Poesen, J., Vandekerckhove, L., Oostwoud Wijdenes, D., Roxo, M., 1999. Testing and evaluating the ephemeral gully erosion model (EGEM) in Mediterranean environments. 10th International Soil Conservation Organization (ISCO) Conference: Sustaining the Global Farm. Local Action for Land Stewardship. Purdue University, West Lafayette, Indiana, USA, May 23-28, 1999.

Poesen, J., Nachtergaele, J., Vandekerckhove, L., Oostwoud Wijdenes, D., Roxo, M., 1999. Prediction of ephemeral gully erosion in Mediterranean environments. I.A.G. Regional Conference on Geomorphology. University of Rio de Janeiro, Brazil, July 17-22, 1999.

Poesen, J., Nachtergaele, J., Vandekerckhove, L., Oostwoud-Wijdenes, D., 1999. Datasets needed for predicting ephemeral gully erosion under global change. BGRG Rainfall Simulation Working Group Concluding Meeting (Joint Meeting with COST 623 Soil Erosion and Global Change). 18-21 April 1999, Leicester, U.K.

Poesen, J., Nachtergaele, J., Verstraeten, G., Oostwoud Wijdenes D., Valentin, C., 2000. Gully erosion under environmental change. International symposium on Gully erosion under Global Change, K.U. Leuven, 16-19 April, 2000.

Poesen, J., Nachtergaele, J., Verstraeten, G., Vandekerckhove, L., Gyssels, G., 2000. Gully erosion as a missing link in erosion models. COST 623 International workshop on Linkage of Hillslope Erosion to Sediment Transport and Storage in river and Floodplain Systems. Almeria, Spain, 7-11 September, 2000.

Rogel Á., J.; Martinez-Mena, M.; Castillo, V. and Albaladejo, J. The effect of vegetation removal on soil organic carbon losses: a 9 years experiment in semiarid SE Spain. Third International Conference on Land Degradation Rio de Janeiro 2001. Poster.

Torri D. , L. Borselli, S. Pellegrini, M.S. Yanez, M.P. Salvador Sanchis, P. Bazzoffi, L.Gabellini, J. Nachtergaele, J Poesen, J Albaladejo, V. Castillo, M. Mena Experiments and Algorithms for Linear Erosion and their Evolution. International Conference: "Sustainable Soil Management for Environmental Protection: Soil Physical Aspects" Florence, Italy, 2-7 July 2001, Book of Abstracts, page 97.

Torri D., L. Borselli, M.Pilar Salvador Sanchis, Marta S. Yañez Splash-Induced Soil Surface Dynamicsn International Symposium "The significance of Soil Surface charcateristic in soil erosion". 20-22 sept. 2001. Strasbourg.

Web Sites

Some of the material has already been made available to users. Models are at the moment either downloadable from the web (freeware) or consultable on the web:

EUROSEM 4 win:
- http://www.silsoe.cranfield.ac.uk/iwe/erosion/eurosem/eurosem_publications.htm

EUROWISE:
- http://www.geog.uu.nl/lisem

SEI:
- http://www.area.fi.cnr.it/iges/pedone/Pedon_introd.htm
- http://www.area.fi.cnr.it/iges/software.htm

RAINGEN 1:
- http://www.area.fi.cnr.it/iges/raingen/raingen.htm

Distribution of results

Four technical implementation plans have been written, one per software packge. Explanations and development programmes are given there.
Other results such as methodologies are or will be described in scientific papers.
Information on other particular topics developed in the project can be asked directly to MWISED partners as listed below:

Infiltration, Ksat	CNR-IGES
Surface roughness, depression storage, ponding	CNR-IGES, ISSDS, CEBAS, CRANFIELD
Ephemeral gully	KULeuven
Rainfall characteristics	BOKU, ISSDS
Validation data sets for models at field and catchment scale	ISSDS, IIA, CEBAS
Soil erosion models	UU, CRANFIELD
Soil algorithms and pedofunctions	CNR-IGES

The **Project Executive Summary** can be found on the web at the following URL:

http://www.area.fi.cnr.it/mwised

II Partner's Reports

- **CNR - Istituto per la Genesi e l'Ecologia del Suolo (CNR-IGES)**
- **Katholieke Universiteit Leuven (KULEUVEN)**
- **Cranfield University, Silsoe (CRANFIELD)**
- **Consejo Superior de Investigaciones Científicas (CSIC-CEBAS)**
- **Istituto di Idraulica Agraria (IIA)**
- **Institut für Bodenforschung, Universität für Bodenkultur (BOKU)**
- **Istituto Sperimentale per lo Studio e la Difesa del Suolo (ISSDS)**
- **Faculty of Geographical Sciences, Utrecht University (UU)**

CONSIGLIO NAZIONALE DELLE RICERCHE
ISTITUTO PER LA GENESI E L'ECOLOGIA DEL SUOLO (IGES)

REPORTING PERIOD: 1 APRIL 1998– 30 JUNE 2001

Contractor:	**Consiglio Nazionale delle Ricerche – Istituto per la Genesi e l'Ecologia del Suolo**
Responsible scientist:	**Dr. Dino Torri**
Scientific staff:	L. Borselli. M.P. Salvador Sanchiz, E. Sparvoli, L. D'Acqui, C. Calzolari, F. Ungaro, M.S. Yanez.
Address:	Istituto per la Genesi e l'Ecologia del Suolo Piazzale delle Cascine 15-28 I-50144 Firenze, Italy
Telephone:	+39 055 3288290
Fax:	+39 055 321148
email:	dbtorri@iges.fi.cnr.it

WORK CARRIED OUT DURING THE REPORTING PERIOD

Introduction

The IGES group has been involved in experimenting and in producing algorithms for soil surface dynamics, infiltration dynamics and gully generation.
This has brought to the definition of two original methodologies regarding rainfall and runoff simulations. Presently algorithms for random roughness decay and water saturated conductivity (*Ksat*) evolution have been prepared. Regarding ephemeral gully generation a set of theoretical equations have been developed in order to have a scientific background for designing experiments and drawing conclusions. The equations have been coded into a provisional model (GULLYER) in order to appreciate the several feedbacks.

WP1-ST1 – rainfall simulation in laboratory

Methodology and results

The methodology that was set up consists of a series of rainfall simulations conducted over the same soil sample (usually 4-5 rainfalls) (Borselli et al. 2001). Each set of experiment is here referred to as '*history*'. Histories are different because of rainfall characteristics (intensity, energy, and rainfall duration), initial soil moisture content, slope gradient. Soil is always prepared in order to reproduce a fine seedbed (the most risky situation for erosion, and the most dynamic because the surface undergoes the greatest modifications). Each rainfall simulation is complemented by soil roughness measurements taken using a laser profile-meter (Borselli, 1999). During later experiments the evolution of the surface of the ponds was followed by means of images taken with a CCD camera connected to a computer (10-15 images per rainfall). The water used for rainfall simulation is of good quality (conductivity smaller than 20 μm cm^{-1}) because the strong influence on experimental results when tap water is used instead (Borselli et al. 2001).

Soil types

Laboratory experiments on samples collected in field were run in order to gain insight in the processes of soil surface modification under air-dried or field capacity initial moisture content. Soil samples were collected in different areas of Italy. Moreover soil samples (900 kg, ca.) from Belgian Loess were received from KUL Leuven (B) to perform experiments on them.

Table with main properties of examined soil

Soil code	Soil Classification U.S.D.A.	Lithology	Clay %	Silt %	Sand %	O.M. %	pH 1:2.5	Mineralogy
ORCIA 31	*Chromic Calcixerert*	Pliocene Clays	53.85	40.70	5.45	2.50	7.40	Vermiculite, Clorite, Kaolinite, Interst. Mi-Sm.
ORCIA 30	*Typic Xerorthent*	Pliocene Clays	53.40	45.50	1.10	2.20	8.30	Clorite,Smectite,Illite, Q,F,C
FAGNA	*Typic Eutrochrept*	Olocene depos.	23.00	42.70	34.30	1.60	7.90	Mica,Vermiculite,I-V,Illite,Kaolinite,InterstCl-Sm
VICARELLO	*Vertic Xerorthemt*	Pliocene Clays	42.00	43.00	15.00	0.50	8.20	Mica,Vermiculite,Illite,Clorite,Kaolinite,InterstMi-Sm.
LOVANIO	*Haplic Luvisol*	Loess	10.00	78.00	12.00	0.42	7.80	Mica, Kaolinite, Interst. V-Sm (disordinato)
SARDO	*Ranker*	Methamorphic rocks	8.00	43.80	48.20	7.04	4.69	
SINORG	*Sulfic Endoaquepts*	Deltaic deposits	16.00	40.00	44.00	9.90	7.60	Smectite, Clorite, Mica, Interst. Cl-Sm.
SINMCB	*Aquic Ustochrept*	Alluvial deposits	17.00	66.00	17.00	1.20	7.90	
SINRNV	*Udertic Ustochrepts*	Alluvial deposits	35.00	57.00	8.00	2.40	7.40	

Measurements of the Saturated Conductivity of topsoil sealing crust

The evolution of saturated conductivity (Ks) during the progress of each history was examined using a constant head permeameter and samples of surface crust collected from the plots at different stages of the rainfall test/histories. The surface crust (irregular form in section view) have generally a depth variable from 0.5 to 1 cm. a special technique allow to insert the sample inside a standard steel cylinder and seal the contacts with steel using silicon and complete the filling of the cylinder using coarse quartz sand (fig. IGES_1).

Two type of crust were examined: 1) the deposition crust made by accumulation of splash detached particles and interrill-overland-flow transported particles in local depressions and 2) the erosion crust formed in non submerged areas which were continuously subject to drop impact.

For some soil a complete evolution of Ks was drawn (Fig.IGES_2). Generally we observed a very rapid decay from the initial Ks values (typical of soil matrix of the Ap horizon far from the soil surface, hence not exposed to the direct effect of rainfall.

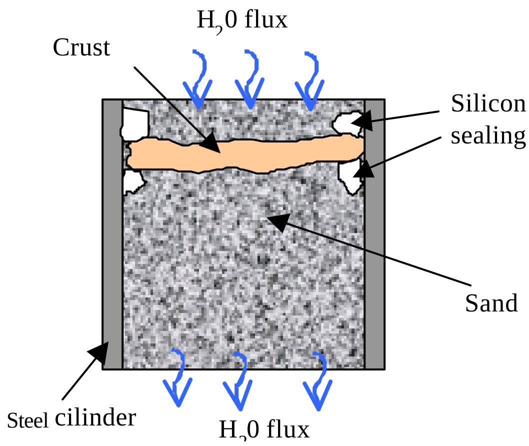


Fig. IGES_1: Sample preparation for the measurement of saturated conductivity of surface sealing crust

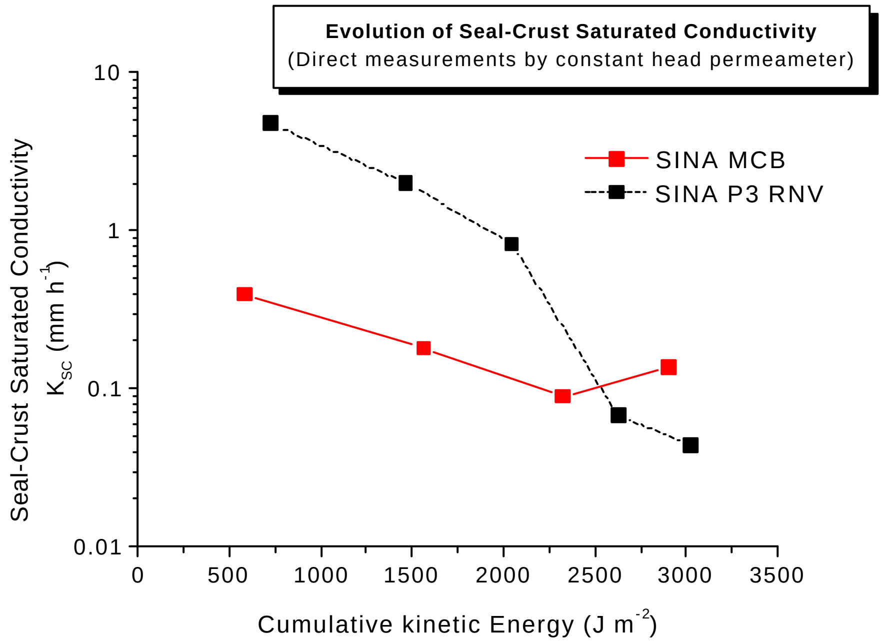


Fig. IGES_2: sample graph on the evolution of the saturated conductivity of surface sealing crust of two studied soils

Porosity

The original planned activity was the collection, at the end of each rainfall simulations, of samples for porosity measurements. This part has undergone a series of modification along the way because of accidents and because of initially poor results. Two lines were initially investigated: 1) identification of the pore size at which crusts are perforated through all its thickness, and 2) 3D reconstruction of the pore system to identify (applying techniques such as ‘percolation’) parameters relevant to the hydraulic behaviour of the soil.

The first approach was deluding because pore size resulted to be within 8 and 12 micron with no apparent dynamics. The second approach was extremely time consuming and the resolution imposed be the machinery (38 micron) resulted to coarse for appreciating real dynamics. Hence it was decided to turn to a more classical approach, through the examination of pore size distribution (from 30 micron up) in samples collected at different times during a succession of rainfall simulations. The results (accepted for publications in the European Journal of Soil Science) are shown in the graph below (Fig. IGES_3). The first graph refers to the decrease of one type of pores (the elongated one, which is the only type exhibiting any dynamics). The equations ruling the process are those by Panini at al (1997) modified for accounting the fact that one parameter, originally assumed to be constant, is actually varying. The second graph describes the evolution of the exponent (the fractal dimension) of the pore volume. Higher values indicate better spatially distributed pores. This also means that pores are much smaller and more disconnected, hence water fluxes are reduced.

The leading equations are:

$$\Delta P = a\,\frac{a\left[P_{\mathrm{EL},0} + P_{\mathrm{EL},1}\{1-\exp(-k'_{\mathrm{E}}\,E)\} - P_{\mathrm{ES}}\right]}{\ddot{a}}\,k_{\mathrm{S}}E + (1-a)P_{\mathrm{ES0}}\{1-\exp(-k_{\mathrm{E}}E\}$$

which represents the reduction of elongated porosity which is driven by rainfall kinetic energy (E), soil detachability (ks) and other parameters reflecting initial pore system characteristics; and

$\Delta D_V = a\,E + b\{1 - \exp(-c\,E)\}$ in the upper 0-3 cm depth and
$\Delta D_V = b\{1 - \exp(-c\,E)\}$ in the lower 3-6 cm depth

where

$N_{>d} \propto d^{(1-D_V)}$,

where $N_{>d}$ is the smallest number of pixels with size d that cover the area occupied by pores (i.e.. it describes pore size distribution).

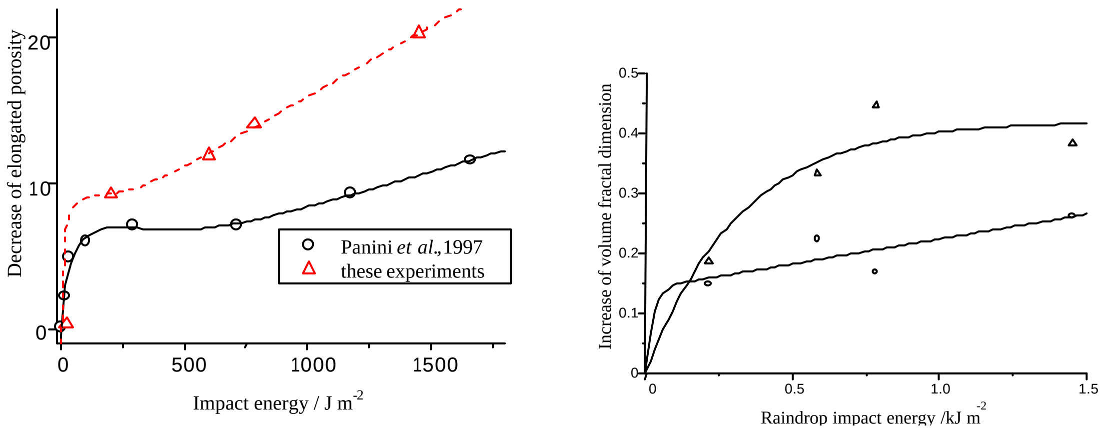
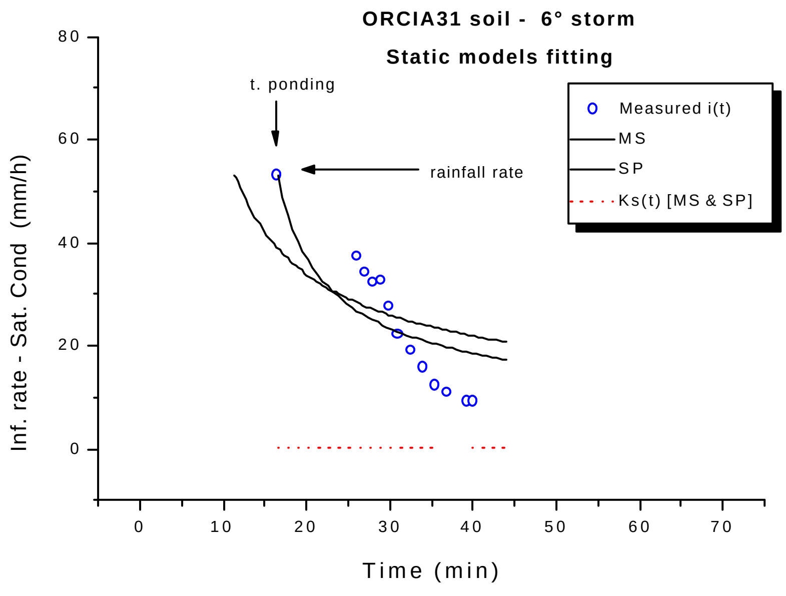


Fig.IGES_3: Decrease of elongated porosity – lines are calculated using a modified Panini et al. (1997) model; Dynamics of the fractal dimension of the pore system while crust develops.

Infiltration models

The processing of rainfall simulation data clearly showed the inadequacy of Smith and Parlange (SP) infiltration equation (Smith & Parlange 1978) used in the previous EUROSEM model (Morgan et al. 1998). In order to make it able to describe the observed behaviour all the variance was attributed by final infiltration rate (variation of the effective Ksat parallel to SP infiltration equation) which is unrealistic. When the soil is dry sorptivity is important and cannot simply disappear. Morel-Seytoux (MS) equation (Morel-Seytoux & Verdin, 1981) seems to perform much better and the MS infiltration curve is not the same as the Ksat curve. It suggest the substitution of the SP equation. Practically, the SP equation posticipates time-to-ponding and underestimate final infiltration rate or, viceversa anticipate time-to-ponding and overestimate final infiltration rate. In the former case runoff is strongly overpredicted while in the latter it is underpredicted. This is due to the structure of the equation which makes it 'rigid' (time-to-ponding and final infiltration rate being too strictly related) and always simulating fast infiltration rate decays. Examples are given in FIG.IGES_4, relative to some experiments conducted during this project. The same techniques were applied to data collected during a previous project in which EUROSEM was developed. (FIG.IGES_5)

Infiltration is clearly well represented when saturated hydraulic conductivity (and connected parameters, such as net capillary drive) are allowed to vary (Fig.IGES_8).



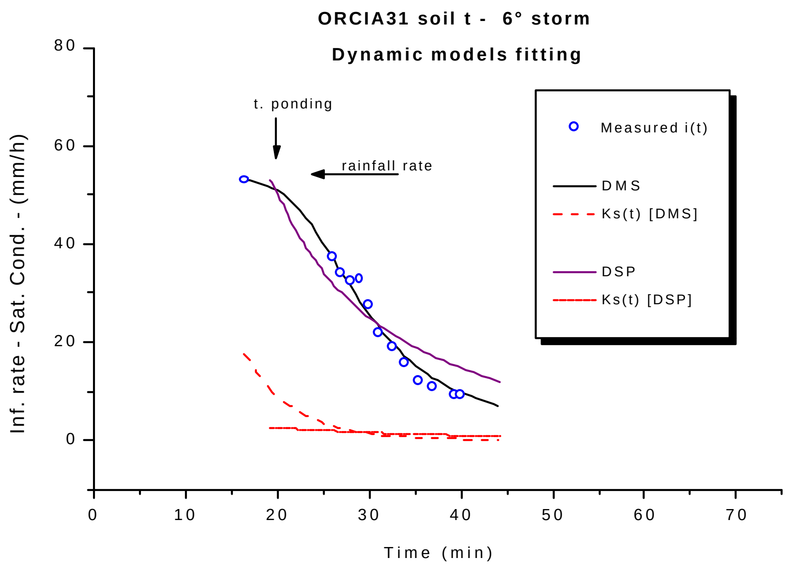


FIG. IGES_4: Non Linear fitting (Borselli, 1998) of Smith and Parlange (1978) and Morel-Seytoux & Verdin (1981) equations using both static and dynamic approaches for two soils.

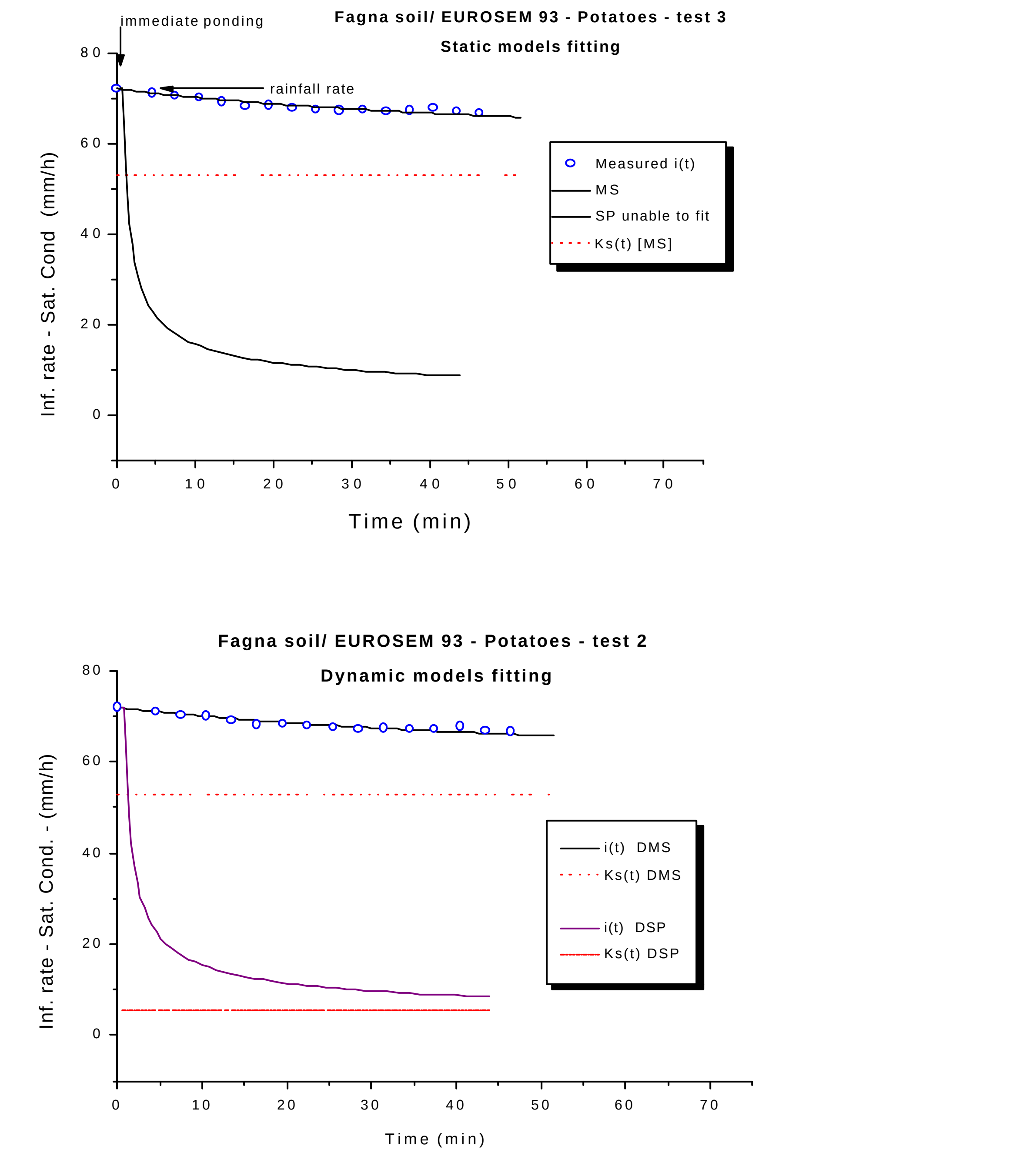


FIG. IGES_5: The same techniques shown in FIG.IGES_4 were applied to data collected in previous experiments.

The Morel-Seytoux & Verdin (1981) equation as infiltration routine

The Morel-Seytoux & Verdin (1981) infiltration model has been adopted as basic equation in an inversion procedure to derive the main soil hydraulic parameters of the studied soils; and as additional infiltration model in the both EUROSEM and EUROWISE codes.

The Basic Soil parameters considered in the model are:
G = net capillary drive or wetting front suction as in Mein-Larson /Green-Ampt models (in mm)
K_s = saturated conductivity (in mm/h)

A composite parameter B is defined as:

$$B = G(q_s - q_i) \qquad [1]$$

(as in Smith-Parlange model (1978)) where:
$(q_s - q_i)$ is the initial water deficit with respect the natural saturation

The model applies once time to ponding (defined as the instant at which the rainfall intensity is equal to the infiltration capacity in soil) is reached.

If *r(t)* is the ietograph (in mm/h) then ponding at time (*t*) occur when the following equation is verified (Mein & Larson,1973, Morel-Seytoux & Verdin 1981):

$$t_p = \frac{K_s B}{r(t)^2 - K_s r(t)} \qquad [2]$$

in this case t = t_p= time to ponding (in hours).

for a constant rainfall of intensity r (rainfall simulation experiments):

$$t_p = \frac{K_s B}{r^2 - K_s r} \qquad [3]$$

for a variable rainfall equation (3) the following equation must be verified at each time step

$$t_p = \frac{K_s B}{\bar{r}^2 - K_s \bar{r}} \qquad [4]$$

where $\bar{r}$ is the average rainfall since rainfall start until ponding occur:

$$\bar{r} = \frac{1}{t_p}\int_0^{t_p} r(t)dt \qquad [5]$$

Eq.(2) shows some difference with the time to ponding calculated in the previous version of EUROSEM (which used only Smith & Parlange, 1978) where:

$$t_p = \frac{G\Delta q}{r}\ln\left(\frac{r}{r-K_s}\right) \qquad [6]$$

In the in the following graphs the functions (2,6) are compared with the help of two auxiliary and composite parameters:

$$a = \frac{G(q_s - q_i)}{r} \qquad \text{(in h)} \qquad [7]$$

$$b = \frac{r}{K_s} \qquad \text{(adimensional)} \qquad [8]$$

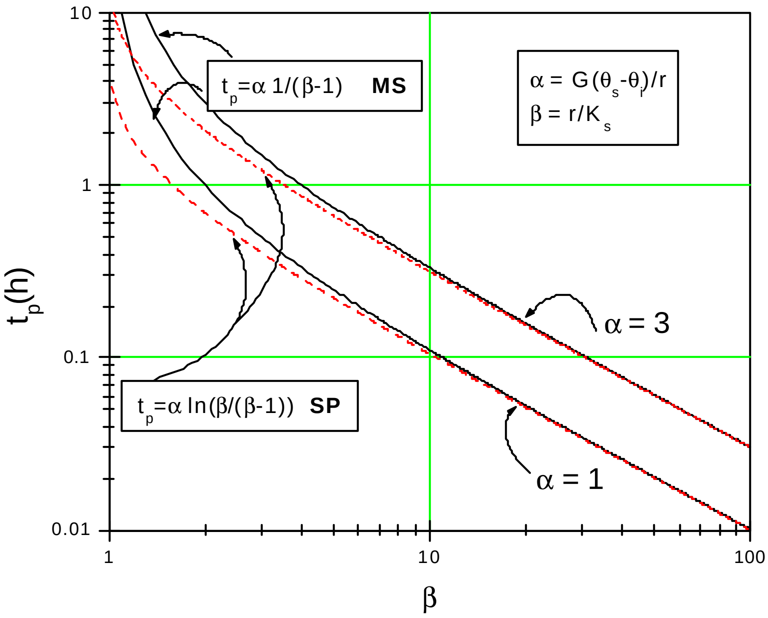


Fig.IGES_6. comparisons between time to ponding as calculated and Morel-Seitoux & Verdin(1981) in eq.(2a), by Smith & Parlange (1978) equation (SP) in eq.(2e).

Infiltration after ponding

if $r(t) > k_s$ then

$$i(t) = \frac{1}{2}\sqrt{\frac{2K_s(B+I_p)^2}{B}}\left(\frac{1}{\sqrt{t-t_p+A}}\right)+K_s \qquad [9]$$

where A is a composite parameter given by:

$$A = \frac{\left(B + I_p\right)^2}{2K_s B\left(\frac{r(t)}{K_s} - 1\right)^2} \qquad [10]$$

and

$$I_p = \int_0^{t_p} r dt \qquad [11]$$

is the cumulative infiltration until the ponding time.

Dynamic form of the eq. (9)

The dynamic behaviour of MS equation is introduced by a time variable Ks that represent the evolution of a sealing surface by the formation of sedimentary crusts and porosity reduction during a storm over the hydrologic history of the soil.

The evolution of the $Ks(t)$ follows a sigmoidal-shape decay curve as theoretically and experimentally derived by some authors (Mualem & Assouline 1990). In our case it is represented by a four parameters hyperbolic tangent function:

$$Ks = Ks_0 - (Ks_0 - Ks_f)\tanh(kt^a) \qquad [17]$$

where:

Ks_0 is the initial value of *Ksat*

Ks_f the final value of *Ksat*

k, a , best fitting coefficients

Aggregate stability

A technique for measuring aggregate characteristics, which was first defined during a previous EU project, then partly refined during an Italian project, has been re-examined and the methodology completely defined. It has been used for measuring the stability of aggregates for the soil used in the laboratory tests and some other experiments have been made for characterising other two soils whose infiltration data will be used for these project. A series of decay curves are shown in FIG.IGES_7.

The data show that the decay constant is related to several soil parameters such as sealing formation rate and hydraulic conductivity decay. Presently no clear trend has been isolated yet, hence the use of this parameter is still under judgement.

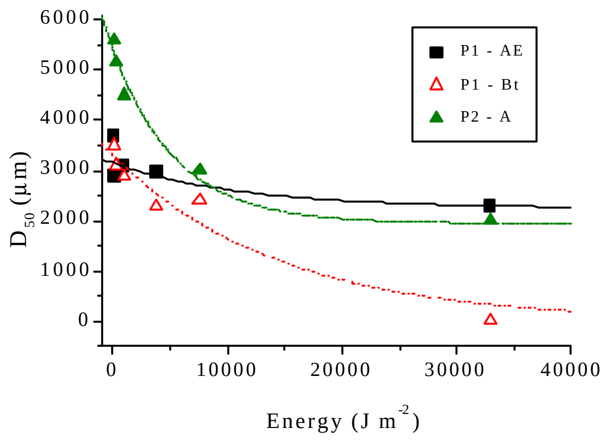


FIG.IGES_7: decay of the aggregate median size with applied energy for different soils and soil horizons.

Effects of water quality

The effect of water quality on erosion and runoff generation has been explored for a series of reasons: 1) the importance of dispersion and of the weakening of soil particle bonds is usually ignored 2) if dispersion is important than soil parameter values measured with rainfall simulation techniques based on tap water must be abandoned.

The study was conducted comparing soil behaviour on two soil types with tap and good quality water. The effects are shown in FIG.IGES_8 and are self commenting. It seems that erosion is 3 times larger when good quality water is used. This means that most of the input data suggested for models represent underestimation, which can be counteracted by the usually poor sedimentation routines.

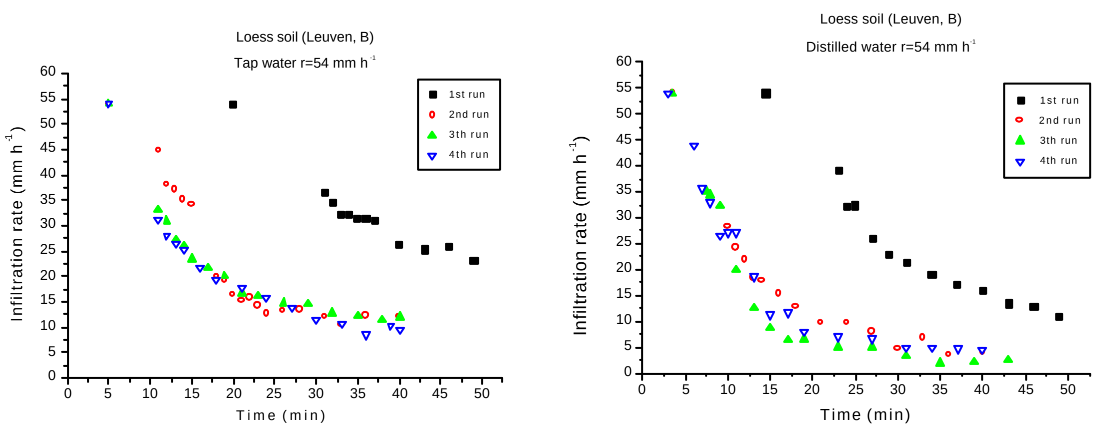
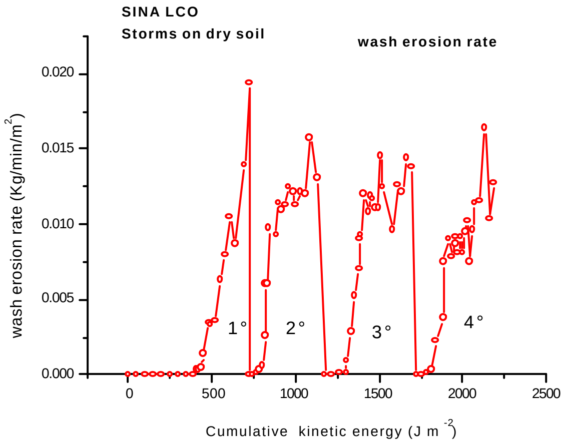


FIG.IGES_8: effect of the chemistry of artificial rainfall on infiltration: time to ponding and final infiltration rates are reduced when good quality water is used.

Dynamics Modelling of Surface Processes

In order to give a unitary view to all the data collected a model was devised for interrrill erosion. It was that developed into a software for extracting erodibility values from experiments. It includes detachment in microheights, deposition and erosion in microlows, effects of local slope gradient, expansion of ponded areas (water cushion effect on detachment), decrease of roughness (an consequently of local slope gradient value).
The aim is that of using detachment rate as a best fitting parameter in order to obtain the correct final roughness and measured net sediment export rate graph.
The variations of soil detachability will be used to suggest mean erodibility values varying following storm duration and soil surface conditions (FIG.IGES_9,10,11).



FigIGES_9: soil loss in a series of 4 successive rainfall experiments.

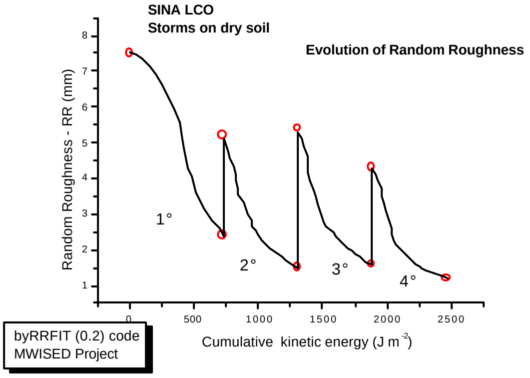


Fig.IGES_10: The line represents the calculated variation of random roughness during the 4 rainfalls (Fig. CNR.2). The circles are the measured RR values.

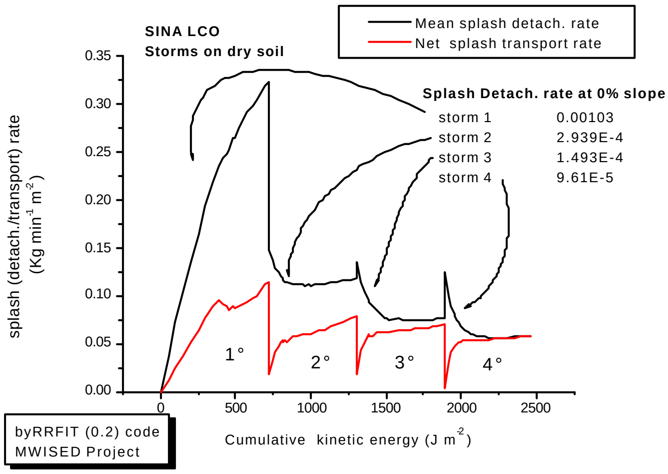


Fig.IGES.11: calculated soil detachability

FIGG.IGES_12 and 13 show the dynamics of surface sealing. It has effect on Ksat and on other surface characteristics that influences soil erosion (e.g. Manning's *n*).

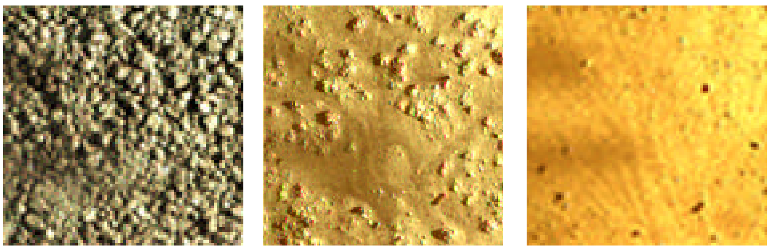


Fig.IGES_12: series of pictures of sealed surface as it expands while roughness is flattened

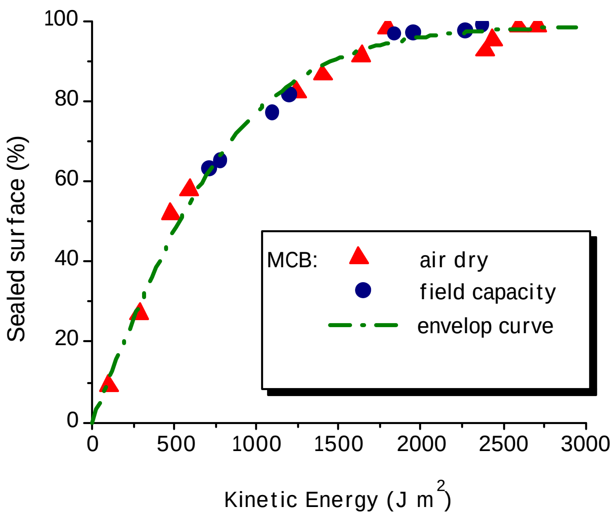


Fig.IGES_13: variation of sealed surfaces during successive rainfall on the same soil surface.

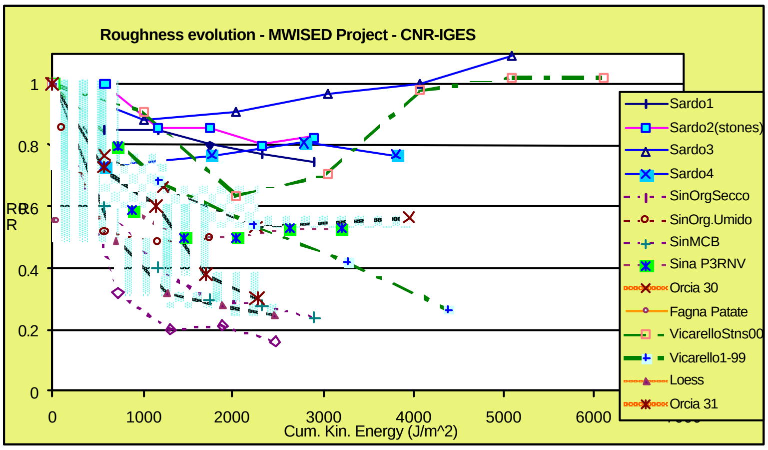


Fig.IGES_14: Random roughness decay for various soils and initial moisture conditions

Random Roughness was examined for 14 soils at different moisture initial conditions.
The results showed in Fig. IGES_14 indicate the existence of a set of conditions as exemplified in Fig. IGES_14

Relative RR decreases with speeds, which belong to 3 main domains. The more resistant group includes skeletal soil. The intermediate group includes soils on which rain fell when they where fairly wet. The third group contains soils unstable or initially air-dried.

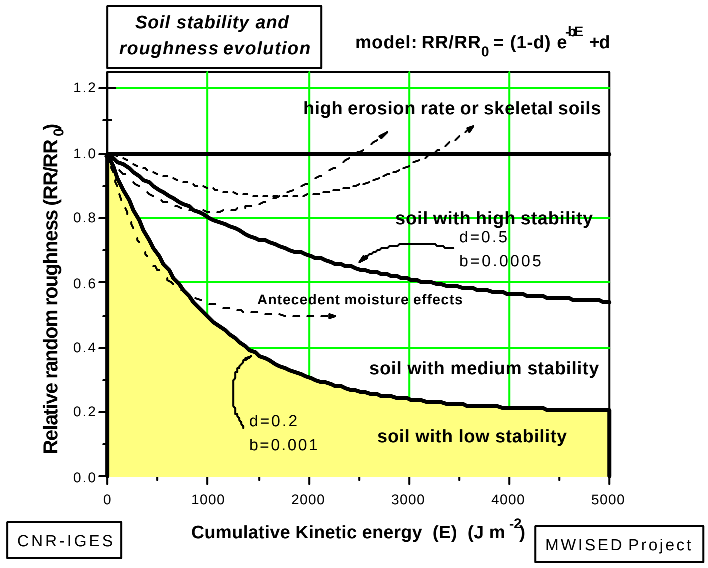


Fig.IGES_14: Suggested subdivision of RR decay in classes

WP2

Gully Generation model
An original model for rill and gully evolution was developed during the second year of activity. The basic equations on which it is based are:

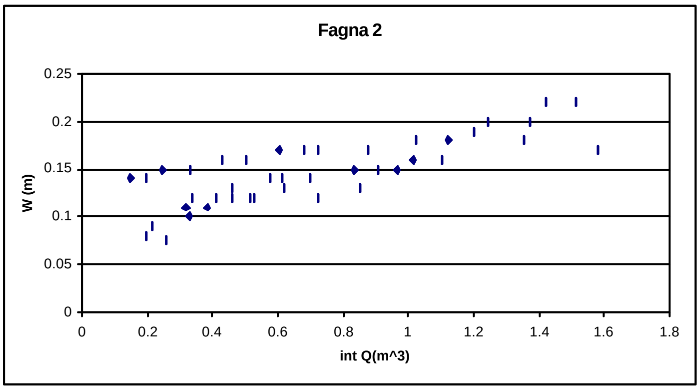
$$\frac{\partial W}{\partial t} = \frac{2k_s\left(e_f\, p - p_{cr,s}\right)}{r} \qquad (1)$$

$$\frac{\partial D}{\partial t} = \frac{1}{r} k_B \left(p - p_{cr,b}\right) - D \frac{\partial W}{\partial t} - s_L U_{sed} \Rightarrow$$
$$\Rightarrow \frac{\partial D}{\partial t} = \frac{1}{r} k_B \left(p - p_{cr,b}\right) - \frac{2}{r} k_S \left(e_f\, p - p_{cr,s}\right) D - s_L U_{sed} \qquad (2)$$

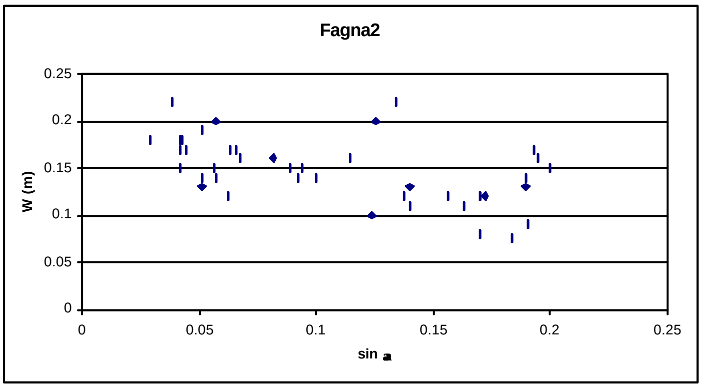
where D is channel depth, W is channel width, k_S and k_B are erodibilities of the side-walls and of the bed, p is flow shear stress $p_{cr,s}$ and $p_{cr,b}$ are threshold shear stress values needed to detach every type of grain or aggregate respectively from the walls and from the bed, e_f is the efficiency of p to erode the wall (generally if 1 is the efficiency for bed/thalweg erosion then the efficiency on the wall is smaller), s_L is sediment load and U_{sed} is sedimentation velocity in turbulent flow.
The terms kB and $p_{cr,b}$ are not proper constants: they vary following the time-dependent fraction of the bed that is covered by sediment deposited from the water, the fraction covered by wall sediment, and the fraction of bed where bed material outcrops.
The two equations cannot be solved explicitly for the general situation. Only solutions valid in particular cases can be analytically derived. Some are shown in the enclosed manuscript (presented at the Gully symposium in Leuven and presently submitted to Catena). The most interesting of these cases is when the channel section is completely inside the upper uniform soil horizon. If erosion is very intense (practically no deposition in the channel - The few experiments with deposition were removed from the pool) then width must grow proportionally to channel depth. This is what happens in all the experiments.
For this special cases D and W must grow proportionally to cumulated flow shear stress. And this has been verified in all the tested soil. The key to get the linear relationship is that erosion occur when the flow is able to express a shear stress larger then $p_{cr,b}$ over a minimum width W_0.

Validation of the equations
A set of field experiment was programmed in order to collect observations and data for gully generation. The methodology was set up in Vicarello during the 2nd year of the project. Beside the field runs, a set of experiments was conducted in the laboratory. The methodology was set up as similar as possible to the one decided for field experiments.- Then other observations were added while learning during experiments.
The data obtained showed that the relationships envisaged by the model hold well (FIG.IGES_15)

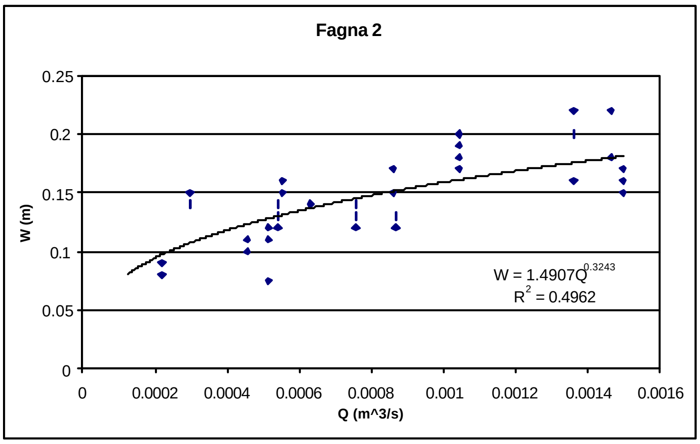
The data have been examined firstly as discussed by the KULeuven team. Width and slope are practically independent. Also W-W0 does not show any strict relationship with slope. The slope that has been used here is not the slope at which the flume was positioned but the slope inside the channel. Slope inside the channel resulted extremely variable (bot temporally and spatially) so it was used the average slope of the channel over 1.1 m where 3 control sections were positioned. Each width and depth is the average value over the three sections.
It can be stated that the degree of similarity with the field trends observed by the KULeuven is acceptable and confirm the reliability of the laboratory experiments.



A)



B)



C)

FIG.IGES_15:
A) Width versus the total volume of runoff (int Q; where int meant integral)
B) Width versus slope in the channel – if slope of the flume was used instead of channel slope then the data plot uniformly everywhere.
C) Width versus total discharge

Other experiments allow the collection of a selected series of data representing the following conditions: a) erosion>>deposition or deposition in the bed negligible; and b) cross section completely included into one uniform soil layer.

Then equations (1) and (2) tell us that both D and W must vary proportionally to the time-integral of shear stress (minus critical shear stress):

$$W - W_0 = \frac{2k_S e_f}{r}\int\left(p - \frac{1}{e_f}p_{cr}\right)dt \qquad (3)$$

$$D - D_0 = \frac{k_B}{r} \int (p - p_{cr}) dt \qquad (4)$$

Equation (4) is valid only when removal of wall collapsed material is very quick.
Under these circumstances we obtained the results shown in Fig. *IGES_16*, which substantially confirm the theory.

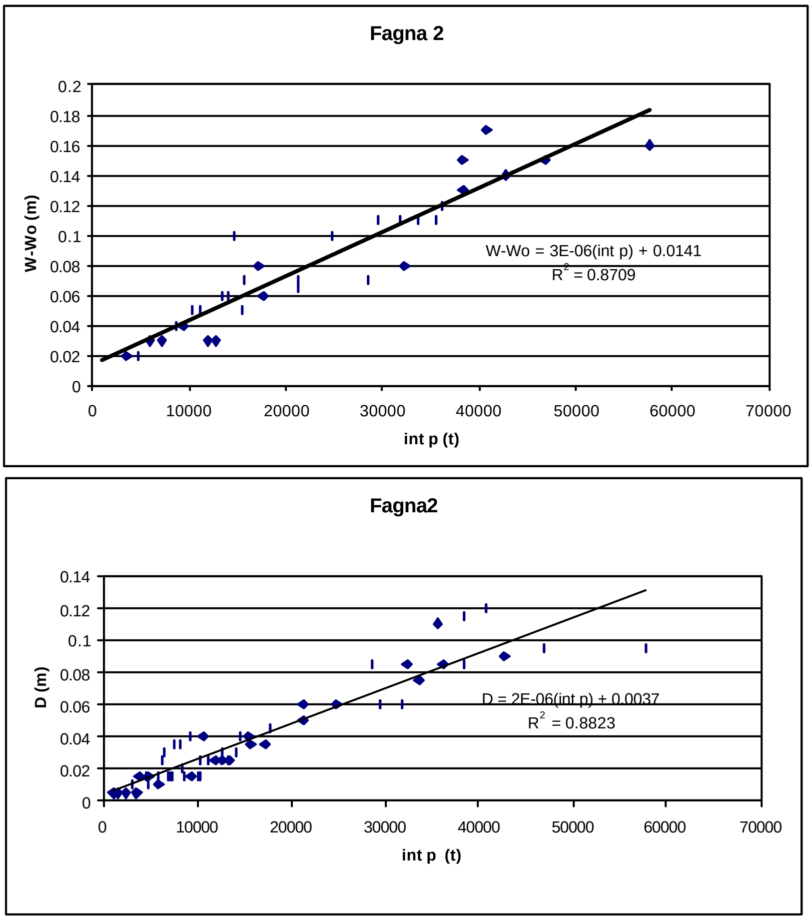


FIG.IGES_16: W-W_0 versus cumulated shear (int p); D versus cumulated shear

During the experiment flow velocity, discharge and slope values were measured and can be used to test Manning equation during intense erosion (mobile-erodible bed). If we take hydraulic roughness as constant and we calculate velocity, we can compare it with the measured one (FIG. IGES_17).
A better agreement is obtained when the velocity is compared with total and unit discharge (FIG.IGES_18)
Consequently, from now on we will use the equation relating velocity to unit discharge fore the further developments.

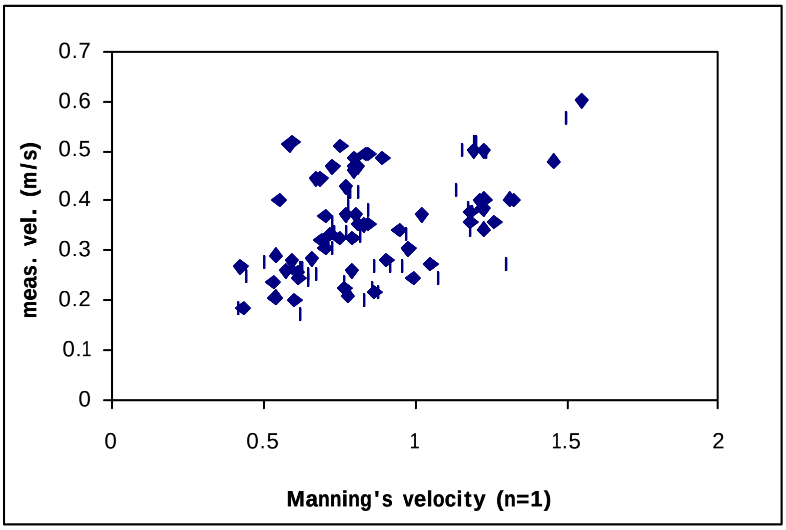


FIG.IGES_17: velocity versus Manning's.

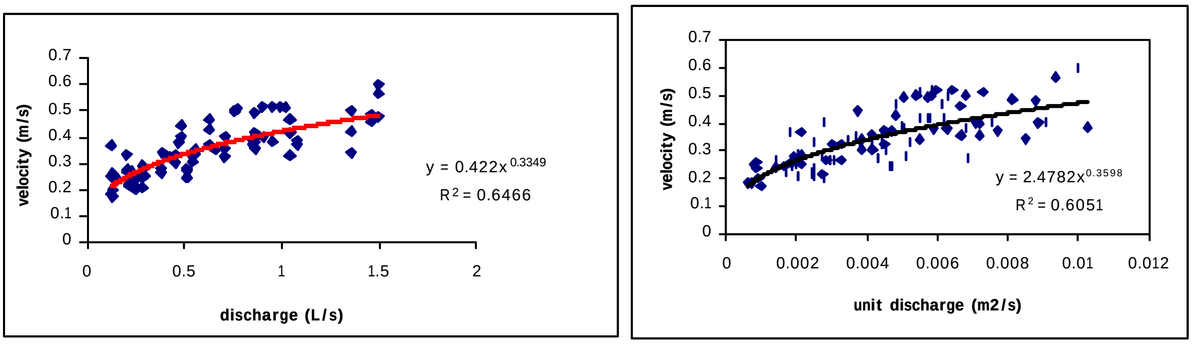


FIG.IGES_18: velocity depends only on discharge. Slope is probably counteracted by modifications of Manning's n running in the opposite direction (in agreement with Govers'interpretation, see one of his paper on Earth Surface Processes).

Towards field conditions

In order to validate the trends obtained in the laboratory we came through a simulation based on the laboratory-validated formula and we projected the trends to the condition DW=0.1 m^2 at which it is more or less considered an incision to be a gully (i.e. about one square foot). This simple relationship was used:

$$Q = I_{eff} A$$

where Ieff is rainfall intensity minus infiltration and storage, and A is catchment area. Initial width was calculated according to this empirical equation derived from experiments:

$$W_0 = 0.15 - 0.3 \sin a \qquad (5)$$

From this, using our regression equations, we calculated catchment areas (A) in order to get about the threshold (0.1m^2± 5%). The results are shown in the Fig. IGES_19.

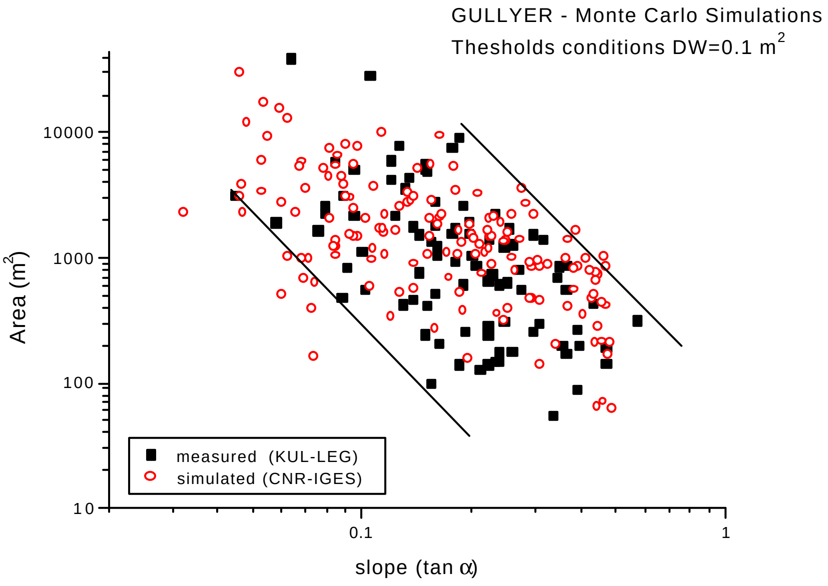


FIG.IGES_19: bilogarithmic representation of catchment area vs. slope relationship.

Simulation condition:

- Unit disharge q (m^2/s) : 0 – 0.1 (uniform distribution)
- Sin a : 0.03 – 0.5 (uniform distribution)
- ΔT (s) : neg exponential distribution – min 300 mean 900
- I_{eff} (mm/h) : neg exponential distribution – min 1 mean 30
- $D_{\max} = 0.5\ (m)$
- $W_0 = 0.15 - 0.3 \sin a \ \ (m)$
- *a (sidewall erosion efficiency coefficient):* : 5E-06 – 1E-05 (uniform distribution)
- *b (bottom erosion efficiency coefficient):* : 3E-06 – 5E-06 (uniform distribution)

threshold condition are satisfied when:

$$\frac{-W_0 b + \sqrt{W_0{}^2 b^2 + 0.4ab}}{2ab} = 9810(0.395q^{0.64}) \sin a \Delta T$$

for each threshold identified S (critical area) is calculated with:

$$S = q * W * \frac{36000000}{I_{eff}} \qquad (m^2)$$

Threshold conditions is retained when $\frac{\sqrt{S}}{\Delta T} < 0.1$

WP4:
As stated in the programme of this project, a package of pedoalgorithms has to be developed. Hence we co-operated with another CNR-IGES group involved in pedofunction validation for the soil database of the Region Emilia-Romagna. This allowed us to obtain some basic pedofunction such as those for Ksat and net capillary drive. We developed a Java applet (Soil Erosion Interface – SEI) which can be used directly from IGES web site.

At present only the most classical part (hydraulic pedofunctions) is fully operational.
The new part is more ambitious and aims at extending the hydrological part and adding soil surface and soil erodibility sections. Despite the new part looks much more than the already achieved part this is not true because all the buttons are already in the applet and most of the algorithms has already been calculated.
The results of the work described in this report and of the part of the job done by CEBAS, ISSDS and KULeuven will also be incorporated in SEI.

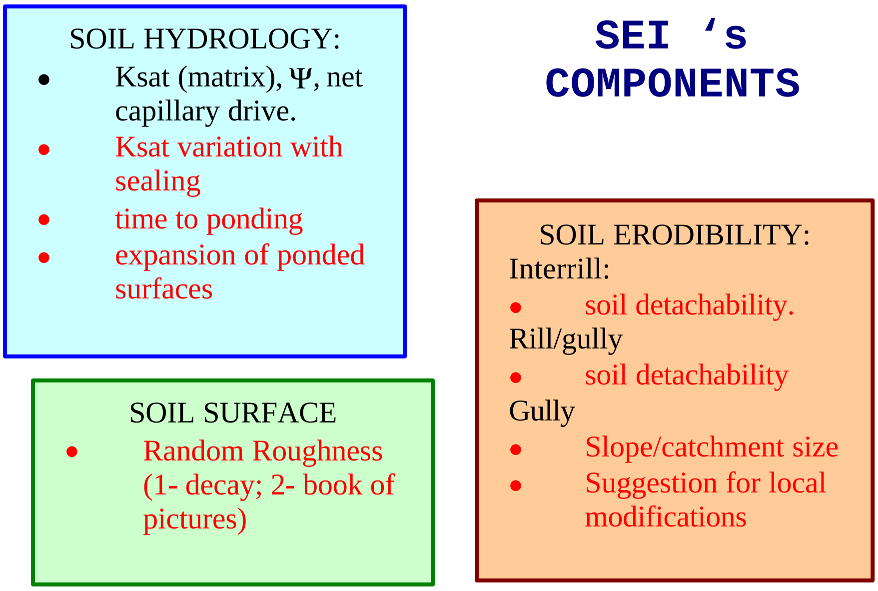


Fig.IGES_20: SEI sketch – red lines indicates parts presently under implementation.

Achievements:
1) a model for describing large part of the processes involved in interrill areas
2) a model for Ksat temporal changes
3) a model fir high-rate rill/gully erosion
4) a computer applet (Soil Equation Interface) for input value (to be completed)

Papers Submitted:
- D.Torri, L. Borselli (2001). “Equations for high rate gully erosion” (submitted, Catena, Elsevier)
- S.Rousseva, D.Torri, M.Pagliai. Effect of rain on the macroporosity at the soil surface. European Journal of Soil Science (accepted).

- L. Borselli, M.P. Salvador Sanchis, M.S. Yanez, D. Torri. “La dinamica degli orizzonti di superficie nel bilancio idrologico del suolo” Available on the Web site of the Regione Emilia Romagna. (PDF format): http://www.regione.emilia-romagna.it/sigeografici/testi/car_suoli/documenti/pdf/soil_surface_dynamics.pdf

Conferenceces:
Presentations for the Symposium on Gully Erosion under Global Change, 16-19 April 2000, Leuven, Belgium:

- Torri D. and Borselli L. – Further equations for high-rate gully erosion
- Borselli L., Pellegrini S., Bazzoffi P., Castillo V., Nachtergaele J., Poesen J., Sardo V. and Torri D. – Field experiments for gully initiation

Participation at Internetional Symposium “The significance of Soil Surface charcateristic in soil erosion”. 20-22 sept. 2001. Strasbourg

- L. Borselli & D. Torri, M. P. Salvador Sanchis, M. S. Yañez Dynamics and properties of Ponding Areas. (oral Presentation).
- D. Torri.L. Borselli, M. P. Salvador Sanchis, M. S. Yañez. Splash-induced Soil Surface Dynamics. (poster presentation)

Other conference presentations:

- Torri D. and Morgan R.P.C., Modelling within-storm soil erosion dynamics. Presented at European Climate Science Conference, Vienna, 19-23 Oct. 1998.
- Torri D., Borselli L., Calzolari C., Salvador Sanchis M.P., Yanez M.S. – Soil erosion, soil qualities and functions. Prersented at the 3rd ESSC Symposium, 27 March – 1 April 2000, Valencia, Spain.

Published:

- Torri D., Regues Munoz D., Pellegrini S. and Bazzoffi P.(1999).Within-Storm Soil Surface Dynamics and Erosive Effects of Rainstorms, Catena, 32, 8, 131-150.
- L. Borselli. (2001). “Capacità di invaso idrico superficiale: dinamica, misura e stima”. Riv. di Irr. e Dren. 48(2):13-20
- L. Borselli, D. Torri, J. Poesen, P. Salvador Sanchis (2001). “Effect of water quality on infiltration, runoff and interrill erosion processes during simulated rainfall. Earth Surface Processes and Landforms, 26:339-342

References

Borselli L., 1998: Soil surface roughness dynamics and its influence on infiltration processes: experimental analysis and modelling. Ph.D thesis. dept of soil science. University of Florence. (in italian).

Knighton D., 1996. Fluvial forms and processes. Arnold, Hodder Headline Group, London, 8th impression, 218 p.

Morel-Seytoux H.J., Verdin J.P., 1981. Extension of the Soil Conservation Service Rainfall-Runoff Methodology for Ungaged watersheed. Federal Highway Adminsitration, Environmental Division Washington D.C. Report No. 81-10.

Sidorchuk A. 1998. A dynamic model of gully erosion. NATO-ASI series, Vol. 155,Springer Verlag, Berlin, 451-460.

Smith R.E., Parlange J.Y, 1978. A parameter-efficient hydrologic infiltration model. Water Resource Research. 14(3):533-538.

Whitehouse D. J., 1994. *Handbook of surface metrology*. Institute of Physics Publishing. Bristol. pp. 998.

FINAL REPORT K.U. LEUVEN
(PERIOD: 1ST APRIL 1998 – 30TH JUNE 2001)

1. PRESENTATION

Contractor: **Katholieke Universiteit Leuven (K.U. Leuven)**
Responsible scientist: **Prof. Dr. Jean Poesen**
Scientific staff: Drs. Jeroen Nachtergaele
Technical staff: Patriek Bleys (01-01-1999 – 31-12-2000)
Address: Laboratory for Experimental Geomorphology
Redingenstraat 16
B-3000 Leuven, Belgium
Telephone: +32 16 32 64 25/26
Fax: +32 16 32 64 00
email: jean.poesen@geo.kuleuven.ac.be
jeroen.nachtergaele@geo.kuleuven.ac.be

2. MAIN WORK CARRIED OUT DURING THE REPORTING PERIOD

A) list of activities subdivided per WP and Subtask

1 Work package 1 (WP1) Within-storm changes in infiltration

1.1 Subtask 3 (ST3)

A data set on the impact of surface roughness on hydraulic roughness using flumes of variable bed roughness and slope and collected previously by K.U. Leuven and CNR has been compiled to increase the existing database.

1.2 Subtask 4 (ST4)

K.U. Leuven has been sending loess soil samples from Belgium to CNR that has been tested intensively for establishing infiltration characteristics and particularly the effect of rainwater quality on runoff and erosion response of topsoils.

1.3 Subtask 5 (ST4) Algorithm development

K.U. Leuven has provided input in the discussion on the development of a new algorithm to describe the within-storm changes in surface depression storage in relation to the decay in surface roughness.

2 Work package 2 (WP2) Development and evolution of ephemeral gullies

2.1 Subtask 1 (ST1) Field inventories

Three data sets on topographical thresholds for locations in the landscape where ephemeral gullies start and end in intensively cultivated lands in Central Belgium, have been collected by K.U. Leuven. One field campaign was conducted at the end of February and the beginning of March 1998 (table

1). During this field survey 10 ephemeral gullies, that developed during the winter season (winter gullies), were assessed. A similar field campaign was conducted one year later, i.e. March 1999. During this campaign 18 ephemeral gullies have been assessed. A third field campaign was conducted in June 1998. This campaign resulted in another 14 ephemeral gullies (summer gullies). Out of these 14 summer gullies, 5 were assessed east of Leuven and 9 west of Leuven. All 14 gullies formed during an intense rainfall event that took place on June 6th 1998, but, as shown in Table 1, total rainfall depth on this day differed significantly from area to area.

Date of survey	Number of gullies surveyed	Date of causative Rainfall event	Causative rainfall (mm) Max. Daily rainfall
Feb.- March 1998	10	2 January 1998	13.8
12 June 1998	5	6 June 1998	55.2
9-18 June 1998	9	6 June 1998	20.8 - 23.6
5-17 March 1999	18	29 November 1998	18.2 – 22

Table 1: Summary of the dates of gully survey in central Belgium and the respective causative rainfall depth. Causative rainfall depth is defined as the maximum daily rainfall depth that occurred between the last tillage pass and ephemeral gully formation.

All three data sets allow 1) to extend the comparison with formerly collected ephemeral gully threshold data sets and 2) to increase our understanding of the effect of different environmental factors on ephemeral gully erosion. An additional advantage is that for all three field campaigns, daily rainfall data from nearby stations are available for the period in which the ephemeral gullies formed.

Data collected during all three aforementioned field campaigns have also been used as input data for the Ephemeral Gully Erosion Model (EGEM) (Merkel, *et al.*, 1988). As the eroded volumes for each ephemeral gully were determined in the field, a comparison between these measured erosion volumes and the predicted erosion volumes (EGEM) could be made.

Before the start of the MWISED-project two data sets, similar to the three data sets described above, had been collected. Four ephemeral gullies were assessed at the end of winter early spring 1997 and twelve gullies were assessed during summer 1997. Table 2 summarises all parameters that have been collected for all ephemeral gullies that developed in the Belgian study area from spring 1997 till spring 1999. Each ephemeral gully was divided in as many segments as there were significant (i.e. observable by eye) changes in gully morphology along the gully profile. For each segment, length was measured by means of differential GPS, while depth and width were measured with a folding rule. Depth and width were stored as attributes of the given segment in the GPS, so that numerical and graphical information for each ephemeral gully was directly linked to each other. Given depth, width and length of each segment, ephemeral gully volume can easily be calculated by summing up the respective volumes for each segment of that ephemeral gully. Figures shown in Table 2 clearly reflect the main differences between ephemeral gullies formed at the end of winter-early spring (winter gullies) and those formed during summer (summer gullies). Summer gullies are on average very wide and shallow. They typically form after high-intensity rainfall events, removing a thin layer of freshly cultivated topsoil (seed-bed). Winter gully formation is a much slower process. First of all rainfall intensity in winter is generally much lower than in summer. Ephemeral gullies therefore, develop only after soils got sealed and crusted and infiltration capacity of the topsoil has decreased so much that even a small rainfall event causes enough runoff to create a gully. The resulting gully is rather small while its depth is generally

Parameter	Data collection method	Winter Gullies (n= 32)		Summer Gullies (n= 26)	
		Mean value	Standard deviation	Mean value	Standard deviation
Mean gully length (m)	GPS	246	325.5	124	72.8
Mean gully width (m)	Tape measure	0.53	0.15	3.07	1.02
Mean gully depth (m)	Tape measure	0.26	0.11	0.09	0.06
Mean gully volume (m^3)	Calculated	70.55	34.88	39.49	24.25
Drainage Area (m^2)	GPS (differential)	61 671	90 479	14 531	10 035
Watershed length (m)	MapInfo analysis	409.4	320.7	202.7	98.7
Concentrated flow length (m)	GPS	246.4	325.5	123.9	72.8
Watershed slope (%)	Clinometer	5.2	2.1	5.2	2.2
Concentrated flow slope (%)	Clinometer	5.5	2.7	6.9	1.9
Curve number	Field observation	84.6	3.0	81.0	6.4
Soil class	Soil sample / granulometric analysis	Silt: 3%, Silt Loam: 97%		Silt Loam: 100%	
Channel erodibility factor (s^{-1})	Auto generated	0.27	0.01	0.23	0.09
Critical shear stress (N/m^2)	Auto generated	0.99	0.149	1.11	0.195
Maximum depth (m)	Field measurement	0.48	0.41	0.12	0.07
Bulk density (kg/m^3)	Literature (Vandaele, 1996)	1300		1300	
Particle diameter (mm)	Auto generated	0.032		0.032	
Particle specific gravity (kg/m^3)	Auto generated	2.62		2.62	
Manning N	Auto generated	0.03		0.03	
Rain distribution type	Rainstorm distribution analysis	II		II	
24 hour rainfall depth (mm)	Rain gauge and/or personal communication	Max daily: 17.2 8 mm threshold: 59.4 10 mm threshold: 33.8	3.0 26.0 18.6	Max daily: 33.1	11.8
Tillage practice	Field observation	Total area tilled: 100%		Total area tilled: 100%	

Table 2: Summary of the EGEM-input parameters and the way they are collected, for all gully surveys. A distinction is made between gullies formed at the end of winter-early spring (winter gullies) and those formed during summer (summer gullies).

limited by the plough pan. (± 30 cm). Differences in the type of “causative rainfall event” are also illustrated by the fact that a typical drainage area for winter gullies is a couple of times larger than for summer gullies (Table 2). There are of course many exceptions to this general scheme. For example, when a more erodible soil horizon (decalcified loess [C1] or calcareous loess [C2]) outcrops, winter gullies as well as summer gullies tend to be much deeper than the mean depth value.
Parallel to the field inventories for ephemeral gullies on loess-derived soils in central Belgium, ephemeral gully field inventories have also been conducted in the Alentejo (SE Portugal) and the Guadalentin (SE Spain). Collection of these data was done within the framework of another project, and has been described in Nachtergaele et al. (2001). The Mediterranean data sets were used to support and extend the results found for ephemeral gullies on loess-derived soils in central Belgium.

Results related to the data collected in both central Belgium and the Mediterranean study areas, are presented and discussed under *Subtask 3 (ST3) algorithm development.*

2.2 Subtask 2 (ST2) Flume experiments

2.2.1 Laboratory experiments

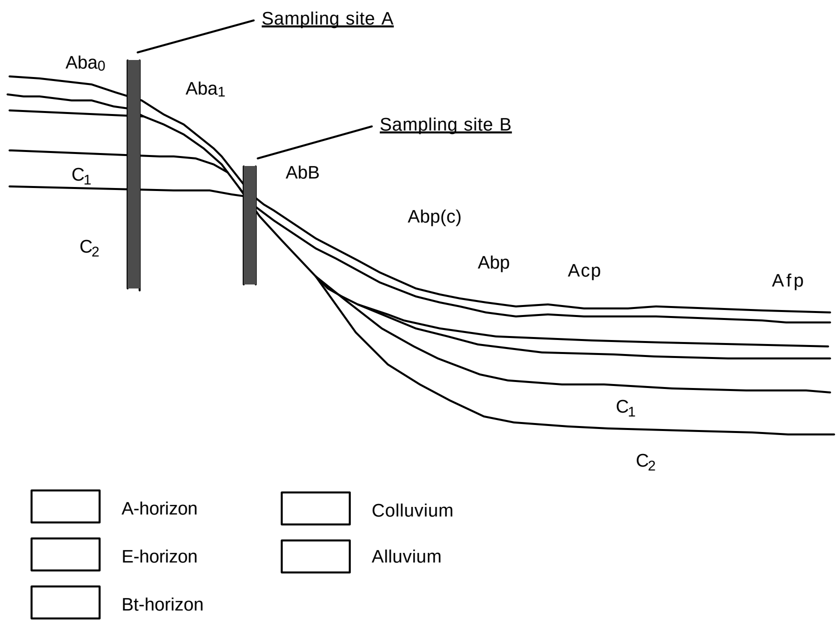


Figure 1: Schematic illustration of soil types that are typically found along a catena in the Belgian loess belt (after Dudal, 1955) and of the topographical position of sampling site A and B. For cultivated areas topsoil (0.3 m) is homogenized.

Legend of soil types indicated (according to F.A.O. et al., 1998)

Aba$_0$: Silt loam soil with argic horizon and thick A-horizon (> 40 cm) (Haplic Luvisol).
Aba$_1$: Silt loam soil with argic horizon and thin A-horizon (< 40 cm) (Haplic Luvisol).
AbB: Silt loam soils with argic or with cambic horizon (association of truncated Luvisols and Cambisols).
Abp(c): Colluvial soil on silt loam (Eutric regosol). Suffix (c) is used when colluvial layer is thin.
Acp: Poorly drained soils on silt loam (Eutric regosol).
Afp: Very poorly drained soil on silt loam (Eutric gleysol).

In order to provide a tool to accurately describe spatial and temporal variations in soil erodibility on loess-derived soils, a series of concentrated flow detachment experi-ments have been conducted. Four different soil horizons (Figure 1 and Table 2), typical for loess-derived soils in Belgium, were sampled seven times during one year.

Sampling site	Soil horizon	Sampling depth (m)	Clay (%) 0-2 µm	Silt (%) 2-50 µm	Sand (%) 50-2000 µm	BD ($kg\ m^{-3}$) (n=3)	OM (%) (n = 4)	CaCo3 (%) (n=5)
A	Ap	0.15	12.8	79.8	7.4	1500	2.4	-
	Bt	0.40	20.7	75.3	4.0	1530	-	-
	C1	1.80	15.8	79.7	4.5	1440	-	-
	C2	2.20	10.4	86.5	3.1	1390	-	16.6
B	C2	0.40	8.7	86.9	4.4	1490	-	16.6

Table 2: Texture, dry bulk density (BD), organic matter content (OM) and $CaCo_3$ content of the soil horizons under study. Location of sampling site A and B is indicated in Figure 1.

A representative range of initial soil moisture contents was thus obtained for each of the horizons under study. Undisturbed soil samples were subjected to five different combinations of slope gradient and concentrated flow discharge (Table 3).

	Slope (m/m)	Discharge ($10^{-5}\ m^3\ s^{-1}$)		Velocity ($m\ s^{-1}$)		Shear stress (Pa)	
		Average	Range	Average	Range	Average	Range
I	0.10	9.4	9.1 - 9.5	0.55	0.54 - 0.56	1.63	1.61 - 1.65
II	0.20	9.3	9.0 - 9.7	0.69	0.67 - 0.70	2.59	2.54 - 2.65
III	0.35	9.4	8.8 - 9.6	0.81	0.79 - 0.83	3.72	3.61 - 3.79
IV	0.20	19.3	19.0 - 19.6	0.93	0.92 - 0.95	3.88	3.83 - 3.91
V	0.35	19.1	17.0 - 19.5	1.09	1.04 - 1.11	5.55	5.23 - 5.62
		Water temperature (°C)		**Reynolds number**		**Froude number**	
		Average	Range	Average	Range	Average	Range
I		15.5	12.0 - 19.0	805	710 - 883	4.3	4.3 - 4.4
II		16.1	13.0 - 20.0	817	722 - 914	6.0	6.1 - 5.9
III		15.8	11.0 - 20.0	817	712 - 924	6.6	6.5 - 6.7
IV		15.3	11.0 - 20.5	1628	1451 - 1870	7.7	7.5 - 7.8
V		15.0	11.0 - 20.0	1567	1319 - 1747	8.4	8.2 - 8.6

Table 3: Flow characteristics for each of 5 combinations of slope and flow discharge that are used for testing soil erodibility for four different soil horizons.

Table 4 summarizes all experimental results. Comparing soil detachment rates (D_r) listed along horizontal lines, illustrates the relation between applied flow shear stress (τ) and D_r for a given soil horizon at a given moment. Along vertical lines, the evolution of D_r with time for each of the considered soil horizons and for a given value of τ can be found. While Table 4 gives a complete overview of the results of the flume experiments, exploring all information embedded in these results requires a fragmented and more graphical representation.

Soil horizon	Sampling Date	Mean GMC ($kg\ kg^{-1}$)		D_r ($kg\ m^{-2}s^{-1}$) at τ (Pa)...........				
		Average	Range	1.63	2.59	3.72	3.88	5.55
A_p	7-Nov-98	17.63	16.97 - 18.25	0.00	0.00	0.00	0.00	0.00
	15-Jan-99	18.17	16.77 - 18.91	0.00	0.00	0.00	*0.00*	0.01
	8-Mar-99	18.89	17.78 - 21.07	0.00	0.00	0.00	0.00	*0.00*
	30-Apr-99	15.38	14.79 - 16.02	0.01	0.01	0.03	*0.01*	0.04
	2-Jun-99	12.61	11.46 - 13.94	0.01	0.03	-	0.03	*0.16*
	25-Jun-99	11.45	9.89 - 13.00	0.01	0.08	0.11	-	0.15
	3-Aug-99	9.63	6.72 - 11.36	0.01	0.05	0.09	0.15	-
B_t	7-Nov-98	17.62	16.37 - 19.11	0.00	0.00	0.01	0.01	0.00
	15-Jan-99	17.46	16.85 - 18.23	0.00	0.00	0.00	0.00	0.01
	8-Mar-99	17.81	16.78 - 18.97	0.00	0.00	0.00	0.00	0.00
	30-Apr-99	15.32	14.87 - 15.68	0.01	0.03	0.03	0.02	0.02
	2-Jun-99	13.84	12.81 - 14.43	0.03	0.12	0.10	0.10	0.11
	25-Jun-99	13.18	11.21 - 14.56	0.07	*0.03*	0.12	-	0.15
	3-Aug-99	13.54	11.59 - 13.28	0.03	0.09	0.01	0.04	-
C_1	7-Nov-98	16.75	15.01 - 18.04	0.01	0.09	*0.24*	0.29	*0.39*
	15-Jan-99	20.89	19.79 - 22.12	0.00	0.00	0.03	0.04	0.16
	8-Mar-99	20.39	19.11 - 21.13	0.01	0.02	0.05	0.04	0.21
	30-Apr-99	16.88	16.12 - 17.66	0.07	0.23	0.40	0.50	0.49
	2-Jun-99	14.58	12.98 - 15.43	0.09	0.28	0.35	0.61	0.56
	25-Jun-99	12.89	12.09 - 13.61	0.02	0.39	0.66	-	0.73
	3-Aug-99	13.18	12.09 - 13.74	0.04	0.24	0.65	0.67	-
C_2 (2.20 m)	7-Nov-98	16.00	15.48 - 16.99	0.01	0.04	0.20	0.11	0.31
	15-Jan-99	19.98	19.10 - 20.97	0.01	0.04	0.05	0.10	0.14
	8-Mar-99	17.67	16.92 - 18.45	0.01	0.05	0.13	0.10	0.30
	30-Apr-99	14.56	12.82 - 15.28	0.01	0.08	0.19	0.32	0.61
	2-Jun-99	13.98	12.97 - 14.94	0.01	0.08	*0.19*	0.20	0.48
	25-Jun-99	13.50	10.82 - 15.33	0.01	0.13	0.26	-	0.43
	3-Aug-99	12.18	5.78 - 14.74	*0.01*	*0.13*	0.34	0.41	-
C_2 (0.40 m)	7-Nov-98	13.53	13.11 - 14.01	*0.01*	0.06	*0.19*	*0.17*	0.59
	15-Jan-99	12.55	11.06 - 13.91	*0.01*	0.04	0.19	0.20	0.64
	8-Mar-99	13.16	12.85 - 13.67	0.01	*0.14*	*0.18*	*0.27*	0.58
	30-Apr-99	10.36	8.34 - 12.04	0.02	0.07	0.39	0.51	0.88
	2-Jun-99	6.91	4.98 - 9.47	0.02	0.16	0.30	0.45	0.63
	25-Jun-99	6.46	5.05 - 8.12	0.01	0.18	*0.59*	-	0.62
	3-Aug-99	4.93	3.49 - 7.65	0.02	0.06	0.26	0.54	-

Table 4: Soil detachment rate (D_r) as a function of flow shear stress (τ) and gravimetric soil moisture content (GMC) for 4 different soil horizons. C_2 (2.20 m) and C_2 (0.40 m) are identical horizons, sampled at different depths (*see* Table 2). Experimental runs were duplicated so that τ-values are mean values. If only one experimental run could be conducted, the corresponding τ-value is given in italics. The number of GMC measurements used to calculate mean GMC-values ranges between six and ten.

When subdividing the data according to soil horizon, it appears that for a given horizon, variations in detachment rate could be very well related to temporal variations in initial soil moisture content (Figure 2). When subdividing the data according to initial soil moisture content, it appears that for a given soil moisture content the ploughed topsoil horizon (Ap) and the underlying clay enriched horizon (Bt), were at least five times less erodible than the decalcified loess horizon (C1) or the calcareous loess horizon (C2) (Figure 3).

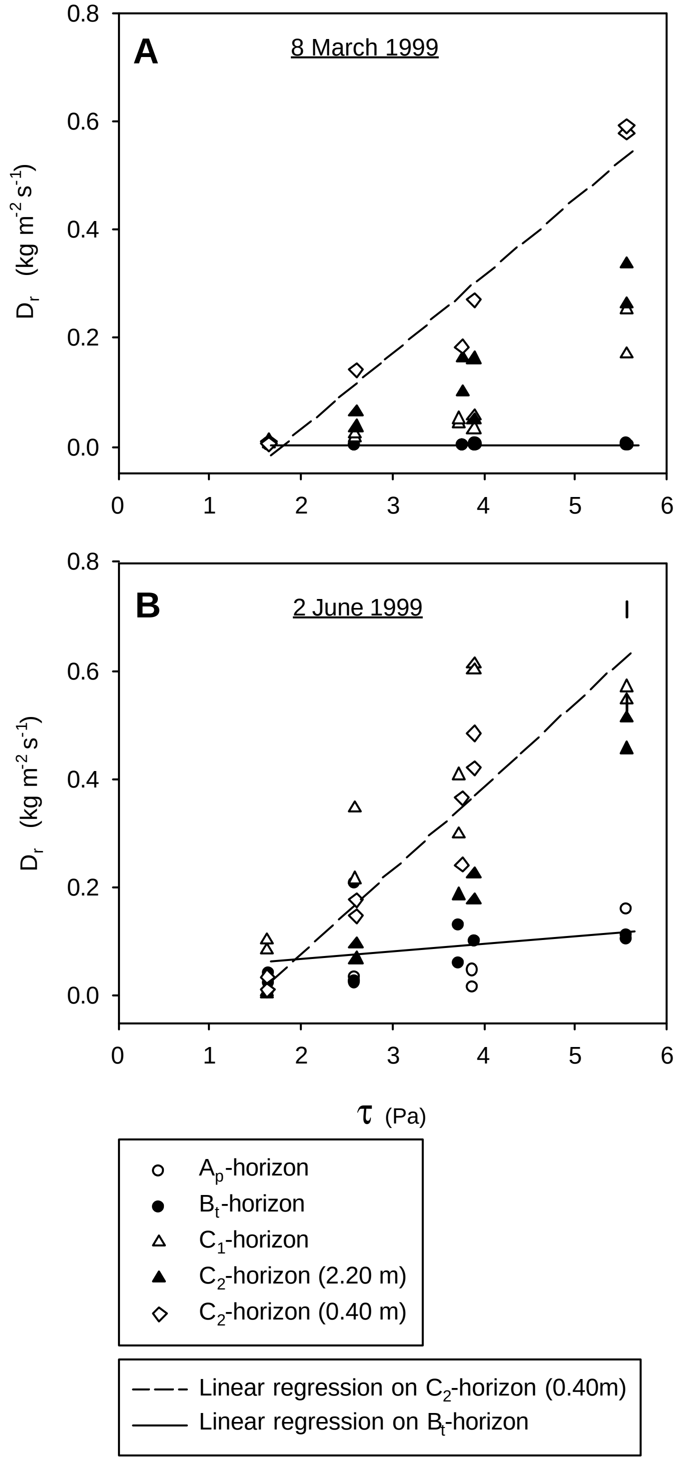


Figure 2: Detachment rate (D_r) as a function of applied flow shear stress (τ) for four different soil horizons, with one horizon (C_2) sampled at two different depths. Sampling depth of the respective horizons is indicated in Table 2. (A) Soil samples used were taken on March, 8, 1999, (B) samples used were taken on June, 2, 1999.

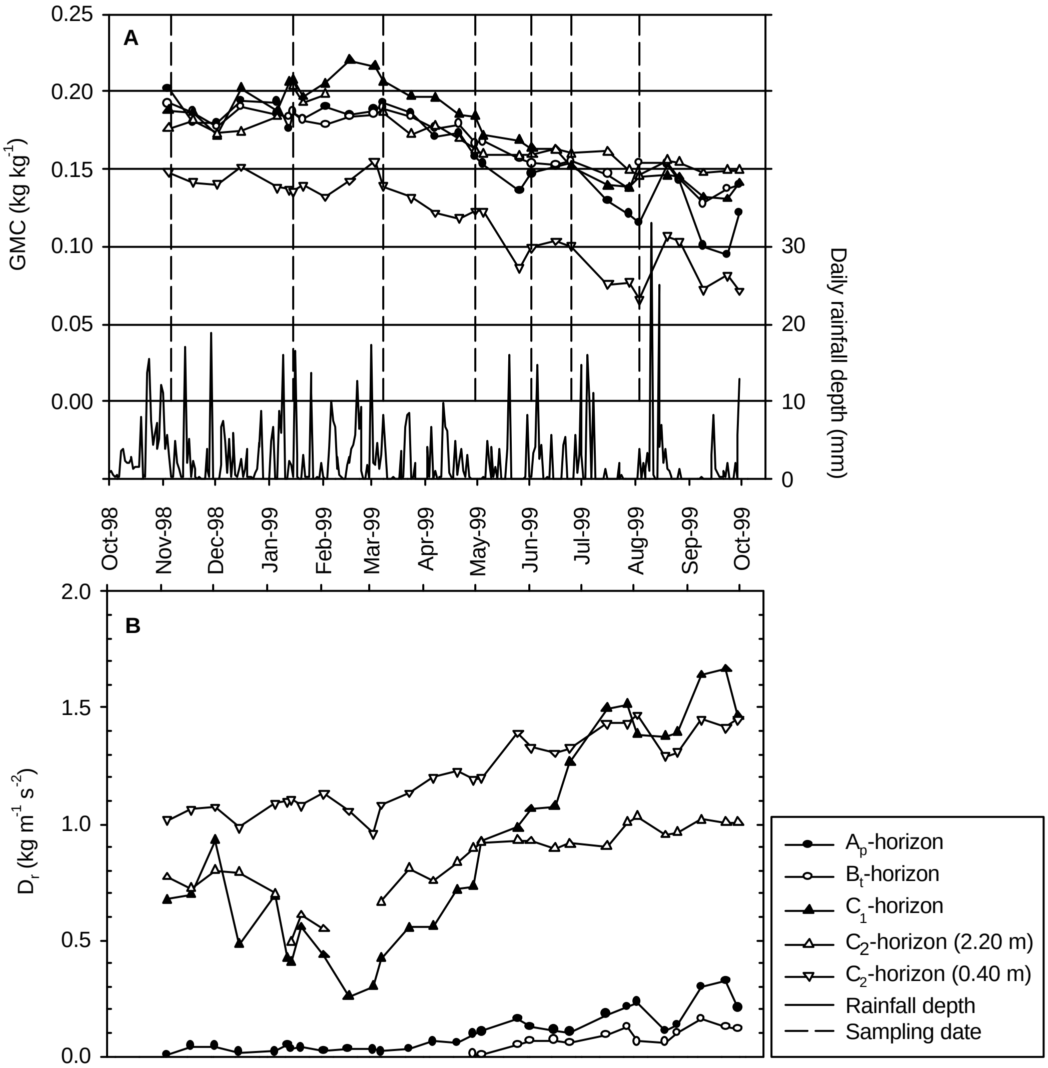


Figure 3: (A) Evolution of soil moisture content (GMC) of four soil horizons typical for the Belgian loess belt during one year (Nov-98 – Oct-99). Every symbol represents a soil moisture measurement (n = 2). The line for the C_2-horizon (2.20 m) is interrupted twice, since at two moments in time ground water level did not allow soil moisture measurements. For a description of the respective soil horizons: see Table 2. Note that the C_2-horizon was sampled at two different depths (and consequently at two different sites). A solid line represents daily rainfall depths. The dotted vertical lines indicate 7 moments when undisturbed soil samples were taken for flume experiments. (B) Evolution of detachment rate (D_r) of four soil horizons typical for the Belgian loess belt during one year (Nov-98 – Oct-99).

D_r-values in Figure 3 are calculated for an average shear stress value of 10 Pa, using the equations:

$$D_r = k_r\ \tau + b \tag{1}$$

$$k_r = n\ GMC^2 - m\ GMC + p \tag{2}$$

where k_r = the erodibility parameter as defined by Foster et al (1995) and Alberts et al. (1995) (s m^{-1}), GMC = initial gravimetric soil moisture content (kg kg^{-1}) and n, m, p and b are regression constants (Table 5).

Soil horizon	Regression coefficients				R^2	GMC (kg kg^{-1})	
	n	m	p	b		β	ω
A_p	1.496	0.737	0.09	-0.016	0.83	0.067	0.211
B_t	-1.422	-0.025	0.036	~0	0.47	0.112	0.191
C_1	4.495	3.154	0.515	-0.135	0.86	0.121	0.221
C_2	-2.857	-0.056	0.18	-0.243	0.83	0.027	0.21

Table 5: Numerical input for Equations 1 and 2 for each of the four soil horizons under study. β and ω are respectively the lower and the upper limit of the initial gravimetric moisture content (GMC).

The potential of Equations 1 and 2 to predict D_r-values for soil horizons typical for loess-derived soils, is illustrated by Figure 4.

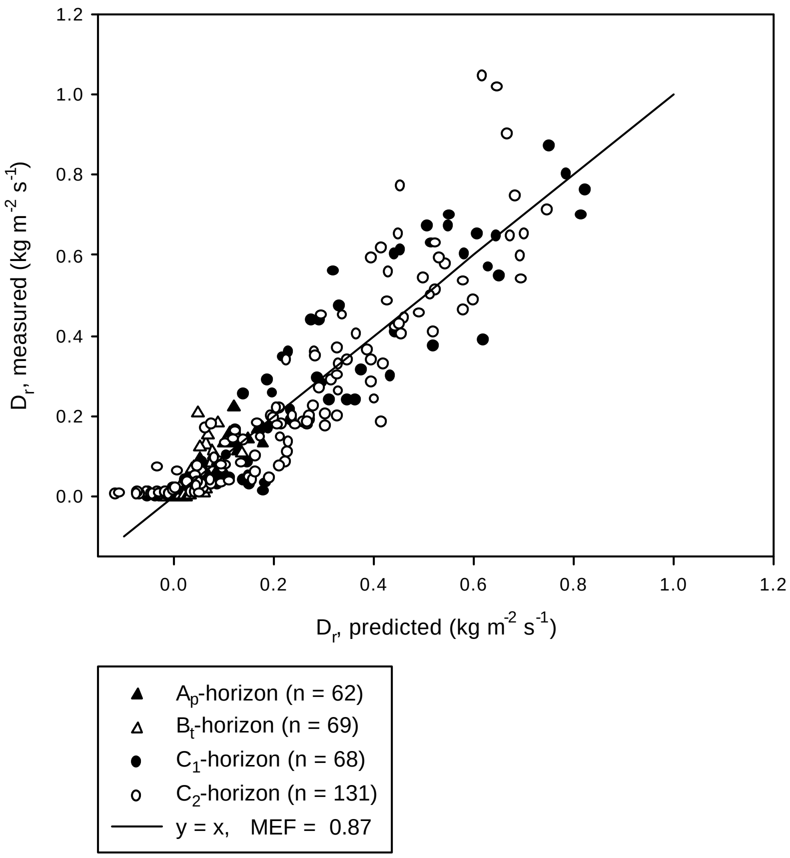


Figure 4: Predicted versus measured detachment rates (D_r) for four different soil horizons. D_r-values were predicted by Equations 1&2. For each soil horizons the parameters in Equations 1&2 (n, m, p and b; Table 5) have been obtained through non-linear regression analysis. The model efficiency statistic (MEF; Nash and Sutcliffe, 1970) indicates how well the line of perfect agreement describes the observed variation in D_r.

Combining knowledge on spatial distribution of soil profiles and initial soil moisture content is the key to explain observed spatial and temporal variations in resistance to ephemeral gully erosion for loess-derived soils. Therefore the knowledge and relations presented above should be included in an ephemeral gully erosion routine.

From equations 1 and 2 the critical shear stress value for a given soil horizon and a given initial soil moisture content can be calculated using the following equation:

$$\tau_c = \frac{-k_r}{b} \tag{3}$$

where τ_c = critical shear stress (Pa). Equation 3 can be solved through Equation 2 to calculate k_r and Table 5 that lists the regression constants for the respective soil horizons of a loess-derived soil. Critical shear stress obtained through Equation 3 represents the intrinsic critical shear stress of a given soil horizon at a given initial soil moisture content. This critical shear stress is in fact related to the initiation of particle motion under the given circumstances. A study related to the actual critical shear stress values for the initiation of ephemeral gullies is presented below (*see*r 2.2.1 Field experiments).

<u>2.2.1 Field experiments</u>

K.U. Leuven has participated intensively in the discussion on the experimental set-up for field experiments on concentrated flow erosion. With respect to the practical implementation of the experimental set-up an excursion to an experimental station in Italy (i.e. Vicarello) was made. Results obtained during the collaborative experiment are used in WP 2, ST3.
Based on field data, shear stress calculations (Figure 5) have been made for the initiation of ephemeral gully erosion in cultivated fields in SE Portugal and central Belgium. Due to logistic limitations no field experiments on ephemeral gully erosion were conducted.

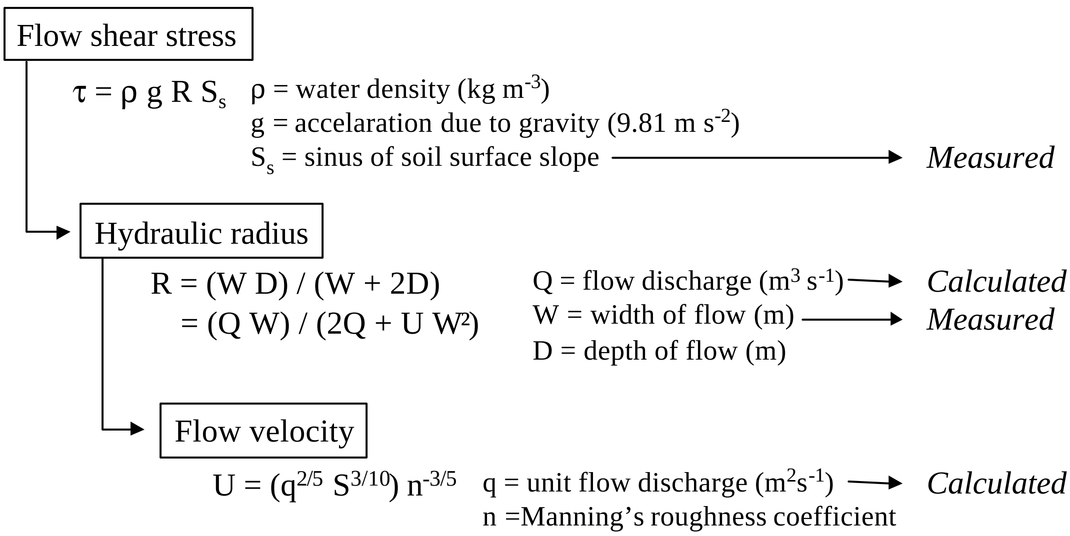


Figure 5: Illustration of flow shear stress calculation. With respect to peak flow shear stress values at ephemeral gully heads in SE Portugal and central Belgium, input parameters required to solve the respective equations were derived from reference tables unless indicated otherwise. To obtain peak flow shear stress-values, calculated flow discharges should be peak flow discharges.

Calculated flow shear stress values represent the situation at the ephemeral gully head at the time of ephemeral gully initiation. These shear stress values are considered to be a good

estimator of critical shear stress (τ_c) for ephemeral gully initiation in the given study area. Runoff discharges at the ephemeral gully head were obtained through the hydrology component of EGEM (Woodward, 1999), while surface slope at the gully head and width of flow, i.c. ephemeral gully channel bottom width, at the gully head have been measured in the field. Other required input parameters were derived from reference tables (Figure 5).
Results presented in Figure 6 and Table 6 show clear differences in τ_c for ephemeral gully initiation in the two study areas. Within the Alentejo study area ephemeral gullies were observed under three types of land use: (1) wheat fields (n = 23), (2) fields under temporal fallow (n = 12) and (3) abandoned fields (n = 5). Average τ_c for ephemeral gully initiation in wheat fields and temporally fallow fields were almost identical, i.e. 42 and 41 Pa respectively, while average τ_c for abandoned fields was somewhat higher, namely 57 Pa. However, due to the small number of observations

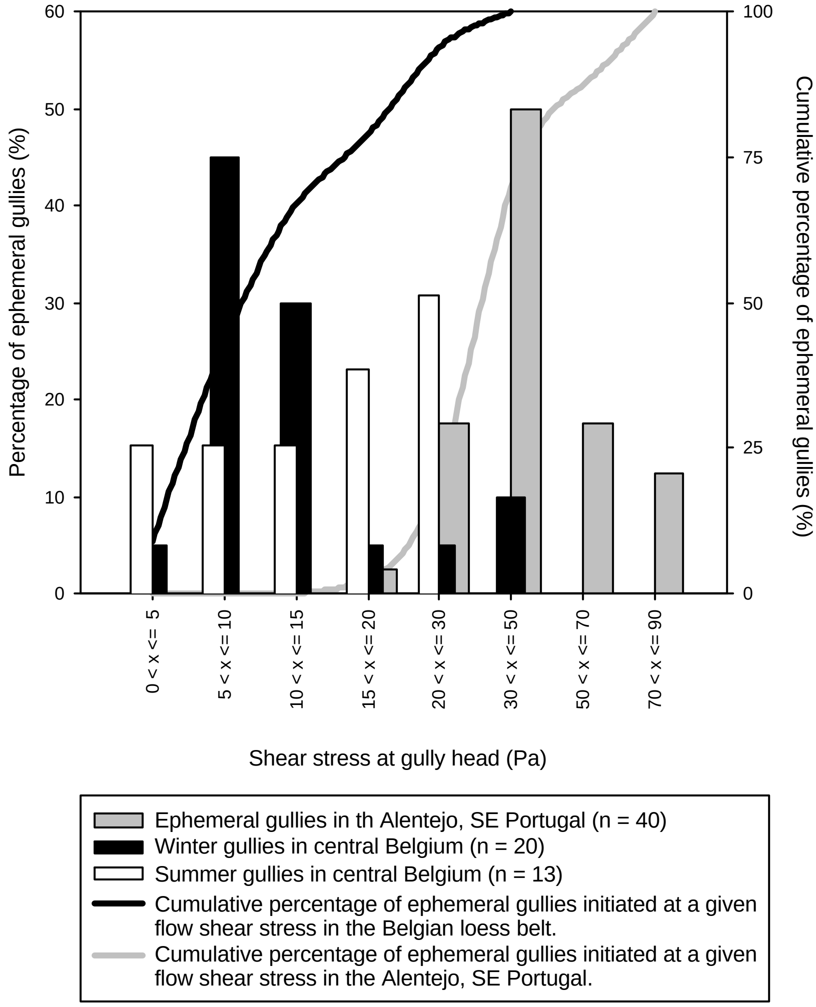


Figure 6: Distribution of peak flow shear stress at ephemeral gully heads (i.e.channel cross-section > 930 cm^2) observed in the Belgian loess belt (n = 33) and in the Alentejo, SE Portugal (n = 40). Shear stress are calculated according to procedures shown in Figure 5.

and a relatively high variation, average τ_c for gully initiation in abandoned fields, is not significantly different (P > 0.05) from τ_c in fields under wheat and/or temporal fallow. Therefore the τ_c-values for ephemeral gully initiation in the Alentejo are treated as one sample. For the Belgian loess belt a distinction between summer and winter gullies has been made. Yet , with respect τ_c-values both gully types of the Belgian loess belt are not significantly different at the 5% level (τ_c winter gullies = 13 Pa and τ_c summer gullies = 15 Pa). Similar τ_c-values for winter and summer gullies were expected, since soil material and land use are very similar for both gully types, i.e. (freshly) cultivated fields on loess-derived soils. From Figure 6, however, it is clear that the distribution of τ_c-values over the considered shear stress classes for winter and summer gullies is not identical. While 75% of the winter gullies initiated at a τ_c-value between 5 and 15 Pa, summer gullies initiated at τ_c-values between 3.3 and 30 Pa. This may be explained as if summer gullies can initiate at low shear stress values (3-4 Pa), but due to high(er) rainfall intensities in summer, large discharges and consequently large shear stress values do occur as well.

Generally it is clear that average τ_c for ephemeral gully initiation in the Belgian loess belt (14 Pa) is significantly different ($P < 0.01$) from average τ_c for the Alentejo (44 Pa). For both study areas mainly cultivated fields were considered, but the most important difference lies in the rock fragment content of the topsoil. Whereas no rock fragments occur in Belgian loess-derived (top)soils, rock fragment content of topsoils in the Alentejo amounts to 30% by mass on average. Poesen et al. (1999) experimentally developed a negative exponential relation between rock fragment cover and sediment concentrations in concentrated flow. They also found that the erosion reducing effect of rock fragments on concentrated flow erosion rates was especially significant in the case of initially wet topsoils, a precondition that can easily be fulfilled for the Portuguese study area, since ephemeral gullies considered there developed during Mediterranean winter.

In conclusion, results of this shear stress threshold analysis reveal clear differences between required concentrated flow shear stress values for the initiation of ephemeral gullies in the Alentejo and in the Belgian loess belt. This information can for example be used to set up experimental programmes for ephemeral gully erosion simulations under the respective circumstances. But τ_c-values as presented here should also be used by ephemeral gully erosion models to define critical thresholds for ephemeral gully initiation and/or to spatially limit zones of potential ephemeral gully erosion.

Table 6A

Alentejo, SE Portugal					
	Runoff Discharge ($m^3 s^{-1}$)	Width (m)	Hydraulic radius (m)	Sine of slope	Shear stress (Pa)
	0.0057	0.80	0.01	0.16	16.8
	0.0085	1.20	0.01	0.21	20.6
	0.0142	0.65	0.02	0.10	22.3
	0.0057	0.50	0.01	0.18	23.4
	0.0085	1.10	0.01	0.30	27.1
	0.0227	0.60	0.03	0.09	27.7
	0.0255	0.75	0.03	0.10	29.8
	0.0680	0.20	0.06	0.05	29.9
	0.0142	0.80	0.02	0.18	30.9
	0.0142	0.65	0.02	0.17	33.1
	0.0113	0.55	0.02	0.19	33.6
	0.0170	0.65	0.02	0.15	33.6
	0.0085	0.40	0.02	0.19	33.9
	0.0085	0.50	0.02	0.22	34.2
	0.0227	0.60	0.03	0.13	36.1
	0.0680	0.55	0.06	0.06	36.7
	0.0227	0.45	0.03	0.12	38.3
	0.0255	0.60	0.03	0.13	38.5
	0.0142	0.50	0.02	0.19	39.7
	0.0170	0.60	0.02	0.19	40.3
	0.0340	0.45	0.04	0.10	41.0
	0.0453	0.65	0.04	0.10	41.8
	0.0198	0.70	0.02	0.20	42.2
	0.0198	0.60	0.02	0.18	42.3
	0.0227	0.60	0.03	0.16	42.8
	0.0113	0.25	0.03	0.18	45.2
	0.0170	0.45	0.03	0.19	46.0
	0.0680	0.55	0.06	0.08	47.9
	0.0227	0.40	0.03	0.17	51.6
	0.1133	0.60	0.07	0.07	54.0
	0.0283	0.25	0.04	0.14	55.0
	0.0481	0.65	0.04	0.14	55.1
	0.0453	0.60	0.04	0.15	57.9
	0.0708	0.45	0.06	0.11	62.2
	0.0255	0.50	0.03	0.23	64.3
	0.0651	0.35	0.06	0.13	70.7
	0.0312	0.20	0.04	0.18	71.3
	0.0708	0.50	0.05	0.14	72.9
	0.0623	0.45	0.05	0.15	74.2
	0.0821	0.60	0.05	0.14	74.4
mean	*0.0326*	*0.56*	*0.03*	*0.15*	*43.5*
St. dev.	*0.0258*	*0.20*	*0.02*	*0.05*	*15.7*

Table 6B

Belgian loess belt, winter gullies					
	Runoff Discharge ($m^3 s^{-1}$)	Width (m)	Hydraulic radius (m)	Sine of slope	Shear stress (Pa)
	0.0028	0.40	0.02	0.02	3.6
	0.0028	0.50	0.01	0.04	5.3
	0.0028	0.40	0.02	0.04	6.0
	0.0028	0.38	0.01	0.05	7.2
	0.0028	0.58	0.01	0.07	7.3
	0.0113	0.60	0.03	0.03	8.6
	0.0057	0.50	0.02	0.05	9.2
	0.0028	0.35	0.01	0.07	9.5
	0.0028	0.40	0.01	0.08	9.8
	0.0028	0.40	0.01	0.08	9.8
	0.0028	0.50	0.01	0.10	10.2
	0.0028	0.45	0.01	0.10	10.8
	0.0028	0.52	0.01	0.11	11.0
	0.0028	0.34	0.01	0.09	12.0
	0.0028	0.35	0.01	0.10	12.3
	0.0085	0.40	0.03	0.05	12.7
	0.0142	0.60	0.03	0.07	17.9
	0.0142	0.37	0.03	0.09	26.2
	0.0113	0.40	0.02	0.14	31.3
	0.0198	0.50	0.03	0.11	32.2
mean	0.0061	0.45	0.02	0.07	12.6
St. dev.	0.0052	0.08	0.01	0.03	8.1

Table 6C

Belgian loess belt, summer gullies					
	Runoff Discharge ($m^3 s^{-1}$)	Width (m)	Hydraulic radius (m)	Sine of slope	Shear stress (Pa)
	0.0028	4.00	0.003	0.11	3.3
	0.0028	2.50	0.004	0.08	3.6
	0.0028	1.20	0.01	0.11	6.7
	0.0283	3.00	0.02	0.05	8.8
	0.0085	1.50	0.01	0.11	11.2
	0.0085	1.80	0.01	0.15	12.5
	0.0198	1.00	0.03	0.06	15.0
	0.0227	0.70	0.04	0.04	15.6
	0.0453	1.40	0.04	0.05	19.0
	0.0538	1.80	0.03	0.07	21.8
	0.0283	1.40	0.02	0.10	22.2
	0.0510	1.70	0.03	0.09	26.0
	0.0368	1.20	0.03	0.11	29.9
mean	0.0240	1.78	0.02	0.09	15.1
St. dev.	0.0185	0.90	0.01	0.03	8.4

Table 6: Measured and calculated flow parameters at ephemeral gully heads in Alentejo, SE Portugal (Table 6A, n = 40), in the Belgian loess belt for winter gullies (Table 6B, n = 20) and for summer gullies (Table 6C, n = 13). Shear stresses listed served as input data for Figure 6.

2.3 Subtask 3 (ST3) algorithm development

One goal of MWISED is to develop a sub-model to predict where and when ephemeral gullies will occur. In order not to have to start from scratch the Ephemeral Gully Erosion Model (EGEM), which is a physically-based model that was specifically developed to predict soil loss by ephemeral gully erosion in North America, was first tested for European ephemeral gullies (central Belgium, SE Spain and SE Portugal). The model has two major components, of which the hydrology component is a physical process model, based on the runoff curve number. The erosion component uses the hydrology outputs to solve a combination of empirical relationships and physical process equations in order to compute the final width and depth of the ephemeral gully (Woodward, 1999). Results of testing EGEM clearly showed that ephemeral gully cross-sections observed in the Mediterranean study areas are overpredicted, while for the Belgian loess belt mean ephemeral gully cross-sections of both winter and summer gullies are underpredicted. (Figure 7). It was concluded that the physically-based erosion technology as included in EGEM, does not yield satisfying results with respect to predicting ephemeral gully cross-sections. Moreover, no routine to predict the length or the location of an ephemeral gully is included in EGEM which is also considered to be a major limitation.

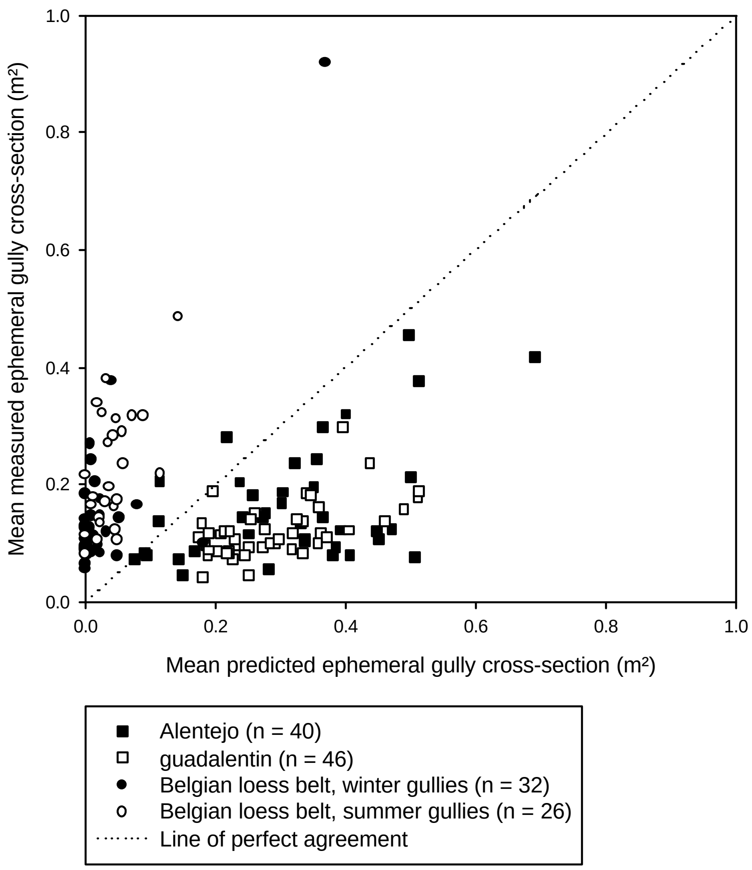


Figure 7: Predicted versus measured mean ephemeral gully cross-sections for two Mediterranean study areas (Alentejo, SE Portugal and Guadalentin, SE Spain) and for summer and winter gullies in the Belgian loess belt. Ephemeral gullies were predicted by EGEM.

With respect to the development of an alternative ephemeral gully erosion routine within the MWISED project (Figure 8) K.U. Leuven provided crucial input (data, equations and algorithms). Three main issues have been addressed (black ellipses in Figure 8): 1) delineate zones prone to ephemeral gully erosion, 2) link the hydrology component to the erosion component and 3) develop a dynamic approach of the soil erodibility concept.

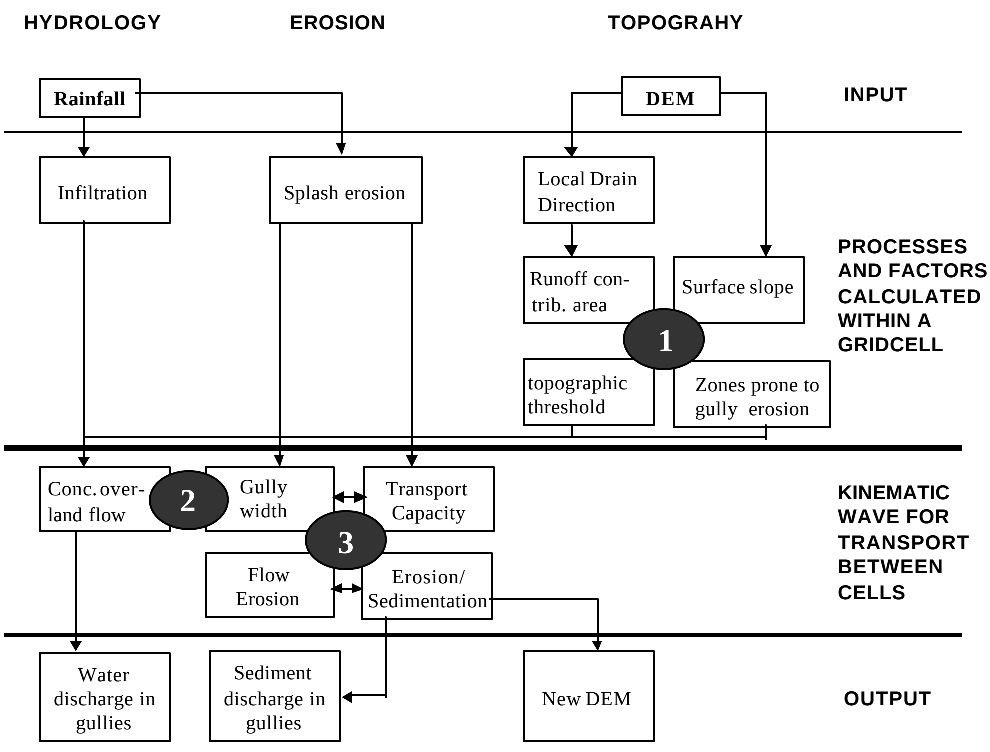


Figure 8: Scheme of the ephemeral gully erosion routine to be implemented in a MWISED (after van de Vlag et al., 2000). Black ellipses indicate newly developped model elements.

<u>Delineate zones prone to ephemeral gully erosion</u>

The procedure to determine zones prone to ephemeral gully erosion can be split up in a procedure to determine where ephemeral gullies will start and where they will end and a procedure to route the water between these two points. Initiation of ephemeral gullies has been described in literature as a threshold phenomenon. Brice (1966) and Patton (1973) were amongst the first to publish data on how the relation between runoff contributing area (A) and slope of soil surface (S) at gully heads may be used to establish a topographical threshold relation for gully initiation. Vandaele et al. (1996) summarized the available information on the initiation and location of (ephemeral) gullies, also reporting SA-relations for the Belgian loess belt, and Vandekerckhove et al. (1998) focused on the potential of the topographical threshold concept for predicting ephemeral gully initiation points in Mediterranean areas.

With respect to points in the landscape where ephemeral gullies end, much less research has been conducted. An attempt to establish a topographical threshold relation for sediment deposition points in the Alentejo and Guadalentin study area is presented in Figure 9. Although a profound study of such threshold relations needs more data from more different environments, it is possible to draw some significant regressions for both study areas. Both relations are significant at the 5% level. From Figure 9 it can be seen that ephemeral gullies in the Guadalentin form sedimentation fans on much steeper slopes than is the case in the Alentejo. This can partly be attributed to the coarser sediment load (rock fragments) transported in the ephemeral gullies of the Guadalentin.

Sediment deposition in the Belgian loess belt appeared to be better predicted by a slope threshold approach instead of a S-A-relation. All sediment deposition points

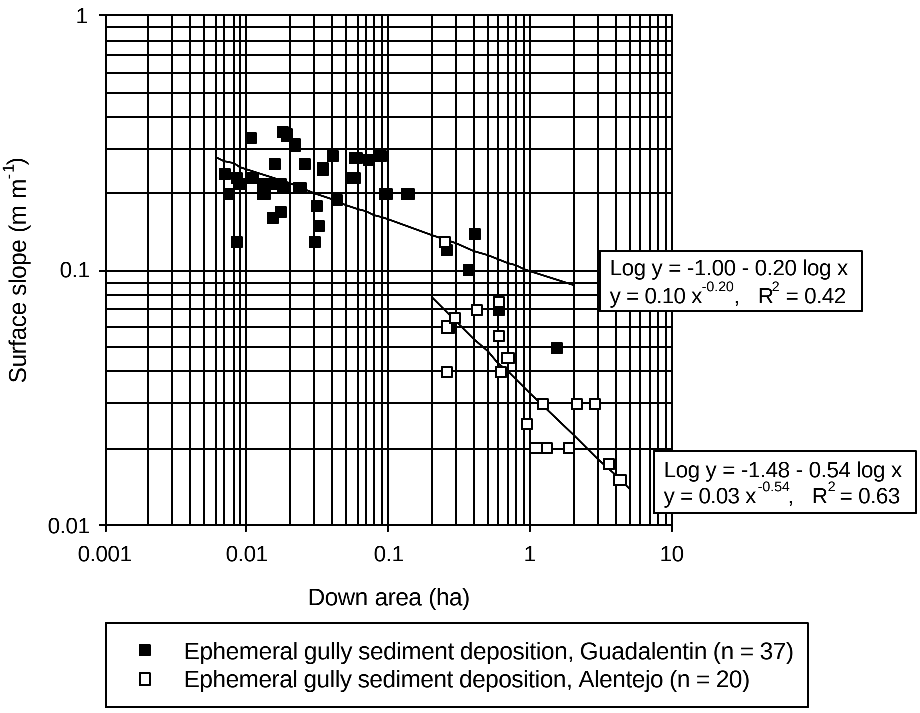


Figure 9: Topographical thresholds for ephemeral gully sediment deposition points in the Guadalentin (SE Spain) and the Alentejo (SE Portugal). Downarea is the runoff contributing area at the gully fan, i.e. sedimentation point.

assessed in the Belgian loess belt were essentially controlled by a change in topography (i.e. a decrease of local slope) and not by a change in land use. For about 90% of the ephemeral gullies in the Belgian loess belt channels end by sediment deposition at slopes of 4% or less (Figure 10). When the lowermost gully points have to be determined from a DEM for example, a slope threshold of 3% seems to be a good estimator.
Whatever method is used, when the initiation point and the sediment deposition point of an ephemeral gully are known, ephemeral gully length can be derived by routing the water from this initiation point (ephemeral gully head) towards the ephemeral gully end. Desmet et al. (1999) showed that zones prone to ephemeral gully erosion can be successfully predicted from a topographical threshold concept.

Once the length of the concentrated flow zone or the expected ephemeral gully is known, the ephemeral gully volume can be directly derived using an equation of the form:

$$V_{eg} = a\, L_{eg}^{b} \qquad (4)$$

where V_{eg} = ephemeral gully volume (m^3) and L_{eg} = ephemeral gully length (m). For the ephemeral gullies in the Mediterranean study areas and for the summer gullies in the Belgian loess belt, a = 0.048 and b = 1.29 (n = 112, R^2 = 0.91). For winter gullies in the Belgian loess belt, a = 0.060 and b = 1.15 (n = 31, R^2 = 0.82) (Figure 11).

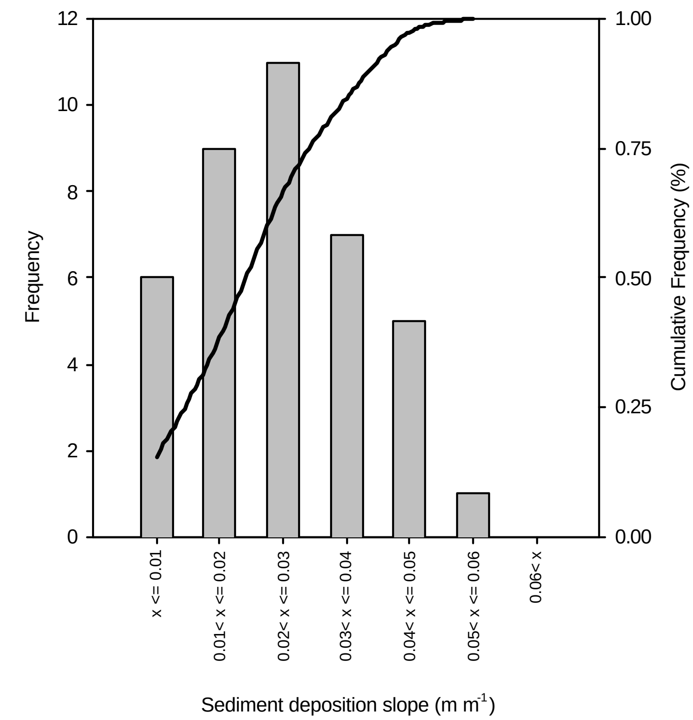


Figure 10: Distribution of slopes where ephemeral gullies end by topographically controlled sediment deposition as measured in the Belgian loess belt for winter gullies and summer gullies. (n = 39)

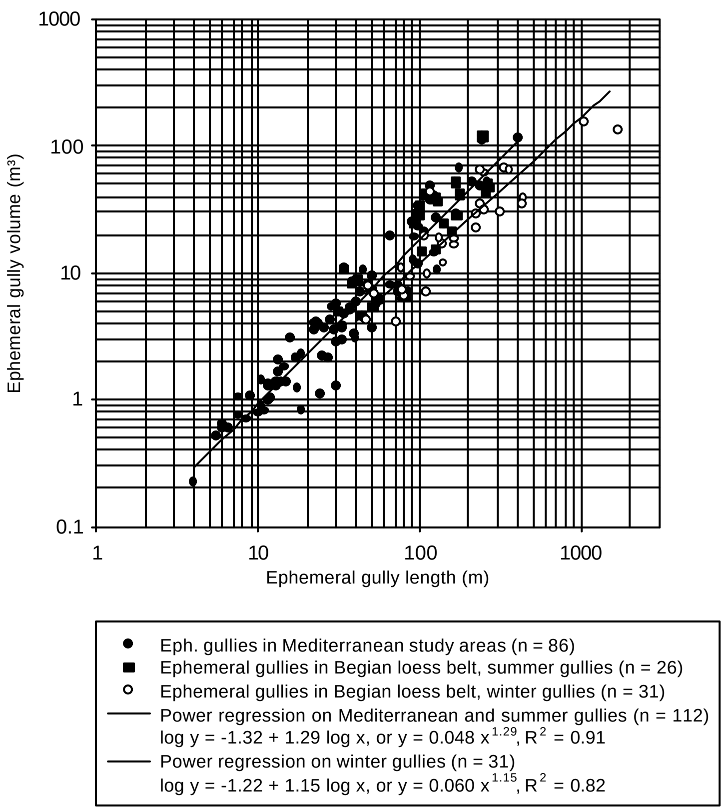


Figure 11: Potential performance of an empirical regression model relating ephemeral gully length and ephemeral gully volume on a double logarithmic scale.

When a more physically-based approach is envisaged, ephemeral gully volumes need to be calculated through process equations describing the detachment process. In this case, a hydrology component can be used to calculate (peak) flow discharge for each cell within the zones classified as ‘prone to ephemeral gully erosion’. Yet, to transform this peak discharge into erosive power of the concentrated flow (e.g. shear stress), flow width has to be known (Figure 8, black ellipse number 2).

Link the hydrology component to the erosion component

Empirical prediction equations of the form $W = a Q^b$ have been reported for rills and rivers, but not for ephemeral gullies. Therefore, six experimental data sets are used to establish a channel width (W, m) – flow discharge (Q, $m^3 s^{-1}$) relation for ephemeral gullies formed on cropland. The resulting regression equation ($W = 2.51 Q^{0.412}$; $R^2 = 0.72$; n = 67) predicts observed channel width reasonably well (Figure 12).

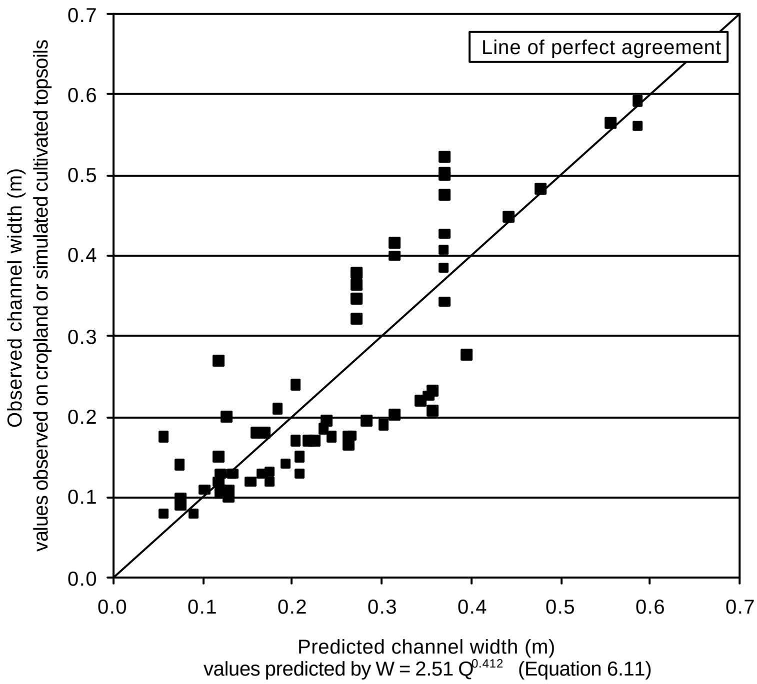


Figure 12: Predicted channel width *versus* observed channel width. The channel width prediction equation was established through a non-linear regression on channel width – flow discharge data for rills and gullies that formed on cropland or in simulated cultivated topsoils.

Data set name	Number of observations	Data collection method	Topsoil condition	Slopes (%)	Flow Discharge (10^{-3} m^3 s^{-1})	Channel width (m)	Data set source
Rieke Zapp	4	Laboratory flume experiments (USA)	Seedbed conditions, stony topsoils	7.0 – 14.0	0.10 – 0.19	0.08 – 0.18	Rieke-Zapp, 1998
Govers	10	Laboratory flume experiments (France)	Seedbed conditions, silt loams	n.a.	0.19 – 0.76	0.10 – 0.27	Govers et al., 1990
Foster	7	Laboratory flume experiments (USA)	Seedbed conditions	8.3 – 9.9	0.30 –2.18	0.08 – 0.24	Lane and Foster, 1980
Gilley	n.a.	Field experiments (USA)	Seedbed conditions, different soils	5.5 – 9.8	0.02 – 1.83	0.02 – 0.27	Gilley et al., 1990
Vicarello	7	Field experiments (Italy)	Cropland, clay rich soils	n.a.	1.34 – 9.30	0.13 – 0.41	Borselli et al., 2000
Sidorchuk (flume)	20	Open air flume experiments (Australia)	Natural soils mainly composed of silt	6.3 – 59.4	1.40 – 11.00	0.12 – 0.23	Sidorchuk, 1998
Bennett	19	Open air flume experiments (USA)	Seedbed conditions, clay loam	0.6-1.0	4.40 – 28.70	0.32 – 0.59	Bennett et al., 2000
Nachtergaele (Belgium)	42	Field measurements (winter gullies; Belgium)	Cropland, loess-derived soils	0.5 – 14.0	2.80 – 53.80*	0.25 – 1.10	Nachtergaele et al. (in press)
Nachtergaele (Portugal)	69	Field measurements (Portugal)	Cropland, stony top soils	5.0-31.0	14.16 – 540.90*	0.18 – 3.70	Nachtergaele et al., 2001

Table 7: Characteristics of the experimental data sets reporting on channel width and flow discharge for rills and gullies developing on cropland or simulated cultivated topsoils. Runoff discharges indicated by * are calculated, n.a. = not available

Due to logistic limitations related to the respective experimental set ups, only relatively small runoff discharges (i.e. $Q < 0.02\ m^3\ s^{-1}$) were covered. Using field data, where measured ephemeral gully channel width was attributed to a calculated peak runoff discharge on sealed cropland, the application field of the regression equation was extended towards larger discharges (i.e. $5\ 10^{-4}\ m^3\ s^{-1} < Q < 0.1\ m^3\ s^{-1}$) (Figure 13).

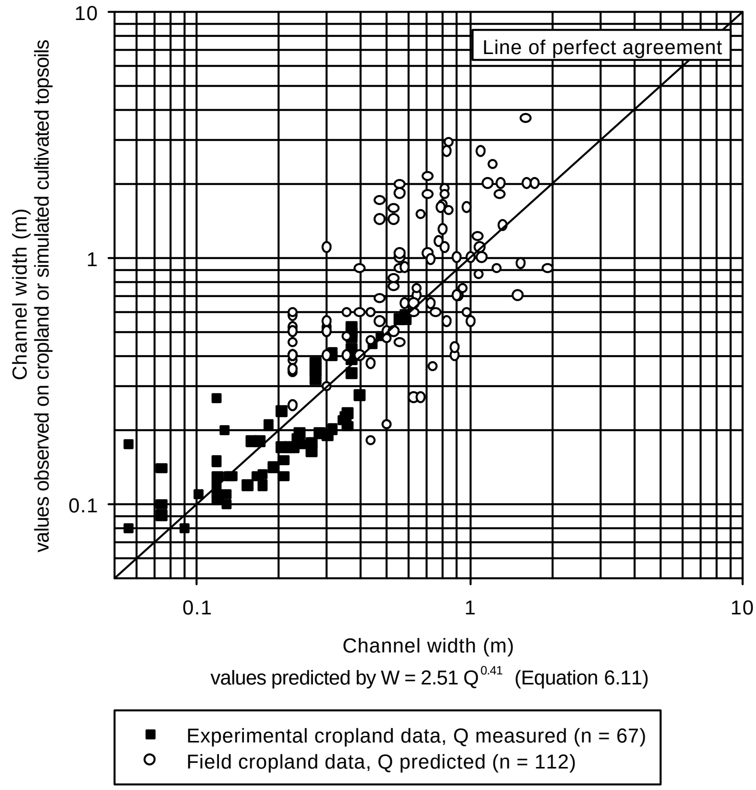


Figure 13: Predicted channel width *versus* observed channel width. ‘Experimental cropland data’ refers to the data presented in Figure 10. ‘Field cropland data’ refers to ephemeral gully data obtained by Nachtergaele et al. (2001 and in press). More information on the respective data sets can be found in Table 7.

Comparing W-Q relations for concentrated flow channels revealed that the discharge exponent (b) varies from 0.3 for rills over 0.4 for gullies to 0.5 for rivers. This shift in b may be due to 1) differences in flow shear stress distribution over the wetted perimeter between rills, gullies and rivers, 2) a decrease in probability of a channel formed in soil material with uniform erosion resistance from rills over gullies to rivers and 3) a decrease in average surface slope from rills over gullies to rivers.

The proposed W-Q equation for ephemeral gullies is valid for (sealed) cropland with no significant change in erosion resistance with depth. In the case of a typical summer situation where the soil moisture profile of an agricultural field makes the top 0.02 m five times more erodible than the underlying soil material (Figure 14), observed W values for summer gullies are larger than those predicted by the established channel width equation for concentrated flow on cropland (Figure 15).

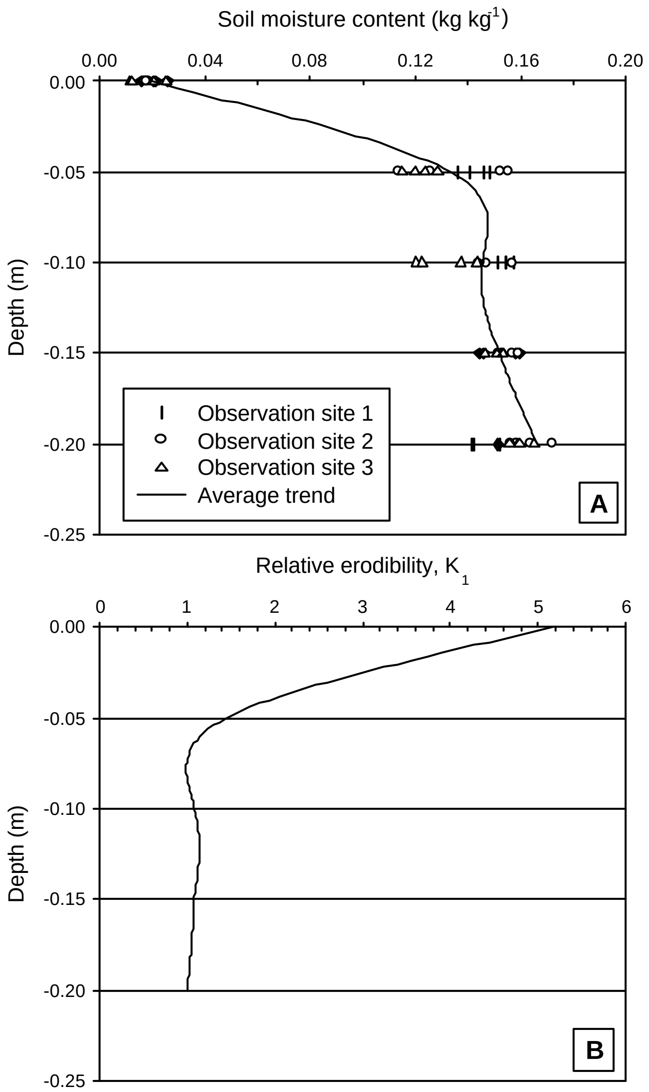


Figure 14: A) Gravimetric soil moisture content profile for three observation sites in the Belgian loess belt. Time (June 2000) and location of soil moisture sampling represent the conditions of potential summer gully initiation. At each observation site two sampling points were selected and soil moisture content of each sample was analysed in duplicate. The average trend therefore, represents the average for 12 gravimetric soil moisture values. B) Relative erodibility during concentrated flow erosion (based on experimental results by Govers et al., 1990)

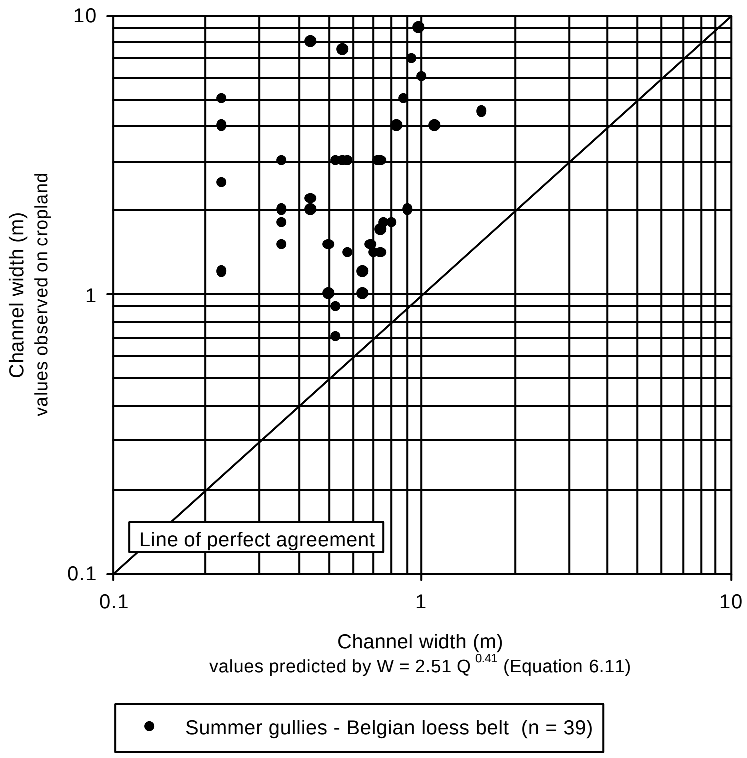


Figure 15: Predicted channel width *versus* observed channel width for ephemeral gullies formed in central Belgium during summer. The prediction equation was established for experimental rills and gullies that formed on cropland soils with uniform erosion resitance.

Besides the development of empirical channel width (W) – flow discharge (Q) relations discussions between K.U. Leuven and CNR also resulted in a more physically based approach. Dino Torri (CNR) developed procedures to predict W from Q, through a process-oriented approach. To investigate how this W-Q relation changes over time, an experimental procedure was elaborated and a first “try-out” experiment was conducted at Vicarello (Italy) from October 1st till October 4th, 1999. This experiment was headed by CNR and ISSDS, and attended by IIA, CSIC and K.U. Leuven. The collaboration resulted in a procedure to conduct ephemeral gully field experiments under standardised conditions.

<u>A dynamic approach of the soil erodibility concept</u>

Field observation showed that both spatial and temporal variations in resistance to ephemeral gully erosion for loess-derived soils exist. At a given moment in time, detachment rates for different soil horizons vary significantly (spatial variations). Soil profiles in the Belgian loess belt are truncated due to water and tillage erosion, resulting in a spatial variation in outcropping soil horizons (Figure 1) and consequent spatial variation in soil erodibility. When modelling soil erosion for loess-derived soils, the use of one single erodibility value will therefore lead to serious errors on predicted erosion volumes and patterns. Besides spatial variations, also temporal variations in soil detachment rates have been observed. For a given soil horizon, these variations could be very well related to temporal changes in initial soil moisture content (Figure 4). Modelling concentrated flow erosion requires that both temporal and spatial variations in detachment rates should be incorporated. The level of incorporation depends on the type of erosion model that is applied. When an empirical erosion model is used, a (relative) distinction in detachability between two time periods (winter and summer) and two groups of soil horizons (A_p-B_t and C_1-C_2) may be sufficient (Figure 3). On the other hand, process-based physical erosion models both enable and require a more detailed approach. To fully incorporate the dynamic approach of the soil erodibility concept, such a process-based physical erosion model should be multi-layered in order to describe soil profiles within the study area. It is important to stress that the progressive availability of digital information (i.c. a digital soil map) will facilitate the development and use of model structures requiring spatially distributed input data (i.c. soil profile distribution) in the near future. From the distribution of soil profiles and the related distribution of gravimetric soil moisture content, spatial and temporal variations in detachability throughout the study area can be calculated using the results presented in Equations 1&2 and in Table 4.

A more detailed description of the development of the dynamic approach of the soil erodibility concept can be found under *2.2 Subtask 2 (ST2) Flume experiments*, 2.2.1 Laboratory experiments.

2.4 Subtask 4 (ST4) GIS development

Within subtask 4 a collaboration between UU and K.U. Leuven was established Figure 8 shows the flowchart of a gully model as it was elaborated by UU and K.U. Leuven. The hydrology component and the erosion component of this model use procedures that were already incorporated in EUROSEM. The topography component results from several discussions between UU and K.U. Leuven. The topography component will delineate zones in the landscape which are potentially prone to ephemeral gully erosion. Critical threshold conditions for ephemeral gully erosion have been discussed. It was agreed with K.U. Leuven and UU to use topographical threshold procedures as they have been reported in literature by members of K.U. Leuven (Vandaele et al. 1996; Desmet et al., 1999). Once these zones have been selected the kinematic wave will only be applied on cells that fall within these zones.

Besides the W-Q relationships (see *2.3 Subtask 3 (ST3) algorithm development*), also some input data to test the ephemeral gully model for a small catchment in the Belgian loess belt was exchanged between K.U. Leuven and UU. K.U. Leuven delivered:

1) 2 DEM's (1x1 m and 5x5m) of the study area ($\pm$ 5 ha);
2) rainfall data (tipping bucket rain gauge; accuracy 0.2mm) of the rain event that created 4 ephemeral gullies in the study area;
3) saturated hydraulic conductivity (K_{sat}), D50 and cohesion values for the Belgian loess soils;
4) location and length, depth, width and eroded volume of 4 ephemeral gullies that were created within the study area.

B) Achievements

1) A field data set on ephemeral gully erosion in central Belgium was collected. In total 58 ephemeral gullies were assessed, 32 ephemeral gullies developed during winter or early spring (winter gullies) and 26 ephemeral gullies developed during summer (summer gullies).

2) The Ephemeral Gully Erosion Model (EGEM) was tested for all 58 ephemeral gullies that were measured in the Belgian loess belt. Results showed that EGEM is not capable of predicting ephemeral gully cross-section in this study area. An identical conclusion was drawn after testing EGEM for data set containing 82 ephemeral gullies that developed in two Mediterranean study areas (Alentejo, SE Portugal and Guadalentin, SE Spain). This data set was collected within another project. Because of EGEM's inability to predict ephemeral gully cross-sections and because of the fact that EGEM does not allow to predict the location and/or length of an ephemeral gully, an alternative ephemeral gully erosion routine had to be developed.

3) Topographical threshold conditions to delineate zones in the landscape that are prone to ephemeral gully erosion have been determined in consultation with UU. Topographical threshold relations for ephemeral gully initiation were derived from literature. Vandaele et al. (1996) reported relations for the Belgian loess belt, while Vandekerckhove et al. (1998) focused on predicting ephemeral gully initiation points in Mediterranean areas. With respect to points in the landscape where ephemeral gullies end a topographical threshold relation is established for the Mediterranean areas (Figure 9), while for the Belgian loess belt a critical slope threshold of 4% was proposed (Figure 10). When initiation and sediment deposition point are known, ephemeral gully length can be derived by routing the water between these two points following an algorithm developed by Desmet et al. (1999).

4) Within an empirical modelling approach procedures described under achievement 3 can be used to directly calculate ephemeral gully volumes from the predicted ephemeral gully length: $V_{eg} = a\, L_{eg}^{b}$ (Equation 4) where V_{eg} = ephemeral gully volume (m^3) and L_{eg} = ephemeral gully length (m). For the ephemeral gullies in the Mediterranean study areas and for the summer gullies in the Belgian loess belt, a = 0.048 and b = 1.29 (n = 112, R^2 = 0.91). For winter gullies in the Belgian loess belt, a = 0.060 and b = 1.15 (n = 31, R^2 = 0.82) (Figure 11).

5) Within a physically-based modelling approach procedures described under achievement 3 will be used to delineate zones prone to ephemeral gully erosion. For each point within these ephemeral gully prone areas, the erosive power can be calculated using the established width-discharge relationship that allows to link the hydrology component (discharge) to the erosion component (erosive power). The proposed relation $W = 2.51\, Q^{0.412}$ is valid for cropland with no significant change in erosion resistance with depth.

6) In order to accurately transform erosive power to erosion rates, flume experiments have been conducted that test differences in erodibility between different soil horizons typical for

the Belgian loess belt. These experiments show that variations in detachment rate (D_r) for a loess-derived soil can be very well predicted as a function of soil horizon type and initial soil moisture content (GMC) (Figure 4). The established equations are:

$$D_r = k_r \tau + b$$

$$k_r = n\, GMC^2 - m\, GMC + p$$

where k_r = the erodibility parameter as defined by Foster et al (1995) and Alberts et al. (1995) (s m^{-1}), GMC = initial gravimetric soil moisture content (kg kg^{-1}) and n, m, p and b are regression constants (*see* Table 5).

7) An analysis of critical shear stress values (τ_c) for ephemeral gully intiation in SE Portugal and the Belgian loess belt has been conducted (Table 6). Based on field data, τ_c was calculated according to procedures presented in Figure 5. Generally, τ_c for ephemeral gully initiation in the Belgian loess belt (14 Pa) was significantly different ($P < 0.01$) from average τ_c for the Alentejo (44 Pa). Since for both study areas mainly cultivated fields had been considered, the difference in τ_c was attributed to the rock fragment content of the topsoil.

3. ACTIVITY INTERNAL TO THE PROJECT.

3.1 Meetings:

1) In the first year two MWISED meetings were organized in Leuven: the start–up meeting, May 29-30, 1998 and a Gully Erosion Workshop, November 14, 1998.
2) In the second year K.U. Leuven, participated in 4 MWISED-meetings
   a) Murcia April 24-28, 1999
   b) Firenze/Vicarello October 1-4, 1999
   c) Utrecht January 14, 2000
   d) Firenze June 8-10, 2000
3) During the second year also three informal meetings related the gully modelling procedures were held in Leuven:
   a) July 1999, Dino Torri (CNR) visited K.U. Leuven to discuss possibilities of predicting cross-sectional areas and/or width and depth of flow at a given point in the landscape, from drainage area (as a substitute for discharge) and local slope. Finally procedures to predict changes of width over time as a function of discharge were elaborated by Dino Torri.
   b) December 1999, Daniel van de Vlag (UU) visited K.U. Leuven to discuss the proposed outline of the ephemeral gully model component for MWISED
   c) January 2000, Victor Jetten and Daniel van de Vlag (UU) visited K.U. Leuven to discuss preliminary results of the ephemeral gully model component for MWISED, and further improvements.

3.2 Data exchange

1) Rainfall data were exchanged with Peter Strauss. Two data sets, each covering 10 years of rainfall data (Uccle, Brussels) with a resolution of 10 minutes (1934-1943 and 1985-

1994), were obtained from the Belgian Royal Meteorological Institute. The data could be obtained at no costs, under the restriction that these data will never be used for commercial purposes of any kind.

2) Input data for the ephemeral gully model as well as data to test the ephemeral gully model were delivered to UU.

4. ACTIVITY EXTERNAL TO THE PROJECT.

<u>4.1 papers</u>

Nachtergaele, J., Poesen, J., 1999. Assessment of soil losses by ephemeral gully erosion using high-altitude (stereo) aerial photographs. **Earth Surface Processes and Landforms**, 24: 693-706.

Poesen, J., de Luna, E., Franca, A., Nachtergaele, J., Govers, G., 1999. Concentrated flow erosion rates as affected by rock fragment cover and initial soil moisture content. **Catena**, 36: 315-329.

Borselli, L., Torri, D., Poesen, J., Sanchis, P.S., 2001. Effects of water quality on infiltration, runoff and interrill erosion processes during simulated rainfall. **Earth Surface Processes and Landforms**, 26: 329-342.

Nachtergaele J, Poesen J, Vandekerckhove L, Oostwoud Wijdenes D, Roxo M. 2001. Testing the Ephemeral Gully Erosion Model (EGEM) for two Mediterranean environments. **Earth Surface Processes and Landforms**, 26 (1): 17-30.

Nachtergaele J., Poesen J., Steegen A., Takken I., Beuselinck L., Vandekerckhove L., Govers G., 2001. The value of a physically-based model versus an empirical approach in the prediction of ephemeral gully erosion for loess-derived soils. Accepted for publication in **Geomorphology**.

Nachtergaele, J., Poesen, J., submitted. Spatial and temporal variations in resistance of loess-derived soils to ephemeral gully erosion. **European Journal of Soil Science**.

Nachtergaele, J., Poesen, J., Oostwoud Wijdenes, D., Vandekerckhove, L., submitted. Medium-term evolution of a gully developed in a loess-derived soil. **Geomorphology**.

Nachtergaele, J., Poesen, J., Sidorchuk, A., Torri, D., submitted. Flow width – discharge relations for rills and (ephemeral) gullies. **Hydrological Processes**.

Nachtergaele, J., Poesen, J., Steegen, A., Takken, I., Beuselinck, L., Vandekerckhove, L., Govers, G., 1999. Prediction of soil losses by ephemeral gully erosion using EGEM (ephemeral gully erosion model). **Pedologie-Themata**, 6: 76-85.

Stalpaert, L., Poesen, J., Nachtergaele, J., 1999. Gevoeligheid van drie lemige bodemhorizonten voor erosie door geconcentreerde afvoer. **De Aardrijkskunde**, 3: 11-18

Nachtergaele J., Poesen J., 2000. EGEM, a potential prediction tool for soil losses by ephemeral gully erosion in the Belgian loess belt?. Gabriels, D., Schiettecatte, W. (Eds.), **Proc. Erosion contact group-meeting**, March 11th, 1999, International

Center for Eremology, Ghent Univeristy, Belgium. I.C.E. Special report No. 2/2000: 55-60.

Nachtergaele, J., Poesen, J., Oostwoud Wijdenes, D., Vandekerckhove, L., 2000. From ephemeral to permanent gully: the medium-term evolution of the Kinderveld gully. In: Verstraeten, G. (ed.), Historical and present-day soil erosion processes in central Belgium. Guide of the annual excursion of the Belgian soil science society, June, 14, 2000. **Pedologie –Themata**, 9: 60-65/81-87.

Nachtergaele, J., Poesen, J., Steegen, A., Takken, I., Beuselinck, B., Govers, G., 2000. Ephemeral gully erosion in the Belgian loess belt. In: Verstraeten, G. (ed.), Historical and present-day soil erosion processes in central Belgium. Guide of the annual excursion of the Belgian soil science society, June, 14, 2000. **Pedologie –Themata**, 9: 56-59/77-80.

Nachtergaele, J., Poesen, J., Vandekerckhove, L., Oostwoud Wijdenes, D., Roxo, M., in press. Testing the Ephemeral Gully Erosion Model (EGEM) in Mediterranean environments. **Proc. 10th International Soil Conservation Organization (ISCO) Conference: Sustaining the Global Farm. Local Action for Land Stewardship**. Purdue University, West Lafayette, Indiana, USA, 23-28 May, 1999.

Poesen, J., Nachtergaele, J., Deckers, J., 2000. Gullies in the Tersaart forest (Huldenberg): climatic or antropogenic cause? In: Verstraeten, G. (ed.), Historical and present-day soil erosion processes in central Belgium. Guide of the annual excursion of the Belgian soil science society, June, 14, 2000. **Pedologie –Themata**, 9: 40-51.

4.2 paper presentations at conferences

Nachtergaele, J., Poesen, J., 1998. Ephemeral Gully Erosion Assessment for the last 50 Years via High Altitude Stereo Aerial Photographs. Case Study: The Belgian Loess Belt. **ESSC-workshop: Long-term Effects of Land Use on Soil Erosion In a historical perspective**, Müncheberg, Germany, Sept. 11-13, 1998.

Nachtergaele, J., Poesen, J., Steegen, A., Takken, I., Beuselinck, L., Vandekerckhove, L., Govers, G., 1998. Prediction of soil losses by ephemeral gully erosion using EGEM (ephemeral gully erosion model). **Gemeenschappelijke studiedag van de Belgische verenigingen voor bodemkunde en landelijk genie "Studie van bodem en duurzame ontwikkeling"**. Centre de Recherches Agronomiques, Gembloux, Belgium, November 25, 1998.

Nachtergaele, J., Poesen, J., 1999. Ravijnerosie en ravijnerosie-onderzoek in de Belgische Leemstreek. **Bijeenkomst contactgroep erosie**, March 11, 1999. Universiteit Gent, centrum voor eremologie, Gent, België.

Nachtergaele, J., Poesen, J., Steegen, A., Takken, I., Beuselinck, L. and Govers, G., 1999. Ephemeral gully erosion in the Belgian Loess Belt. **2nd Int. Symposium on Tillage Erosion and Tillage Translocation**. K.U. Leuven, Belgium, 12-14 April 1999.

Poesen, J., Nachtergaele, J., Vandekerckhove, L., Oostwoud-Wijdenes, D., 1999. Datasets needed for predicting ephemeral gully erosion under global change. **BGRG Rainfall Simulation Working Group Concluding Meeting** (Joint Meeting with COST 623 Soil Erosion and Global Change). 18-21 April 1999, Leicester, U.K.

Nachtergaele, J., Poesen, J., Vandekerckhove, L., Oostwoud Wijdenes, D., Roxo, M., 1999. Testing and evaluating the ephemeral gully erosion model (EGEM) in Mediterranean environments. **10th International Soil Conservation Organization (ISCO) Conference: Sustaining the Global Farm. Local Action for Land Stewardship**. Purdue University, West Lafayette, Indiana, USA, May 23-28, 1999.

Poesen, J., Nachtergaele, J., Vandekerckhove, L., Oostwoud Wijdenes, D., Roxo, M., 1999. Prediction of ephemeral gully erosion in Mediterranean environments. **I.A.G. Regional Conference on Geomorphology**. University of Rio de Janeiro, Brazil, July 17-22, 1999.

Nachtergaele, J., Poesen, J., Oostwoud Wijdenes, D., Vandekerckhove, L. and Roxo, M., 1999. Testing and evaluating the Ephemeral Gully Erosion Model (EGEM) in Southern Europe (SE-Spain and SE-Portugal) and the loess belt (Belgium). Ephemeral gully erosion studies, possibilities of joint research. USDA-NRCS, National Sedimentation Laboratory - Oxford Mississippi, 23-25 August, 1999.

Nachtergaele, J., Poesen, J., Steegen, A., Takken, I., Beuselinck, L., Govers, G., 2000. Ephemeral gully erosion in the Belgian loess belt. **International symposium on Gully erosion under Global Change**, K.U. Leuven, 16-19 April, 2000.

Poesen, J., Nachtergaele, J., Verstraeten, G., Oostwoud Wijdenes D., Valentin, C., 2000. Gully erosion under environmental change. **International symposium on Gully erosion under Global Change**, K.U. Leuven, 16-19 April, 2000.

Poesen, J., Nachtergaele, J., Verstraeten, G., Vandekerckhove, L., Gyssels, G., 2000. Gully erosion as a missing link in erosion models. COST 623 International workshop on Linkage of Hillslope Erosion to Sediment Transport and Storage in river and Floodplain Systems. Almeria, Spain, 7-11 September, 2000.

Nachtergaele, J., Poesen, J., Sidorchuk, A., Torri, D., 2001. Flow width prediction for concentrated flow on agricultural fields. **Cost 623: 'Snowmelt erosion and related problems'**. The Norwegian State Pollution Control Authority (Jordfrosk), Oslo, Norway, 28-30 March, 2001.

4.3 Organization of the International Symposium

The International Symposium on Gully Erosion under Global Change was held at the K.U. Leuven, April 16-19, 2000. During this symposium the MWISED project was presented through the following papers:

a) Borselli L., Pellegrini, S., Bazzoffi, P., Castillo, V., Nachtergaele, J., Poesen, J., Sardo, V., Torri, D. *Field experiments for gully initiation.* (poster presentation)
b) van de Vlag, D., Jetten V., Nachtergaele J., Poesen J. *Event based modelling of gully incision and development in the Belgian loess belt.* (oral presentation)
c) Torri, D., Borselli, L. *Some Further Equation for High-Rate Gully Erosion*. (oral presentation)

Besides presentations directly related to the MWISED project, other presentations on topics related to MWISED were discussed.

5. REFERENCES

Alberts, E.E., Nearing, M.A., Weltz, M.A., Risse, L.M., Pierson, F.B., Zhang, X.C., Laflen, J.M., Simanton, J.R. 1995. Soil component. In: Flanagan, D.C., Nearing, M.A. (Eds.) *USDA – Water Erosion Prediction Project. Hillslope profile and watershed model documentation*. NSERL Report n°10, USDA-ARS National Soil Erosion Laboratory, West Lafayette, Indiana: 7.1-7.47.

Bennet, S., Casalí, J., Robinson, K.M., Kadavy, K.C., 2000. Characteristics of actively eroding ephemeral gullies in an experimental channel. *Transactions of the ASAE*. 43 (3): 641-649.

Brice, J.B., 1966. Erosion and deposition in the loess mantled Great Plains, Medicine Creek drainage basin, Nebraska. U.S. *Geology Survey Professional paper* 352(H): 347-350.

Desmet, P.J.J., Poesen, J., Govers, G., Vandaele, K., 1999. Importance of slope gradient and contributing area for optimal prediction of the initiation and trajectory of ephemeral gullies. *Catena*, 37: 377-392.

Foster, G.R., Flanagan, D.C., Nearing, M.A., Lane, L.J., Risse, L.M., Finker, S.C. 1995. Hillslope erosion component. In: Flanagan, D.C., Nearing, M.A. (Eds.) *USDA – Water erosion prediction project. Hillslope profile and watershed model documentation*. NSERL Report n°10, USDA-ARS National Soil Erosion Laboratory, West Lafayette, Indiana: 11.1-11.12.

Knisel, W.G., 1980. CREAMS: A field scale model for chemicals, runoff and erosion from agricultural management systems. *U.S. Department of Agriculture. Conservation research report* **26**: 480-485.

Merkel, W.H., Woodward, D.E. and Clarke, C.D., 1988. Ephemeral gully erosion model (EGEM). In: *Modelling Agricultural, Forest and Rangeland Hydrology*, American Society of Agricultural Engineers Publication, 07-88: 315-323.

Nachtergaele J., Poesen J., 1999. Assessment of soil losses by ephemeral gully erosion using high-altitude (stereo) aerial photographs. *Earth Surface Processes and Landforms*, 24, 693-706.

Nachtergaele J., Poesen J., Vandekerckhove L., Oostwoud Wijdenes D., Roxo M., 2001. Testing the Ephemeral Gully Erosion Model (EGEM) for two Mediterranean environments. *Earth Surface Processes and Landforms*, 26: 17-30.

Nash, J.E., Sutcliffe, J.E., 1970. River flow forecasting through conceptual models. Part 1 – A discussion of principles. *Journal of Hydrology* 10: 282-290.

Patton, P.C., 1973. *Gully erosion in the semi-arid West*. MSc. thesis. Colorado State University, Fort Collins, CO, pp. 129.

Poesen J.W.A., 1992. Mechanisms of overland-flow generation and sediment production on loamy and sandy soils with and without rock fragments. In: *Overland flow hydraulics and erosion mechanics,* Parsons A.J., Abrahams A.D. (eds), UCL Press, London: 275-305.

Poesen, J., De Luna, E., Franca, A., Nachtergaele, J., Govers, G., 1999. Concentrated flow erosion rates as affected by rock fragment cover and initial soil moisture content. *Catena*, 36: 315-329.

Shirazi, M. and Boersma, L., 1984. A unifying quantitative analysis of soil texture. *Soil Science Society of America Journal*, 48: 142-147

Smerdon E.T. and Beasley, R.P., 1961. Critical tractive forces in cohesive soils. *Agricultural Engineering*, 42: 26-29.

Vandaele, K., Poesen, J., Govers, G. and van Wesemael, B., 1996. Geomorphic threshold conditions for ephemeral gully incision. *Geomorphology*, 16(2): 161-173.

Vandekerckhove, L., Poesen, J., Oostwoud Wijdenes, D., de Figueiredo, T., 1998. Topographical thresholds for ephemeral gully initiation in intensively cultivated areas of the Mediterranean. *Catena*, 33: 271-292.

Wischmeier W.H., Smith D.D., 1978. *Predicting rainfall erosion losses – A guide to conservation planning*. United States Department of Agriculture Agricultural Handbook, 537.

Woodward, DE. 1999. Method to predict cropland ephemeral gully erosion. *Catena* 37: 393-399.

CRANFIELD UNIVERSITY (CRANFIELD)

REPORTING PERIOD: 1 APRIL 1998– 30 JUNE 2001

Contractor:	Cranfield University
Responsible scientist:	Professor R P C Morgan
Address:	Cranfield University at Silsoe Silsoe, Bedford MK45 4DT United Kingdom
Telephone:	+ 44 - (0)1525 - 863059
Fax:	+ 44 - (0)1525 - 863344
E-mail:	r.morgan@cranfield.ac.uk
Other scientists: Dr J. N. Quinton, Dr. A. Veihe, M. Kotova	

Scientific activity

1 WP1. Within storm changes in infiltration

ST2 Soil Roughness

1.1 Assessment of surface roughness and depression storage

The objective of the research on surface roughness and depression storage was to see whether a better procedure could be developed to assess the volume of depression storage than the method currently proposed in the EUROSEM User Manual (Morgan et al. 1998). The present approach uses measurements of roughness made with a 1-m long chain with 5 mm links along transects in the field to obtain a roughness index (RFR), defined as the ratio of straight-line distance of the transect (*X*) to the actual distance measured over the microtopographic irregularities (*Y*):

$$RFR\ (\mathrm{cm/m}) = \frac{Y - X}{Y} \times 100$$

A formula developed by Auerswald is then applied to estimate the depth of depression storage from the roughness index:

$$D\ (\mathrm{mm}) = exp(-6.6 + 0.27RFR)$$

This study investigated the feasibility of estimating depression storage from digital terrain models (DTMs) of the surface, validating the method against laboratory measurements. The work was undertaken in three phases:

- establishment of reliable data on depression storage for surfaces of varying roughness in the laboratory;
- development of a methodology for estimating depression storage from a DTM; and
- validation of the method by comparing estimates with the laboratory values.

1.1.1 Laboratory determination of surface roughness

Samples of a sandy loam soil of the Cottenham Series, a locally-available erodible soil, were air dried and passed through a 3-mm sieve. The clods remaining on the sieve were sprayed with diluted PVA glue (ratio 1:3) and then placed in an oven at 110°C until dry. The dry clods were placed into wet cement in three metal boxes, measuring 2 x 1 m, to give three soil surfaces of low (< 4 mm), medium (> 4mm) and high (> 4 mm with added topography to give a maximum height difference of 100 mm) micro-topographic roughness.

In order to ensure the stability of each surface, protect it from raindrop impact and avoid infiltration, the surfaces were covered with PVC-based cling film which was glued to the soil with PVA glue. This allowed each surface to be used again as replicate treatments. The boxes were placed in a runoff rig to which simulated rainfall was applied at nominal intensity of 103 mm/h. Measurements were made of the time for runoff to start, the time at which a constant runoff rate was achieved and the roughness of the surface using the RFR index of EUROSEM. Since there was no infiltration, the accumulated rainfall at the onset of overland flow was considered to equal the surface depression storage. Four different slopes, 1.7°, 3.7°, 5.7° and 6.9°, were used with three replications of each slope-roughness level combination.

The results of the experiments showed that depression storage decreased with slope, the form of the relationship depending on the surface roughness (Figure 1). With high roughness, depression storage declined much faster compared to medium and low roughness. Although graphical plots indicate that the relationships might be curvilinear, linear relationships provide an excellent description of the trends (Table 1). These findings correspond to those of Onstad (1984) and Linden et al. (1988) who obtained linear relationships between depression storage and slope at constant roughness, using digitised surfaces. However, Huang and Bradford (1990) found an exponentially decreasing relationship using Markov-Gaussian simulated surfaces and Edwards (1991) obtained a linear relationship when using a cube model and an exponential relationship with an inverted pyramid model. The findings indicate that the relationship between slope and surface roughness depends on the type of roughness, e.g. clod or micro-topographic roughness.

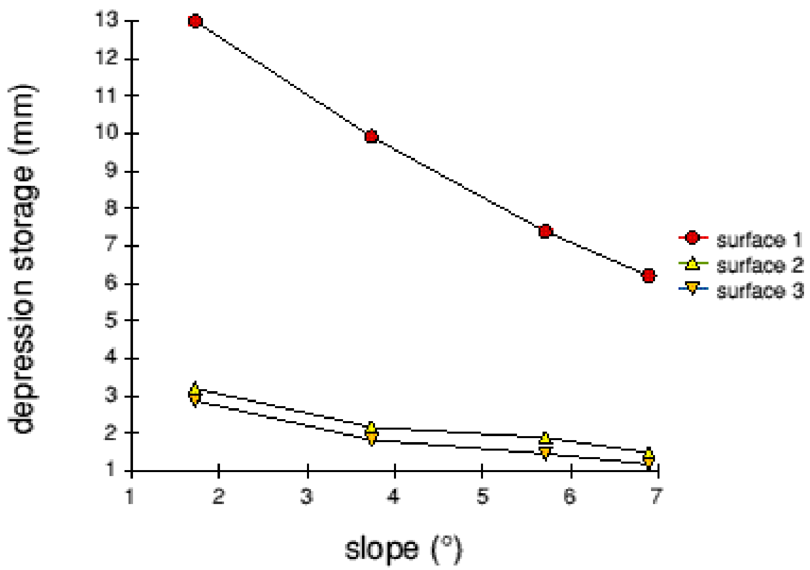


Figure 1 Relationship between depression storage and slope for three surfaces of different roughness

Table 1. Relationships between depression storage (*D*; mm) and slope (*S*; degrees) for the surface tested in the laboratory at Cranfield University

Surface	RFR (cm/m)	Linear regression	R^2
1	9.70	$D = 15.0851 - 1.3917\ S$	0.9939
2	8.01	$D = 3.5934 - 0.3116\ S$	0.9399
3	3.39	$D = 3.2597 - 0.3157\ S$	0.9414

The measured levels of depression storage are very high compared with those predicted by Auerswald's formula (Table 2). They are, however, compatible with measurements made by Moore and Larson (1979) and Folly (1996) and estimations made by Hansen et al. (1999) which generally range between 1 and 12 mm, depending on the roughness of the surface. In contrast, Helming et al. (1993) give values between 0.06 and 0.6 mm for surfaces of similar degrees of roughness. Ullah and Dickinson (1979) and Huang and Bradford (1990) also produce estimates of depression storage which are less than 2 mm.

Table 2. Comparisons of depression storage measured in the laboratory on a 1.7° slope with those estimated from Auerswald's formula

Surface	RFR (cm/m)	Measured depression storage (mm)	Estimated depression storage (mm)
1	9.70	13.00	0.0176
2	8.01	3.20	0.0111
3	3.39	2.87	0.0032

1.1.2 Establishment of methodology for estimating depression storage from DTMs.

Images for developing the methodology were obtained from two sources:

- the laboratory experiments carried out at Cranfield University, giving the three surfaces described above; and
- laboratory investigations undertaken at the Istituto per la Genesi e la Ecologia del Suolo, Firenze, giving a further two surfaces.

Pairs of stereophotographs were taken of the surfaces ensuring that the portion of the soil surface for detailed analysis was contained completely in the area of overlap between adjacent photographs. At Cranfield University photographs were taken from a height of 280 cm using a pair of digital KODAK camera (type DCS 420 with a Nikkor lens of 18.392 mm), placed side-by-side. At Firenze, the photographs were taken with a single Rollei 35 Metric Camera with a focal length of 40 mm and a calibrated graticule. To obtain the stereophotographs, the camera was physically moved between exposures.

Photogrammetry

The negatives of the photographs taken in Firenze were scanned as grey-scale images at 1200 dpi to obtain TIFF files suitable for use in the digital photogrammetry software. The digital images from the Kodak DCS420 were transferred from the cameras and converted to TIFF files. Calibration of the Rollei camera was obtained from the calibration certificate supplied with the camera. As the focus of this study was to examine the utility of the method for determining surface roughness rather than testing the photogrammetric fidelity of the camera, calibration for the Kodak DCS420 cameras was obtained from Warner and Slaattelid (1997). Image registration, correction and processing were carried out following standard photogrammetric procedures using the block tool of the ERDAS Imagine OrthoMax software running on a UNIX platform. After triangulation, the stereopairs were used to create a 10-mm resolution DTM of each surface. Stereo editing of the Silsoe surface DTMs was required to ensure that all the heights of the elevation points within the soil box corresponded with the stereo perception of the height of the soil surface. This was necessary because the super wide-angle lens used on the Kodak cameras caused the height points to fold back upon themselves towards the image edge. An ortho-rectified image of each soil surface was then created from the corrected DTMs.

ARC/INFO processing

The DTM and ortho images were exported from ERDAS Imagine as ARC/INFO grids (raster files) with elevation values forming floating point values for each pixel in the DYM grid. Prior to the calculation of depression storage, a polygon coverage was digitised from the ortho image of each soil surface. This was used to define the extent of the DTM to process. In the case of the Cranfield surfaces this corresponded to the edge of the soil box. The Italian soil surfaces had a defined rectangle within the soil box. The ARCINFO GRIDCLIP function was used with the respective polygon coverages to cut the areas of interest out of the DTM images.

The ‘clipped’ elevation grids were then processed using the ARC/INFO ARC Macro Language (AML) to compute the depression storage. For this purpose, it was necessary to have a clear definition of ‘depression storage’. Depression storage was therefore defined as ‘the sum of the volumes of water held in depressions within the defined watersheds, divided by the sum of the plan areas of the watersheds’. The AML calculated the depression storage according to this definition in each individual watershed within the DTM. No attempt was made to model flow from one watershed to another. Volume was reported in m^3 and area in m^2 and the resulting depth in mm.

AML programme: description of process

Prior to running the AML, an elevation point file (%.WS_PT%) is prepared from the elevation raster derived from the OrthoMax software. This is used as input to the AML to construct a Triangulated Irregular Network (TIN) for each watershed. The main processes followed by the AML are described in Table 3.

The main components of each watershed are (Figure 2):

- a sink (the lowest point within the watershed)
- a watershed boundary (the line of highest points from which water will drain towards the sink)
- a pour point (the lowest point along the watershed boundary over which water will spill if the sink is filled to capacity).

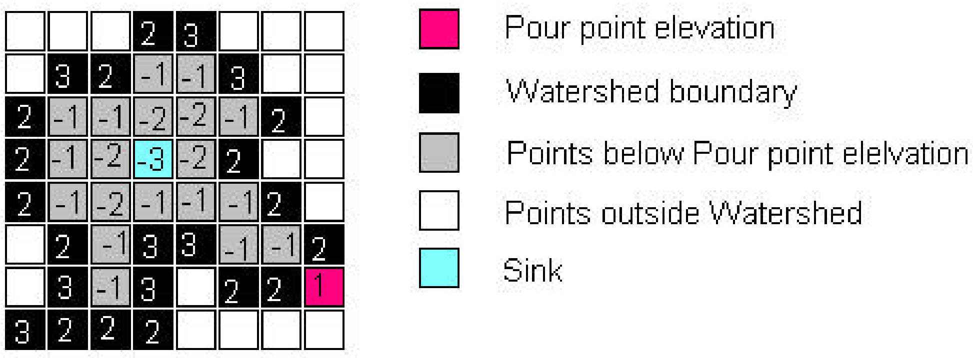


Figure 2 Grid showing elevations and designations for watershed definition

Results

The estimated values of depression storage for the five surfaces, based on the DTMs, are given in Table 4.

Table 3. Steps in the AML procedure to determine depression storage

Step	*Procedure*
1	On running AML, the user is prompted to enter the name of the 'clipped' elevation grid and a short ID for the data sets that will be created.
2	AML creates a point coverage from the elevation grid consisting of a point for every pixel in the original grids.
3	Using the hydrological commands available within the GRID module of ARC/INFO, the number and extent of watersheds in the study area are determined and defined using the following procedure: (a) determination of the flow direction for each pixel in the elevation grid; (b) identification of the sinks in the study area from the flow directions; (c) definition of the watersheds associated with each sink using outputs from (a) and (b).
4	The resulting watershed grid is converted to a 'coverage' in order to determine the surface area of each defined watershed.
5	The watersheds are numbered and the total number of watersheds determined. The user is then asked to enter the start and finish numbers of the watersheds for further processing; this feature enables the user to specify a subset of watersheds for analysis rather than processing the whole file.
6.	The AML cycles through the selected set of watersheds, in turn, following this sequence: (a) the first watershed is selected and named (%.DATASET_ID%_%.WS%) (b) using the GRIDPOLY command, a coverage is created of the watershed (%.DATASET_ID%_%.WS%_cov1); this is used later to cut out the elevation data from the elevation grid in order to calculate the storage volume for the watershed (c) the 'pour point' elevation is determined using the ZONALFILL command and the result is assigned to a variable (d) using the watershed 'coverage' to define the boundary, GRIDCLIP is used to cut out or clip the elevation pixels within the watershed for further analysis (e) the individual watershed area of elevation pixels is used to select all points with elevations less than or equal to the elevation of the pour point (f) if there are no points that meet the criterion for (e), i.e. there is no area within the watershed that lies below the pour point, a value of -999999 is assigned to the variable %wstest2% and the program calls a subroutine (loop_end) which jumps over the remaining steps and moves on to the next watershed (g) if the variable %wstest2% is assigned a value other than -999999, the program creates an integer grid of the watershed elevation values; values are rounded down if the lie between 0.1 and 0.49 and rounded up if they lie between 0.5 and 0.99 (h) a coverage (%.DATASET_ID%_&.WS%_poly2) of the integer grid is created using the GRIDPOLY command (i) the watershed elevation coverage is required to perform a HARDCLIP when creating the Triangulated Irregular Network (TIN) of the watershed; to enable this step, a new field (height) is added to the coverage polygon attribute table and all records are assigned the value -9999 (j) a TIN of the area bounded by the watershed is constructed from the elevation point file (%.WS_PT%) prepared prior to the running of this AML from the elevation raster derived from the OrthoMax software; the hardclip coverage is set to %.DATASET_ID%_%.WS%_poly2 (k) the volume of the TIN below the pour point elevation is calculated and stored in an attribute table within INFO (%.DATASET_ID%_dep.att)(l) unwanted TINs, coverages and grids are deleted before returning to the loop to analyse the next watershed
7	The AML cycles through all the watersheds and a second AML is executed to sum the volumes of the individual watersheds

Table 4. Results from the ARC/INFO depression storage calculations

Surface	Number of watersheds	Area of watersheds (m^2)	Volume of depression storage (m^3)	Depth of depression storage (mm)
Cranfield (high roughness)	524	1.98	0.0006600	0.33
Cranfield (moderate roughness)	693	1.82	0.000656	0.36
Cranfield (low roughness)	514	1.76	0.000241	0.14
Firenze 1	511	0.0038	0.000013	3.42
Firenze 2	126	0.0035	0.000003	0.86

1.2.5 Discussion

The automated generation of height values within OrthoMax was successful. An important aspect of this method to consider is the time required to derive the data for the calculation of depression storage. Data capture is instantaneous once the cameras are in position. Triangulation, DTM and orthoimage creation are rapid due to the small file sizes involved. However, all surfaces had to be carefully checked to confirm that the automated heighting of DTM points was correct with respect to the stereo perception of the soil surfaces. Some heights were incorrect in the Silsoe surfaces due to the edge problems described earlier. This adds to the processing time of the data. On average, for the rougher surfaces at Cranfield, the time required to derive the clipped DTM was 1.5 days. The time required for the calculation of depression storage varied according to the number of watersheds to process. As an example, the rough Cranfield surface took 5 hours to process using the ARC/INFO AML.

Close examination of the processed data files shows that many watersheds defined by the AML do not have any depression storage associated with them and consequently return a volume of 0.00000 m^3. This is in part due to the default field width of five decimal places applied by ARC/INFO in the data table created by the VOLUME command. It is possible to create a volume measurement for some of these shallow depressions by multiplying the x, y and z dimensions by an appropriate factor, for example, 10. This was done for the rough Cranfield surface giving a volume of 0.00067 m^3.

In a physical model there is likely to be some residual volume of water retained in all watersheds due to surface tension and micro relief that is not modelled by the AML. The AML assumes no retention of water other than that held within the watershed below the pour point of the depression.

The resolution at which the surface is modelled will have a significant effect on the output. The computed volume is influenced by the number of points used in the TIN procedure, which in turn is influenced by the resolution of the DTM. The higher the resolution of the DTM, the closer the *modelled* surface will be to the *actual* surface, and visa versa. A horizontal resolution of 10mm was used in this study because this was seen to be a good compromise between the amount of data to be processed and how representative the DTM was of the soil surface.

The AML could be modified to incorporate other features. The effect of tilting the surface, variations in rainfall intensity and soil permeability could be useful extensions to the present model.

1.2 Discussion

Values of depression storage derived from the DTMs are very low compared with those measured in the laboratory and the estimates from Auerswald's formula. There is no reason to believe that any of the values are incorrect, so the differences must relate to the way in which they have been derived and, therefore, to the definitions used for depression storage.

Depression storage can be considered as the amount of water held in the surface depressions, none of which runs off, and which may subsequently be evaporated or infiltrated. It excludes surface detention which is storage of overland flow in transit (Chorley, 1980). In the laboratory experiments described above, depression storage is defined as the amount of water held in surface depressions when runoff starts to flow from the base of the slope. By the time this occurs, water will have already filled some of the smaller depressions and overflowed into larger ones, contributing to the storage there until their pour point is reached. The measurements made from the DTMs give the storage of each depression and do not allow for water moving on the surface from one depression to another but not flowing to the base of the slope. The latter is similar to the methodology adopted by Helming et al. (1993) who considered only the storage capacity of each depression from estimates of its circumference, area and volume. Auerswald's formula is based on data from Helming (1992).

The key questions for the estimation of depression storage are to decide when runoff begins and how best to describe the dynamics of storage and runoff generation. The traditional hydrological approach (Horton, 1937) is to assume that depression storage must be satisfied before runoff can begin. In reality, however, surface depressions are not all the same size and volume and flow from the smaller depressions can begin before the storage of the large ones is filled. In the laboratory it is possible to decide that runoff occurs when flow reaches the bottom of the slope. In the field, the slope length may be tens of metres or more and runoff can produce serious erosion before it reaches the base of the slope. Either a threshold length of flow has to be determined which, when exceeded, defines the point at which runoff starts or the approach of Helming et al. (1993) has to be adopted which means that runoff occurs as soon as any of the depressions overflow. If the latter approach is taken, the situation arises in which runoff is occurring whilst depression storage is still increasing. The question then arises as to whether it is necessary to model the dynamics of this phase of runoff generation.

Over a complete storm it is clear that the rainfall which goes to depression storage does not contribute to runoff and that, numerically, Horton's (1937) approach holds. Since the volumes of surface depressions are rather small, generally less than an equivalent depth of 0.5 mm (Helming et al. 1993), it could be argued that for the storms in which most erosion occurs there is no need to model depression storage at all. However, if EUROSEM is to be used for storms of high frequency and moderate magnitude, which will be the case for pollution modelling (Quinton et al. 2001), there is a need to retain the depression storage component which, on rough (ploughed) surfaces would be sufficient to store 20-30 per cent of the rainfall.

DTMs with a 10-mm resolution can be used to obtain reliable estimates of depression storage but the method is rather time-consuming, particularly for rough surfaces. The present method of measuring roughness in the field and estimating depression storage from a roughness index is an appropriate way of obtaining data quickly with a sufficient level of accuracy for modelling purposes, given the small values involved. Except for very high values of roughness (25-40 cm/m), Auerswald's formula seems to underestimate depression storage by up to an order of magnitude.

1.3 Conclusions and recommendations

For modelling purposes, depression storage is best defined in relation to the volume of all the depressions on the surface to the point at which each depression overflows. This avoids the problem of having to define when runoff occurs. Stereophotographic pairs of the slope surface can be used to obtain DTMs from which depression storage can be calculated using ARC/INFO ARC Macro Language. However, the method is time consuming. The present procedures for estimating depression storage from field measurements of roughness are adequate as data input to EUROSEM provided that improvements can be made to Auerswald's formula. Further work is recommended to obtain data on depression storage from the literature and develop a new algorithm for estimating depression storage as a function of roughness.

2 WP4: Simulation of within storm erosion dynamics.

2.1 Recoding of EUROSEM

The focus of our work since the last interim report has been on the completion of the graphical user interface (GUI) and the incorporation of new routines for gully erosion and infiltration.

It was originally proposed to recode EUROSEM in Fortran 90. However, after contracting a programmer we were advised to use an object orientated language. To facilitate the development of a Graphical User Interface (GUI) the Delphi language was chosen.

The EUROSEM model has been completely recoded from Fortran 77 into Delphi. The resulting product has received the name EUROSEM 4 Win. The Window based application includes a graphical interface which incorporates sheets for catchment definition (Figure 3), rainfall description (Figure4) and the display of output (Figures 5 and 6). The model can be parameterised on an element-by-element basis (Figure 7) or use can be made of data dictionaries, which facilitate the use of information derived from pedoalgorithms or other environmental data sources. The software also incorporates full help support and online documentation.

The major components of the application and some details of their implementation are as follows (Figure 8).

I. Data declaration section. This describes the complete set of global objects, data types and structures. It provides the visibility of data for all subroutines involved in the data processing.

The main data structures are:

- Simulation record, which keeps the information on the simulation options and the data sets used in the simulation.
- Catchment record, which keeps the general catchment parameters and the list of elements comprising the catchment.
- Element data record which incorporates the data on each element along with data describing its appearance and methods to realise its visualisation. Element numeric data are used by simulation routines; visualisation data and methods are used by GUI.
- Rainfall data are declared as static array of records and used by simulation routines to perform the simulation.
- The observed data record is used for displaying measured data sets to compare them with modelled results.
- Output data are declared as a several sets of records with different structures (dynamic output, static element-wise output, static summary output).
- Data dictionary structures.
- Runtime messages and help references which are sensitive to context.

II. The GUI is the main controlling component, maintaining interaction with the user, as well as interaction between the other components of the software.

Interaction with the user is realised by a set of controls within subroutines that implement the response to all user actions and perform the required operation.

The other important function of GUI is to provide access to a visualised input data to make data entry and editing possible.

During the simulation run, the GUI accepts the information on the simulation progress generated by the simulation routines and displays this information on a dedicated panel. At the end of simulation run, the GUI displays output data in a dynamically created output form from the temporary output disk files created by the simulation routines.

III. The data management section is a set of routines implementing data saving and loading to and from the disk files having binary internal structure. To provide additional data safety, before file saving, a backup copy of the previous version of each file is created.

IV. The simulation algorithms are the core of the EUROSEM model. Logical and numerical interpretation of the model was translated from the Fortran 77 code based on the latest EUROSEM version 3.2 of 11/97. In the Windows based version simulation routines are declared as the methods of a thread object. The simulation thread is executed as a separate process, constantly generating messages to notify the system on its progress and status. The messages are processed by the main application to display the simulation progress. At the end of a successful completion of the simulation, a set of temporary output files is created, which are used by the output display functions of the GUI. If the simulation is terminated, the simulation thread notifies the calling application about the reason for termination (i.e. cancellation by user or abortion due to the run time errors). The detailed simulation progress is registered in the log file, which can be used later for debugging purposes or to trace the sequence of calculation.

If necessary, the simulation unit can be compiled and distributed as a dynamically linked

library, which allows users to embed EUROSEM routines into other specialised software.

Using the thread object for simulating routines has the advantage of allowing several simulation processes to run simultaneously, if required. In this case, using a thread provides an effective use of system time and faster execution of the simulation (e.g. on multiple rainfall simulations).

V. A Data Conversion Utility was developed to help DOS version users convert their data into the format compatible with the Windows based version. It is accessible from the main menu of the EUROSEM 4 Win.

VI. The Data Dictionaries Utility (DDU) is one of the additional features designed to simplify the input of element data. It also may be used for user data systematisation. For the DDU the creation of the data dictionaries, data input and editing, is implemented as a stand-alone application, accessible from the main menu of the EUROSEM software. The format of data files (soil, surface condition, and vegetation) created by the DDU is recognisable by EUROSEM 4 Win. Using an option of the data entry form, the data from the dictionary can be inserted into the corresponding fields of the data entry form. Both EUROSEM 4 Win and the Data Dictionary Utility share a common dynamically linked library implementing all functions dealing with the data dictionaries.

VII. Online user help is developed in WinHelp format. Access to the help content is available from the main menu featuring standard WinHelp keyword search and global search functions. Some elements of user interface provide direct links to help topics. Also, context-sensitive help is available from the data entry form, giving the user a description of the input parameters.

The main advantages of the Windows based version over the DOS based one are:

- convenient and easy to use interface
- visualisation of input and output data
- export of output data into graphic and table data formats
- using of time saving options on the data editing, like element copying, data paste and copy via Windows clipboard, data export from the data dictionaries, etc.
- removal of DOS version bugs which were detected and eliminated in the Windows-based version.

In addition to the basic functions available in the DOS version of EUROSEM, the Windows based version has the following new features:

- multiple rainfall simulation
- incorporation of new algorithms of infiltration and ephemeral gully formation developed within the framework of the MWISED project.

Testing and debugging. Currently the main routines have been programmed, determining application functionality, its appearance and user interface concept. Considering the relatively short time devoted to the application development, the authors have not had an opportunity to test it comprehensively.

Although the application has been constantly tested during its development, using a sample data set, the testing is not complete and the application cannot be guaranteed bug free. In addition to the further debugging of the application by its developers, feedback with the potential users on bug reports is strongly desirable.

2.2 Incorporation of new infiltration routines

New routines, using equations supplied by CNR Firenze, have been added to EUROSEM to describe within-storm changes in infiltration.

Algorithmically, these equations have been embedded into existing EUROSEM subroutines for calculating the infiltration rate

User interface provides controls to select between infiltration equations Parlange-Smith and Morel-Seytoux.

The dynamics of the infiltration rate calculation is illustrated by the simulation results for the sample data set having the parameters given in Figure 9. Figures 10 and 11 display the infiltration rate for each calculated time increment at each distance node of the investigated plane using both algorithms. Figure 12 shows the comparative dynamics of the infiltration at the last node of the plane.

Compared with results from the Parlange-Smith equation, the Morel-Seytoux equation gives longer predicted time to saturation; the infiltration decreases more slowly while a rainfall continues, and faster after the rainfall recession. Also, the global volume balance error is less when using Morel-Seytoux equation.

More informative assessment of the reliability of both algorithms can be done through comparison of the modelled and measured data.

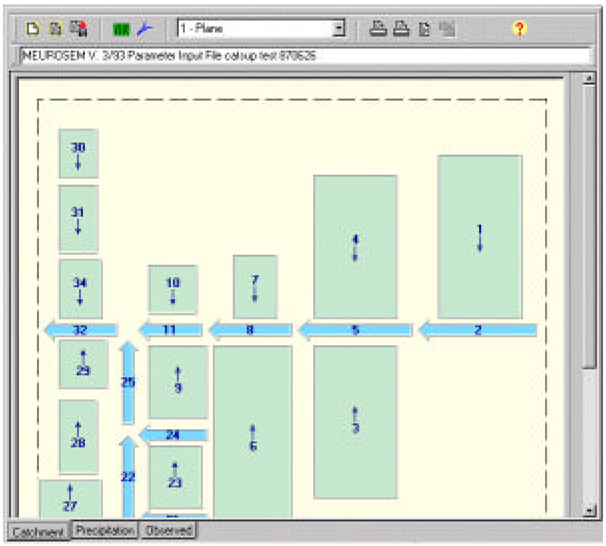


Figure 3. Catchment definition screen showing plane elements (rectangles) and channel elements (arrows).

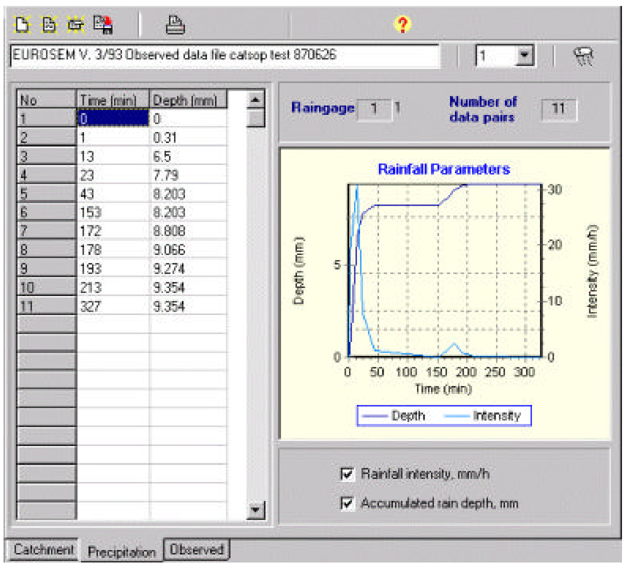


Figure 4. Rainfall input dialogue box.

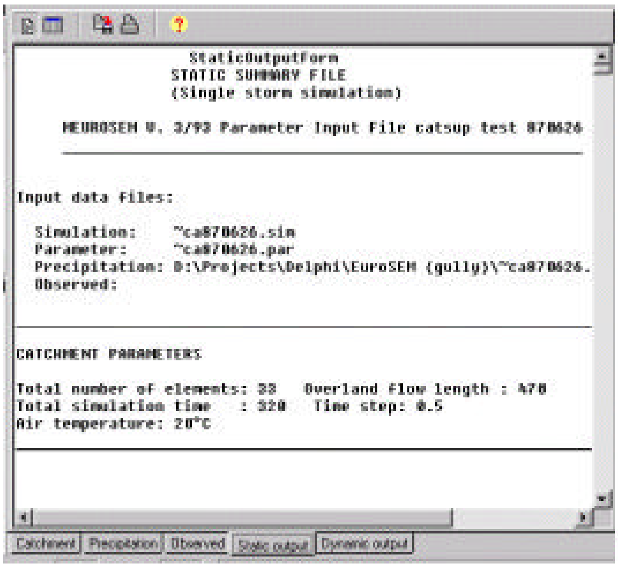


Figure 5. Output displayed as text.

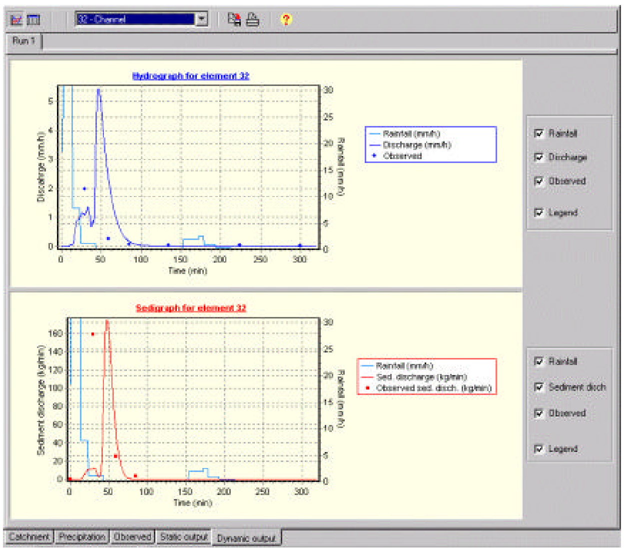


Figure 6. Output displayed graphically.

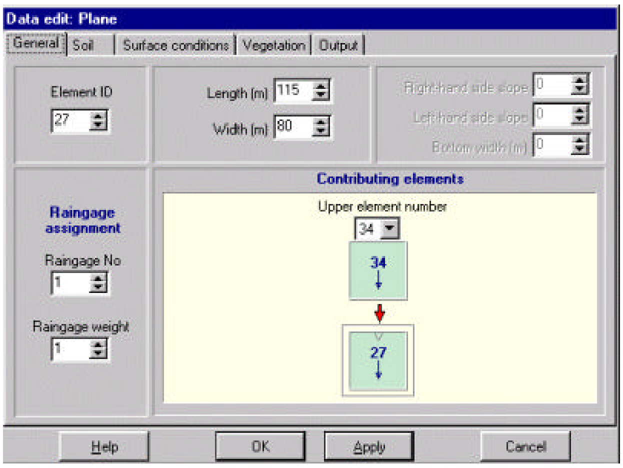


Figure 7. Parameterisation dialogue.

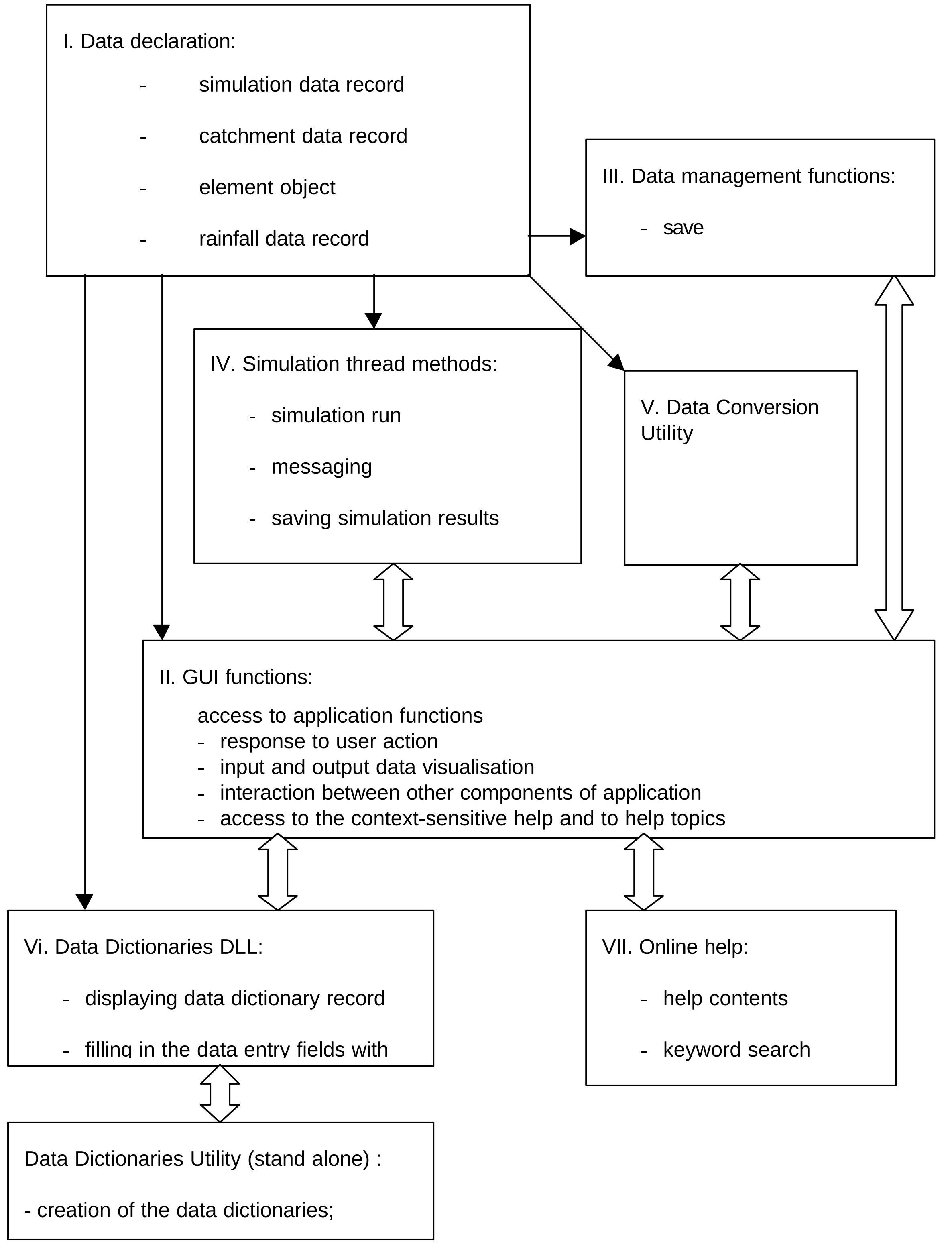


Figure 8. Diagrammatic representation of program fucntioning.

```
         CATCHMENT PARAMETERS
         --------------------

Total number of elements: 1   Overland flow length : 100
Total simulation time   : 60   Time step: 0.5
Air temperature: 10°C

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

PLANE 1, INPUT DATA

Element geometry:
   Length: 50.00 m   Width : 20.00 m

Soil hydrology
   Saturated hydraulic conductivity: 50.00 mm
   Capillary drive: 240.00 m   Porosity: 0.45 %
   Moisture   Initial: 0.40   Maximum: 0.42 % v/v

Soil physical properties
   D50: 125.00 µm3   Specific gravity: 2.65 mg/m
   Erodibility: 1.60 g/J   Cohesion: 5.00 kPa
Depth to non-erodible layer      : 3.00 m
   Soil particle detachment exponent: 2.00

   Rocks
   Rock fragment cover   : 0.40%
   Rock fragment content : 0.40% v/v
   Rock fragments are not embedded into a surface

Surface conditions
   Number of rills: 0.00
   Rill width: 0.00 m      Rill depth: 0.00 m   Rill side slope: 0.00
   Slope: Rill: 0.00   Interril: 0.10
   Manning's N:   Rill: 0.00   Interrill: 0.06
   Roughness:   1.00 cm/mm      Recession factor: 10.00 cm
   Rills dimensions are constand along the slope

Vegetation parameters
   Vegetation cover: 0.00   Plant height: 0.00
```

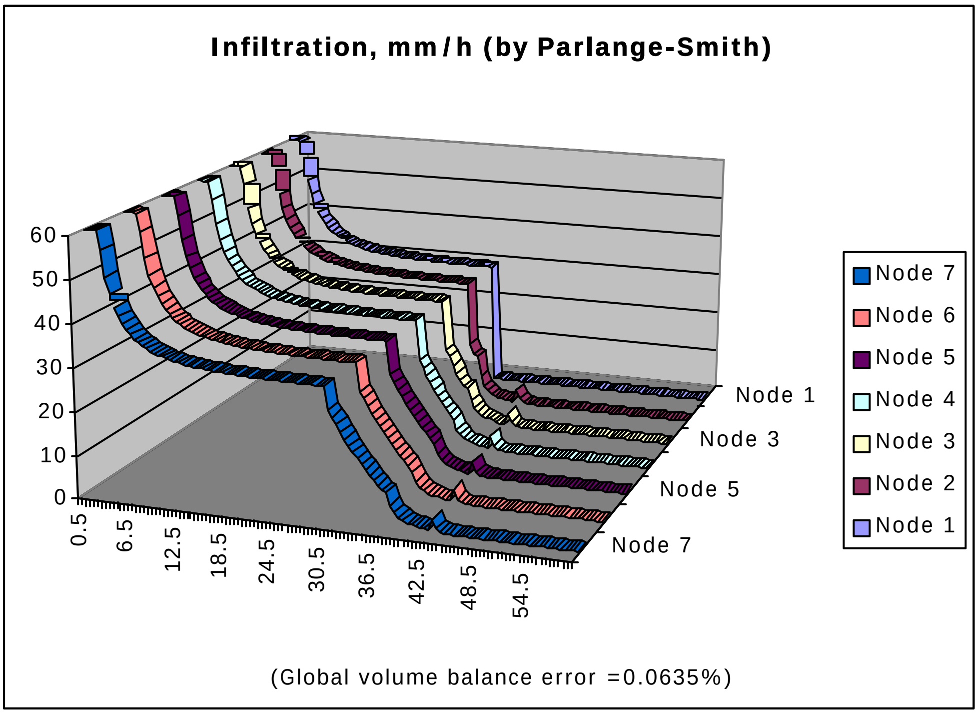


Figure 10. Infiltration rate (mm/h) plotted against time at different computational nodes for the Parlange-Smith equation.

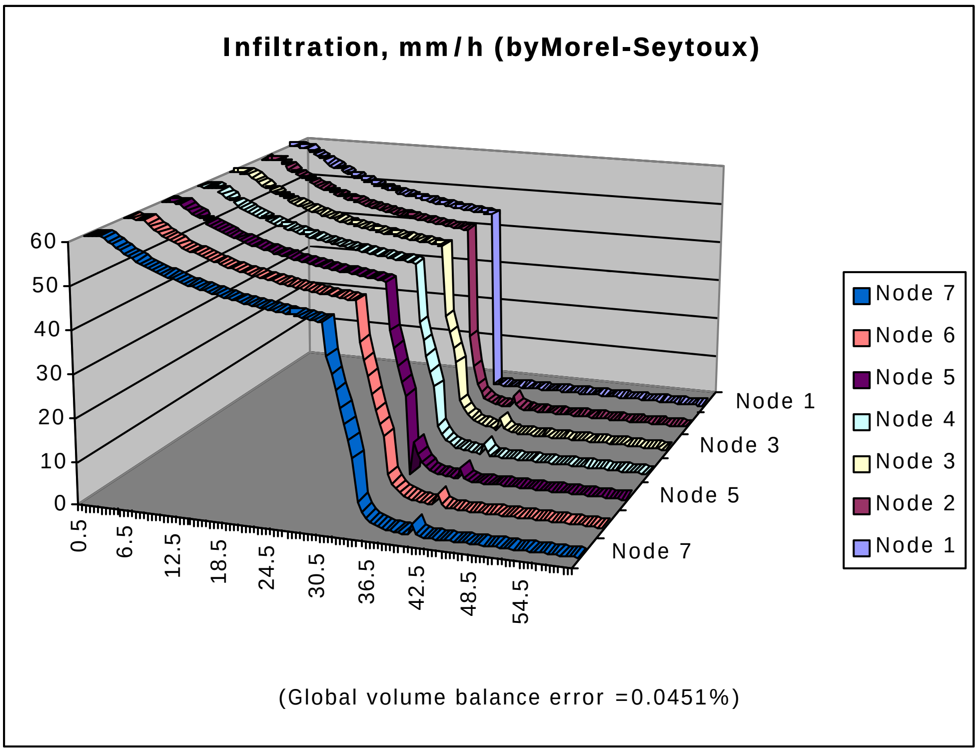


Figure 11. Infiltration rate (mm/h) plotted against time at different computational **nodes for the**Morel -Seytoux **equation.**

2.3

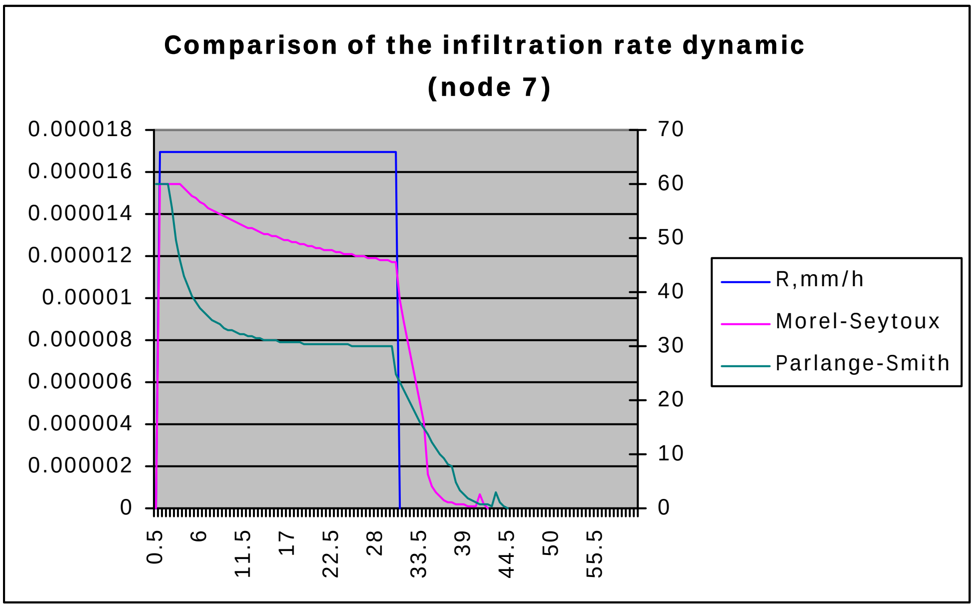


Figure 12. Comparison of infiltration rate using the Morel-Seytoux and ParlangeSmith equations

Incorporation of Gully Routines

In the process of the application development an attempt has been made to incorporate ephemeral gully calculations into the EUROSEM model.

The main idea on gully routines implementation implies in declaring of the new type of element called thalweg (valley bottom) where the initiation of ephemeral gully is possible under certain rainfall conditions. The new element is very similar to the plane element having one rill along the main slope in the middle of it. The shape of the rill is described as a trapezoid having the same side slope as the interrill slope of the thalweg element, thus representing a continuous surface of the specified shape. Like the plane, the thalweg element can accept runoff and sediment from the upslope element. In addition, it can receive runoff contributed by right and left hand planes (Figure 13). The runoff from the upslope plane is added to the first (topmost) distance node of the thalweg element; the contribution from side planes is added to a first node of an interrill area.

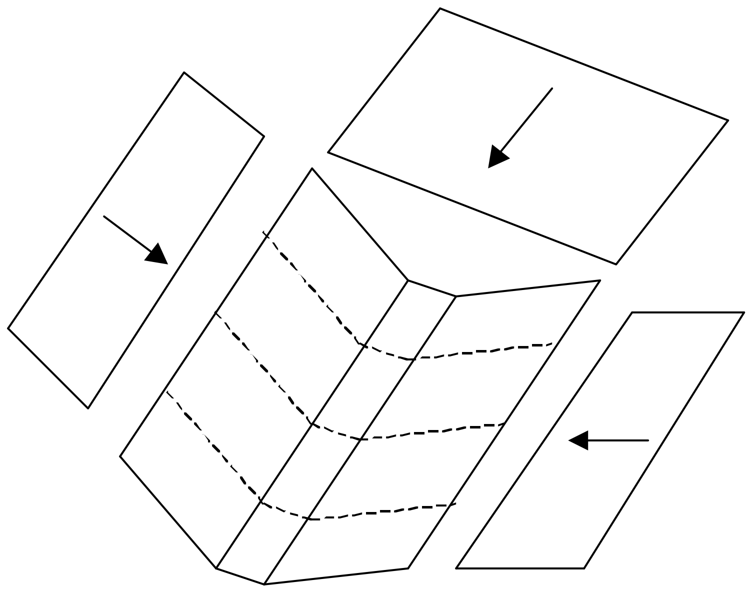


Figure 13. Ephemeral Gully element with contribution, left, right and upper planes.

At the end of each time step a gully initiation threshold is checked. As a threshold of gully initiation and initial gully parameters the following relationship has been used (provided by MWISED partners Jean Poesen and Jeroen Nachtergaele): the threshold based on the discharge Q for gullies in cultivated European fields is 0.002 m^3 s-1 < Q < 1 m^3 s-1 and the initial width W of a gully is $W = 2.51\ Q^{0.41}$.

While the value of discharge is below the threshold value, the normal EUROSEM routines implementing rill and interrill calculations apply. When the gully threshold is exceeded, the rill dimensions and shape is recalculated: the width of rill is determined as described above, the cross section of gully is determined as rectangular, and the depth of the gully is calculated so that accommodate the available runoff. The width of interrill area is recalculated, and the supply of sediment is computed from the difference in the cross section area before and after gully formation. Until the discharge falls below the threshold the gully routines are applied, when discharge falls below the threshold value, the algorithm switches back to standard EUROSEM rill and interrill routines.

The modelled gully parameters are stored into the special data structure, which could be used for analysis and visualisation.

The approach described is illustrated on the fragment of the Rottingdean catchment. The catchment configuration is shown in figures 14.

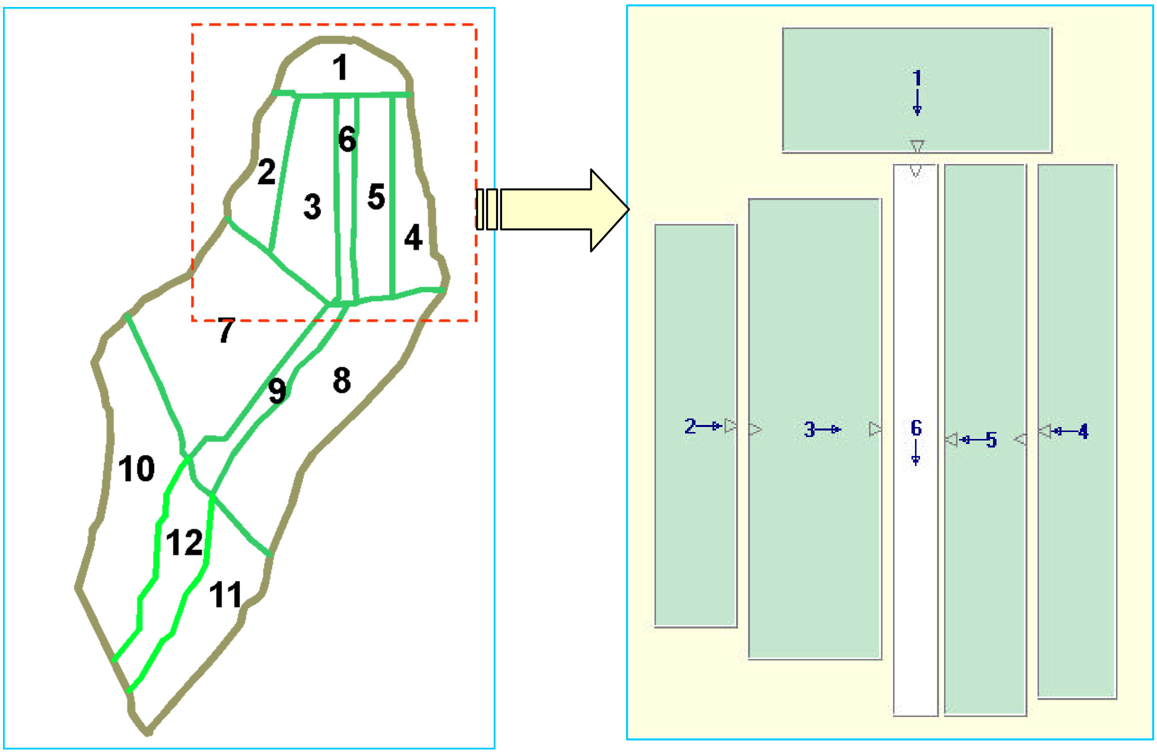


Figure 14. Diagrammatic representation of the upper reaches of the Rottingdean catchment.

Figure 15 shows the hydrograph for a test simulation compared to the critical threshold. Figure 16 shows the dynamical change of the modelled gully cross section (a- at the beginning of simulation; b – the time step before gully initiation; c – gully initiation; d – gully growth; e – gully cross section when the discharge decreases; f – final gully cross section).

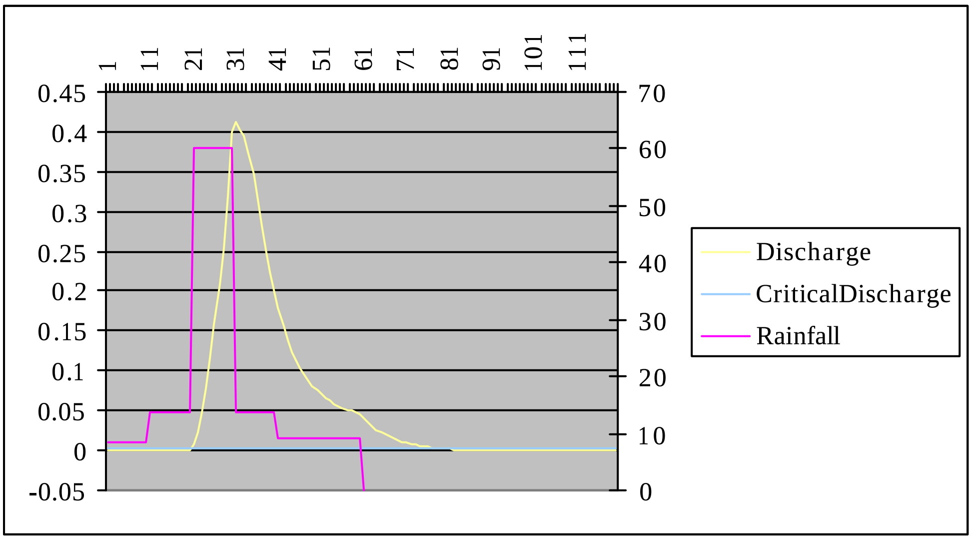


Figure 15 Hydrograph, hyetograph and threshold for gully initiation for the Rottingdean catchment (Discharge is plotted on the left hand axis, Rainfall on the right hand axis).

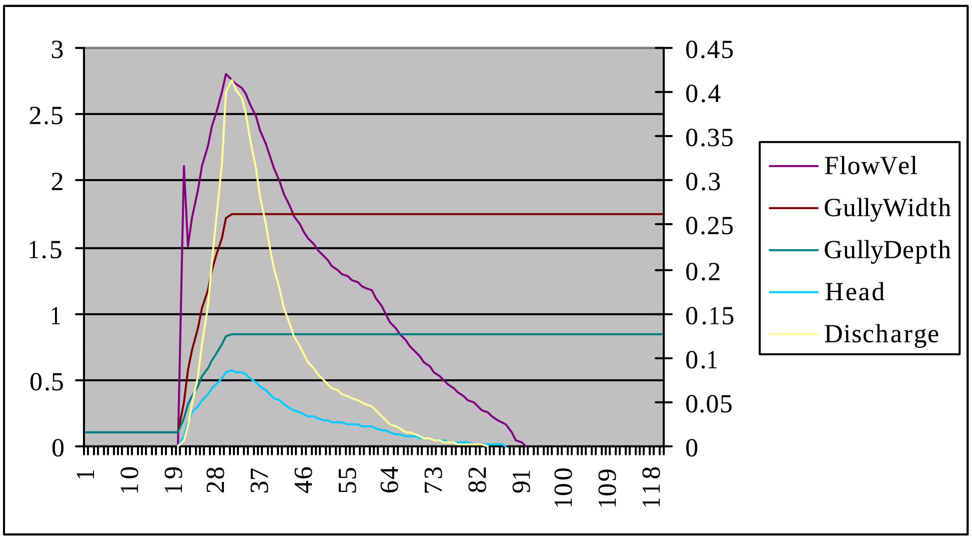


Figure 16, Changes in gully dimensions through time for the Rottingdean test catchment (Gully dimensions and flow velocity are plotted on the left hand axis, discharge is plotted on the right hand axis).

This approach has certain limitations. Since the main functions of the thalweg element implementation have been adopted from the EUROSEM plane element, it is not possible to define different parameters for the different sides of the thalweg element, such as slope, width, and vegetation. Also, it is impossible to describe a rilled surface onthe side of the thalweg. This can be overcame by the defining the thalweg element as narrow as possible, so that the conditions at both sides were similar, and describing differences in conditions of the contributing areas by parameterisation of the contributing side planes.

The advantage of this approach is that it could be implemented using other parameters (or combinations of parameters) as a thresholds and for initial gully dimensions calculations, namely, runoff cross section area, cross section dimensions, flow velocity, slope.

The development of ephemeral gully routines is currently at the experimental stage. Before introducing it to the user, more tests and trials should be made, the visualisation functions and user interface service functions for the thalweg element will need to bebe programmed.

3 ST2 field validation

Late completion of the finalised EUROSEM model has prevented us from testing the model against the Woburn dataset within the timespan of the project. However, it is our intention to fully test the model over the coming months.

4 References

Chorley, R.J. 1980. The hillslope hydrological cycle. In Kirkby, M.J. (ed), Hillslope hydrology. Wiley, Chichester: 1-42

Edwards, G. 1991. The influence of soil surface configuration on depression storage and soil loss. MSc Thesis, Cranfield University.

Folly, A. 1996. Soil surface roughness an infiltration in the savanna ecosystem and its impact on erosion. Geografisk Tidsskrift 96: 32-39.

Hansen, B., Schjønning, P. and Sibbesen, E. 1999. Roughness indices for estimation of depression storage capacity of tilled soil surfaces. Soil & Tillage Research 52: 103-111.

Helming, K. 1992. Die Bedeutung des Mikroreliefs für die Regentropfenerosion. Bodenökologie und Bodengenese 7, 155 pp.

Helming, K., Roth, Ch.H., Wolf, R. and Diestel, H. 1993. Characterization of rainfall - microrelief interactions with runoff using parameters derived from Digital Elevation Models (DEMs). Soil Technology 6: 273-286.

Horton, R.E. 1937. Hydrologic interactions of water and soils. Proceedings of the Soil Science Society of America 1: 401-429.

Huang, C. and Bradford, J.M. 1990. Depressional storage for Markov-Gaussian surfaces. Water Resources Research 26 (9): 2235-2242.

Linden, D.L., van Doren, D.M. and Allmaras, R. 1988. A model of the effects of tillage-induced soil surface roughness on erosion. 11th International Conference of the International Soil Tillage Research Organisation, Edinburgh, 11-15 July 1988, Volume 1: 373-378.

Moore, I.D. and Larson, C.L. 1979. Estimating microrelief surface storage from point data. Transactions of the American Society of Agricultural Engineers 22: 1073-1077.

Morgan, R.P.C., Quinton, J.N., Smith, R.E., Govers, G., Poesen, J.W.A., Auerswald, K., Chisci, G., Torri, D., Styczen, M. and Folly, A.J.V. 1998. The European Soil Erosion Model (EUROSEM): Documentation and User Guide. Cranfield University at Silsoe

Onstad, C.A. 1984. Depressional storage on tilled soil surfaces. Transactions of the American Society of Agricultural Engineers 27 (3): 729-732.

Quinton, J.N., Catt, J.A. and Hess, T.M. 2001. The selective removal of phosphorus from soil: is event size important? Journal of Environmental Quality 30: 538-545.

Ullah, W. and Dickinson, W.T. 1979. Quantitative description of depression storage using a digital surface model. Journal of Hydrology 42: 63-90.

Warner, W. S. & Slaattelid, B. R. 1997. Multiplotting with images from a Kodak DCS420 digital camera. Photogrammetric Record 15(89): 665-672.

5 Appendix 1

Introducing the Morel-Seytoux & Verdin (1981) equation as infiltration routine

Lorenzo Borselli

CNR-IGES Florence , IT

borselli@iges.fi.cnr.it

(static model)

Basic Soil parameters:

G = net capillary drive or wtting front suction as in Mein and Larson /Green-Ampt models (in mm)

K_s = saturated conductivity (in mm/h)

The composite parameter B is given as:

$$B = G(q_s - q_i)$$ (like in eurosem)

where

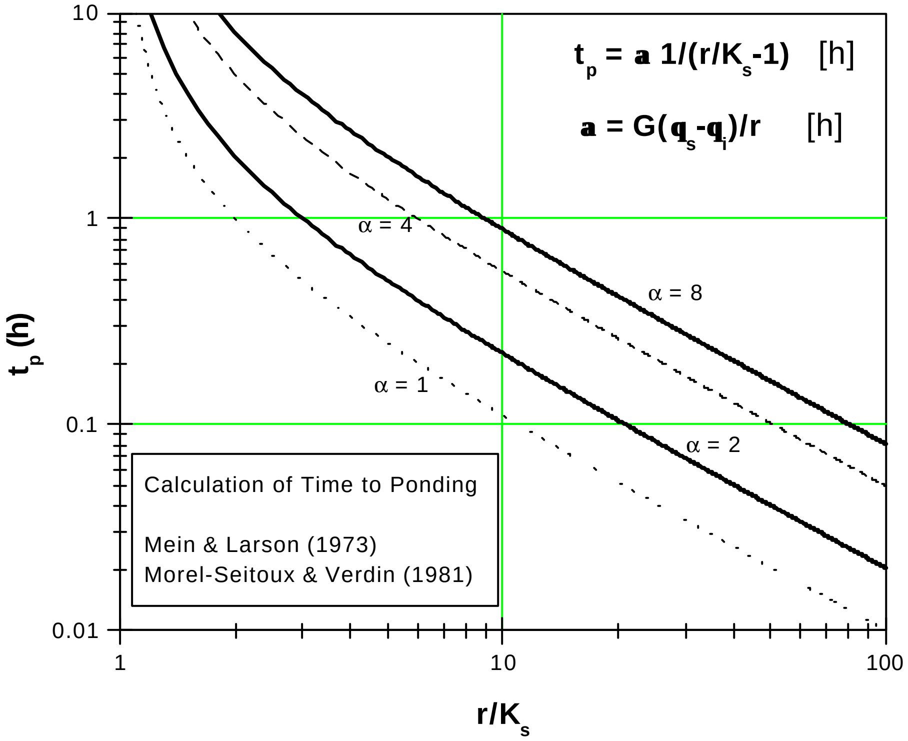
$(q_s - q_i)$ is the initial water deficit with respect the natural saturation

Time to ponding for a variable rainfall:

Given *r(t)* , the ietograph (in mm/h), ponding at time *t* occur when the following equation is verified:

$$t = \frac{K_s B}{r(t)^2 - K_s r(t)}$$

in this case t = t_p= time to ponding (in h)



Infiltration after ponding :

if $r(t) > k_s$ then

$$i(t) = \frac{1}{2}\sqrt{\frac{2K_s(B+I_p)^2}{B}}\left(\frac{1}{\sqrt{t-t_p+A}}\right)+K_s$$

where A is a composite parameter given by:

$$A = \frac{\left(B + I_p\right)^2}{2K_s B\left(\frac{r(t)}{K_s} - 1\right)^2}$$

and

$$I_p = \int_0^{t_p} r dt$$

is the cumulative infiltration until the ponding time

Notes:

be sure to check at every time step that: $r(t) > k_s$ **!!**

References:

Borselli L., 1998: Soil surface roughness dynamics and its influence on infiltration processes: experimental analysis and modelling. Ph.D thesis. dept of soil science. University of Florence. (in italian).

Morel-Seytoux H.J., Verdin J.P., 1981. Extension of the Soil Conservation Service Rainfall-Runoff Methodology for Ungaged watersheed. Federal Highway Adminsitration, Environmental Division Washington D.C. Report No. 81-10.

Consejo Superior de Investigaciones Científicas
Centro de Edafologia y Biologia Aplicada del Segura,Murcia (CSIC-CEBAS)

REPORTING PERIOD: APRIL 1998-30 JUNE 2001

Contractor:	**Consejo Superior de Investigaciones Científicas - Centro de Edafologia y Biologia Aplicada del Segura.-CSIC. Murcia**
Responsible scientist:	**Dr. Juan Albaladejo**
Scientific staff:	Dr. Victor M. Castillo
	Dra. María Martínez-Mena
Address:	Centro de Edafología y Biología Aplicada del Segura
	Campus Universitario de Espinardo. Apartado 4195
	E30080 Murcia. España
Telephone:	+34-968-396200
Fax:	+34-968-396213
email:	jalba@cebas.csic.es
	victor@cebas.csic.es; mmena@cebas.csic.es

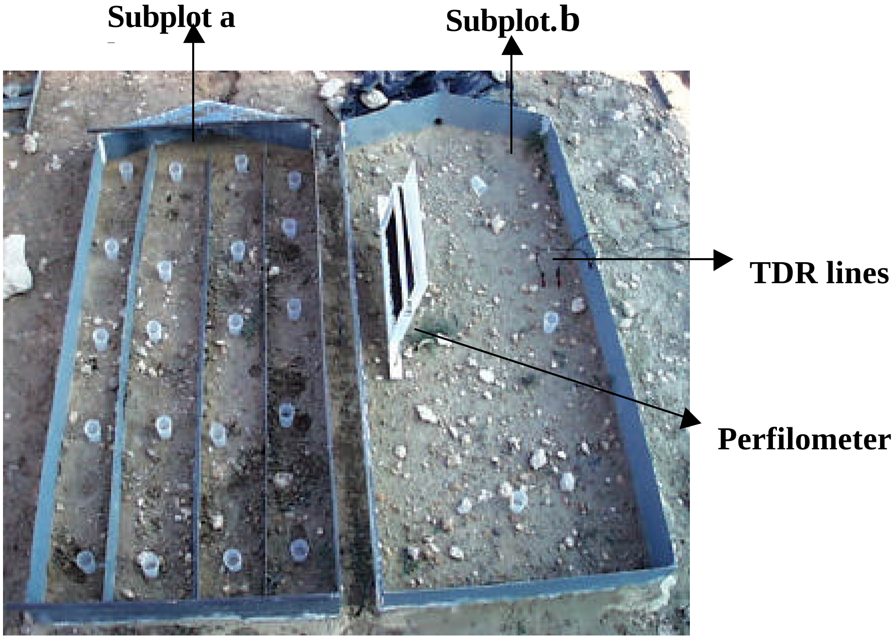
2 Work package 1 (WP1) Within-storm chages in infiltration

2.1 Sub task 4 (ST4) Field experiments conducted for validating ST1,2, and 3

2.1. Field experiments

Figure1 shows a view from one of the two agricultural experimental sites selected for rainfall simulations. The plot 2x2 m is split in two subplots. Subplot a, is used to obtain the hydrograph and sedigraph for each simulation event, and subplot b is split into four parts, (0.25 x 1m) and is used for sampling and monitoring within-storm soil property changes. Each part is covered every 5 minutes from the beginning of the rain simulation to estimate the soil conditions at 5t minutes intervals (t = 1, 2, 3 and 4) (Figure 1).

Figure 1. Simulation plot view



Seventeen rainfall simulation experiments have been carried out on the two experimental sites selected: Site 1: Quaternary plot (Q) and Site 2: Tertiary marls (M). The range of rainfall intensities, initial soil moisture conditions and soil practices (non tillage (NT) and ploughed (T)) tested are displayed in table 1.

Table 1. Simulation conditions

Type of soil	**Tillage practice**	**Nº SIMU**	**INTENSITY (mmh^{-1})**		**SOIL MOISTURE (%)**	
			MEDIUM	**HIGH**	**First run**	**Second run**
QUATERNATY						
	NT	**5**	**31-34**	**54-56**	**14-17**	**21-25**
	T	**4**	**32-34**	**54**	**13-18**	**17-34**
MARL						
	NT	**4**	**30**	**55-57**	**7-11**	**12-17**
	T	**4**	**28.66-30**	**58.8-60.7**	**16-18**	**22**

The taxonomic and physical properties of the soil at the experimental field sites are displayed in table 2 and 3.

Table 2. Taxonomic and soil physical properties

		Texture				*Aggregate Stability*				
Site	*Depth (m)*	*Clay (%)*	*Silt (%)*	*Sand (%)*	*Textural classification*	*RSSI %*	*MWD (mm)*	*O.C (%)*	*BD ($g\ cm^{-3}$)*	*N ($g\ K^{-1}$)*
1	0-10	11.38	58.43	30.18	Silt loam	56.51	1.64	0.94	1.33	4.96
	10-20	12.94	56.99	30.07	Silt loam	63.56	0.94	0.79	1.22	4.06
	30	9.33	59.25	31.42	Silt loam	87.30	3.11	0.64	1.20	4.13
2	crust	16.39	69.46	14.15	Silt loam	*	*	0.30	1.52	1.98
	3-10	17.14	68.58	14.27	Silt loam	43.53	1.00	0.44	1.23	1.08
	10-20	18.7	61.57	19.73	Silt loam	33.27	0.80	0.40	1.26	2.53
	20-30	17.81	59.64	22.54	Silt loam	36.69	1.05	0.69	1.29	1.29
	40	17.97	60.18	21.85	Silt loam	62.16	1.70	0.54	1.53	3.37

Table 3.

Site	Parent material	Soil type
1	Quaternary colluvia limestone	Haplic calcisol
2	Tertiary marls	Calcaric regosol

Table 4 shows the nozzels type used for each simulation intensity and its characteristics in relation to pressure, rainfall uniformity, water supply, drops velocity and size and kinetic energy.

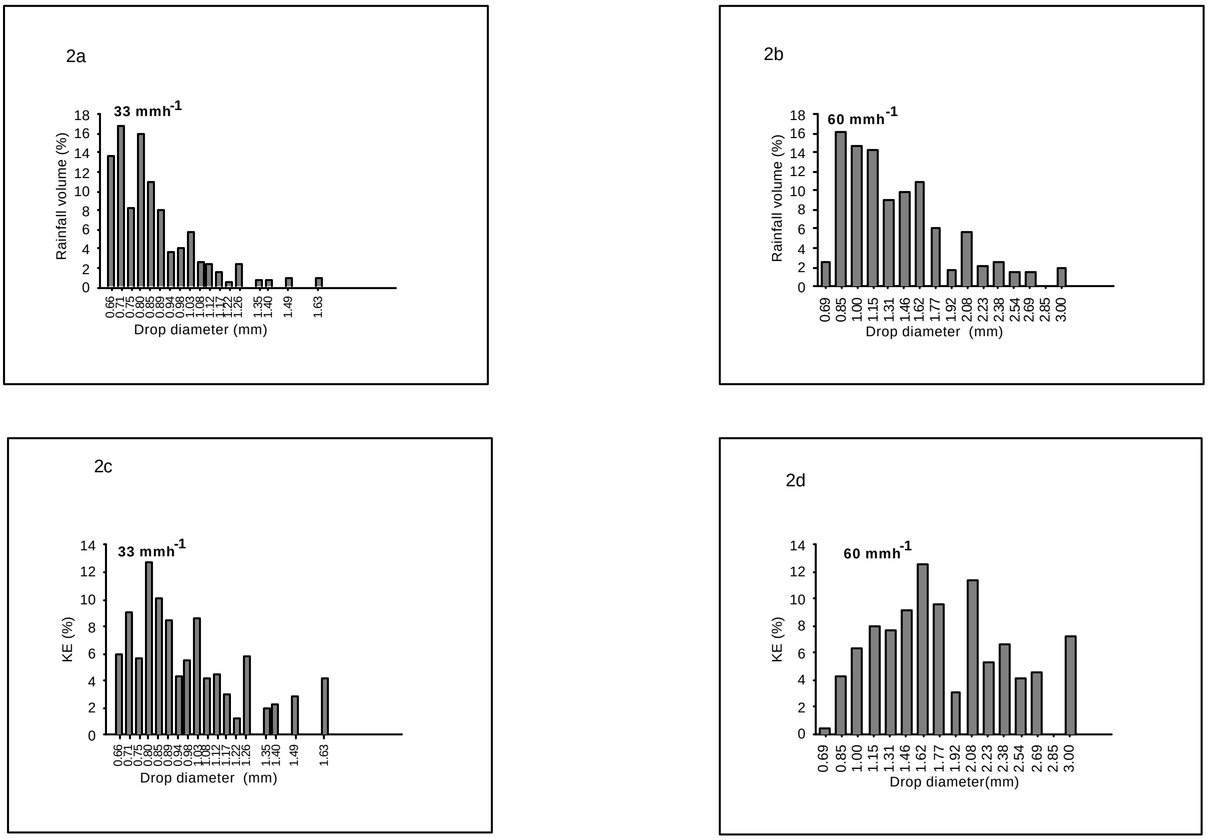
Table 4

Nozzel	Pressure	Rainfall intensity (mm h^{-1})	Water supply (l m^{-1})	CU (%)	V (m s^{-1})	D_{50} (mm)	Ec (J m^{-2} h^{-1})
3/8GG20W	1	33	10.21	88.76	4.51	1.05	275.07
1/3HH35W	0.9	60	17.46	91.29	5.94	1.85	1070.29

CU: uniformity coefficient; V: drop velocity; Ec: kinetic energy

Figure 2 displays the size drop distribution related to rainfall volume (2a and b) and kinetic energy (2c and d) for each rainfall intensity selected.

Figure 2. Size drop distribution related to rainfall volume



The parameters sampling to study the soil changes within-storm have been done each five minutes since the storm started on plot b during the first run. Tables 5 and 6 show the parameters measured, and number of samples taken in each simulation in subplot a and b respectively.

Table 5. Soil and surface properties measured in each rainfall simulation (subplot b)

Plot	Initial Conditions		Sampling			
			Surface		Crust	Soil
	I (mmh^{-1})	Moisture (%)	Roughness	Shear Strenght	Thin sections	PF,BD,Ks, Stability
QNT	56.59	15.8				9(d)
QNT	54.54	21.46	d			
QNT	31	17	d	16 (d)		8(d)
QNT	33.65	14.12	d			
QNT	32.93	24.67	d		6(a)	
QT	32.00	13.16	b,a	12(d)		6(d)
QT	34.00	17.51	d			
QT	54.33	17.76	b,a	16(d)	6(d)	8(d)
QT	53.4	34.27	d			
MNT	30.0	6.47	b,a	16(d)		7(d)
MNT	30.0	17.03	d		6(a)	
MNT	55.0	11.3	b,a	19(d)		8(d)
MNT	57.61	15.56	d			
MT	30	16.54	b,a	19(d)		8(d)
MT	28.66	22.45	d		6(a)	
MT	58.8	16.05	b,a	16(d)		8 (d)
MT	30	16.54	d	19(d)		8(d)

a:after simulation (runoff plot)
b: before simulation (sampling plot)
d: during simulation (sampling plot)

Table 6. Measures taken each minute. (Subplot a)

Level	Parameter
Soil	Moisture (15cm)
	Moisture (30cm)
Sediment	Sedigraph
	Size particle distribution (dispersed and undispersed)
Hydrology	Hydrograph
	Time to ponding

2.2. Results

The results from the seventeen rainfall simulations for each selected condition are displayed in table 7.

Table 7. Results from rainfall simulation

Plot	Rainfall Intensity	Total Rainfall	Initial Soil moisture (15cm)	Final Soil moisture (15cm)	Initial Soil moisture (30cm)	Final Soil moisture (30cm)	Qt	St	Sediment Size MEDIAN effective	MEDIAN dispersed
	mm h^{-1}	mm	%	%	%	%	mm	g/m2	µ	µ
QNT	56.59	23.82	15.08	30.66	18.5	28.07	5.89	33.92	13.86	7.87
QNT	54.54	14.91	21.46	32.27	20.97	36.53	5.85	36.52	16.43	6.63
QNT	31	20.4	17	30.66	17.02	28.07	2.45	5.15	17.38	7.21
QNT	33.65	15.87	14.12	25.65	18.99	26.26	2.4	7.43	15.78	7.33
QNT	32.93	6.36	24.67	26.86	24.3	27.59	2.52	7.9	15.61	5.91
QT	32	21.59	13.16	28.54	13.99	23.93	0	0	.	.
QT	34	16.56	17.51	30.66	17.51	23.69	2.78	3.61	16.57	5.43
QT	54.3	26.24	17.76	36.00	16.29	24.91	6.73	9.14	13.34	4.86
QT	54.3	14.65	34.27	38.05	22.82	25.64	7.01	9.26	12.82	4.85
MNT	30	9.15	6.47	12.7	8.93	14.12	2.12	62.98	25.11	11.09
MNT	25	8.1	11.76	17.52	11.53	16.05	.	.	16.83	8.06
MNT	55	17.64	11.3	16.54	11.64	16.54	7.53	32.15	17.23	10.36
MNT	57.1	11.95	15.56	18.5	14.84	17.52	9.52	35.21	17.46	17.26
MNT	30	7.57	17.03	18.99	17.03	17.76	4.53	11.96	17.56	8.26
MT	30	10.76	16.54	27.35	16.29	23.44	4.29	13.8	11.19	6.55
MT	28.66	16.46	22.45	25.4	18.99	20.97	5.31	9.4	17.06	6.29
MT	58.8	17.05	16.05	23.44	15.32	20.23	10.3	20.62	11.32	5.36
MT	60.7	13.57	22.45	24.91	19.24	21.46	10.45	26.26	11.53	5.11

2.2.1. Hydrological and erosional response

Table 8 shows the hydrological and erosional response of 15 rainfall simulations. No statistical significant differences were found neither in the hydrological nor in the erosional response between management practices (NT and T). For this reason the data analysis realised was based in the different soil litologhy (Quaternary and marl).

Table 8. Results from rainfall simulations in a 1 m wide x 2 m long plot.

Simulation Number	Rainfall (mm)	Rainfall intensity (mm h^{-1})	Kinetic energy ($Jm^{-2}h^{-1}$)	Tq (minutes)	q (mm h^{-1})	qp (mm h^{-1})	qc (%)	Cs (g L^{-1})	Cm (g L^{-1})	er (g $m^{-2}min^{-1}$)
Q1	23.8	56.6	385.41	8.55	21.64	34.93	24.70	5.53	7.90	1.33
Q2	14.9	54.5	241.24	4.40	30.49	39.36	39.27	6.74	10.40	2.23
Q3	20.4	31.0	163.43	19.49	7.64	13.77	11.98	2.09	2.60	0.13
Q4	15.9	33.6	127.13	13.30	10.04	16.79	15.13	2.43	5.07	0.26
Q5	6.4	32.9	50.94	2.59	17.48	22.59	39.56	3.13	3.57	0.68
Q6	16.6	34.0	132.65	10.23	9.16	11.67	16.81	1.29	1.95	0.12
Q7	26.2	54.3	424.56	10.00	22.13	37.41	25.64	1.31	1.68	0.32
Q8	14.6	54.3	237.04	2.43	31.29	43.40	47.84	1.61	4.02	0.56
M1	7.6	30.0	60.60	1.13	20.26	23.04	59.88	2.71	4.05	0.79
M2	17.6	55.0	285.42	1.25	39.51	45.49	64.49	4.08	5.35	1.67
M3	11.9	57.1	193.35	0.45	45.77	50.58	79.65	3.72	4.67	2.62
M4	10.8	30.0	86.18	4.59	15.76	22.68	34.02	4.29	18.09	0.64
M5	7.9	28.7	62.98	1.46	22.11	25.44	67.49	3.77	3.77	0.57
M6	17.0	58.8	286.47	17.05	42.91	50.88	60.39	2.12	4.33	1.19
M7	13.6	60.7	227.11	13.60	50.22	54.77	76.99	2.52	3.33	1.96

Tq: time to start runoff; q: runoff rate; qp: peak discharge; qc: runoff coefficient; Cs: sediment concentration; Cm: maximum sediment concentration; er: erosion rate.

Statistically significant differences were found between soils in the runoff rates and runoff coefficients of both soils, M soil having in all cases higher values for both parameters (80 and 129%, respectively) regardless of the rainfall intensity. A significant interaction between soils type and rainfall intensity was also found. Thus, the differences in runoff rate between soil was greater with the high rainfall intensity ($F=92.475$, $p<0.001$) than those with the medium rainfall intensity events ($F=8.796$, $p=0.016$). The time elapsing before runoff started was significantly shorter in high than in medium rainfall intensity rainfalls. The response was slower in Q than in marl soil, although these differences were not statistically different due to the great variability observed in the response of Q soil.

The erosion rate was significantly ($p<0.10$) higher in M than in Q soil regardless of the rainfall intensity (1.35 and 0.70 g m^{-2} h^{-1}, in M and Q soil respectively). However, the sediment concentration showed a significant ($p<0.05$) interaction between soil type and rainfall intensity. There were no significant differences ($F=0.162$ $p=0.697$) in sediment concentration between soil types for medium intensity rainfalls, although the value in M soil (3.59 gL^{-1}) was higher than in Q soil (2.23 gL^{-1}). For the high rainfall events, on the other hand, the sediment concentration was statistically higher ($F=8.449$, $p<0.05$) in Q (3.79 gL^{-1}) than in M soil (3.11 gL^{-1}).

2.2.2. Changes in runoff rate and sediment concentration with time

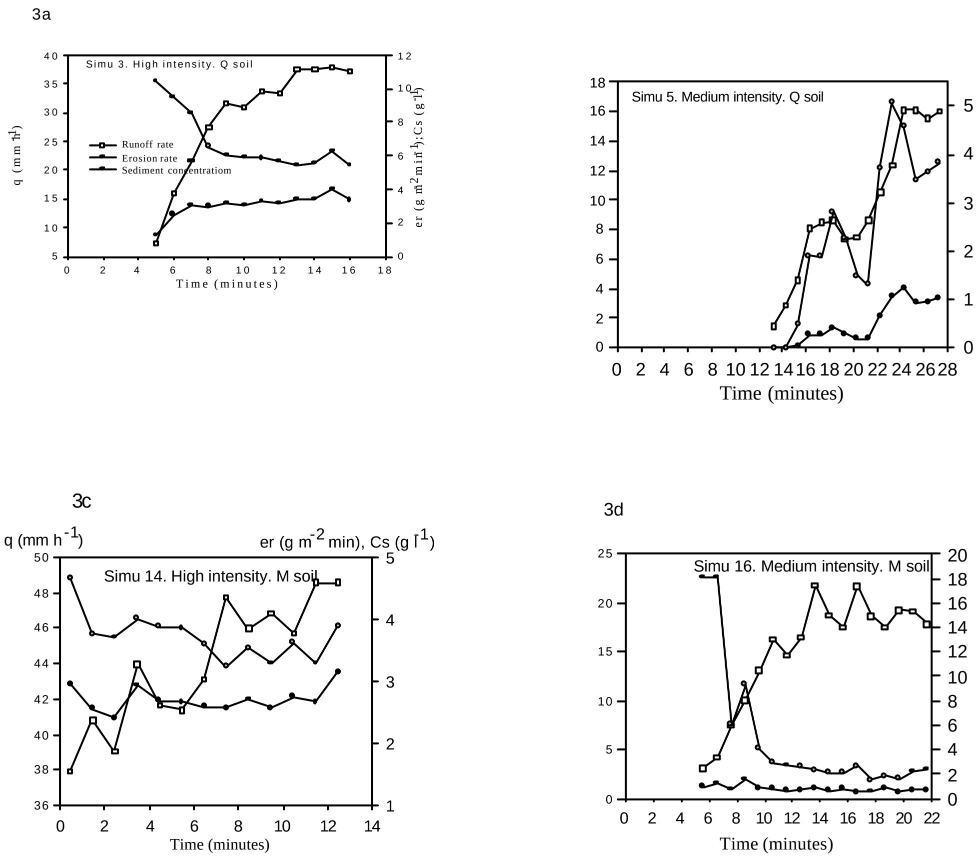
Figure 3 shows the changes with time in runoff rate, erosion rate and sediment concentration for different rainfall intensities in some Q and M soil tests.

The sediment concentration behaved differently in soil Q depending on the rainfall intensity. High intensity events led to a high sediment concentration during the first few minutes of runoff. The concentration then fell until it became constant, this decrease in sediment concentration being matched by an increase in runoff rate (Fig. 3a).

Medium intensity events, on the other hand, led to an increasing sediment concentration and runoff rate until both became more or less constant (Fig. 3b). Under these conditions maximum sediment concentration occurred at the same time as the peak discharge.. In M soil, the sediment concentration during runoff tended to fall sharply from the maximum value of the first reading to lower and relatively stable values, independently of the rainfall energy for most of the tests carried out (Fig. 3c and d). The change in erosion rate with time was similar to that of the sediment concentration, which means that the increased runoff rate (and hence stream power) did not increase sediment concentration or the erosion rate, indicating the lack of flow detachment under these conditions.

The negative linear trend between sediment concentration and erosion rate on the one hand, and runoff rate on the other for most of the simulations pointed to a diminution of soil erodibility with time, which in turn, suggested the existence of a detachment limited condition on the marl soil for all the rainfall intensities tested (Durnford and King, 1993). The fact that the discharge peak did not occurred at the same time as the sediment concentration peak in any experiment on this soil emphasised the predominance of supply-limited conditions.

Figure 3. Change in runoff rate and sediment concentration with time



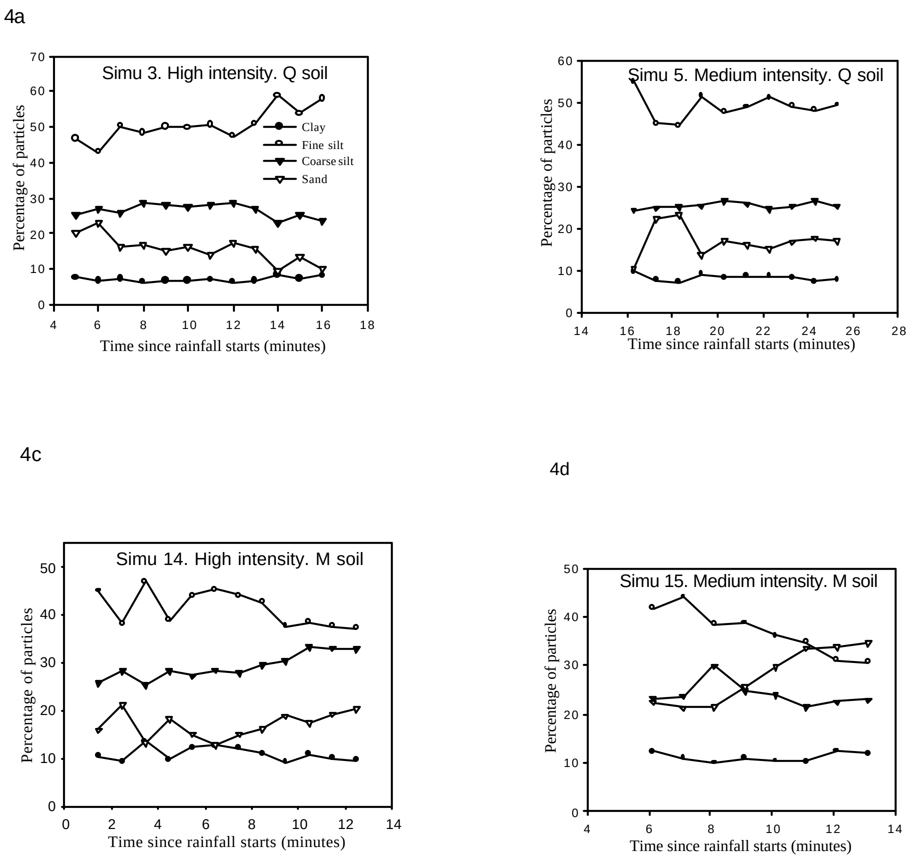
2.2.2.Change in the effective sediment-size with time

The way in which the effective sediment size changed with time in Q soil was seen to depend on rainfall intensity. For high intensity events, the effective median size decreased with time and runoff rate, which was reflected in the increasing percentage of fine silt sediment sized and decreasing percentage of sand sized sediment (Fig. 4a).

For medium intensity events these relations were not as clear as in high intensity events and no sediment size change with time was observed for most of the simulations (Fig. 4b). The constant discharge of all the size fractions may indicate possible transport limitation conditions (Durnford and King, 1993).

In M soil, the percentage of coarse material increased with time, while the percentage of fine-size sediment decreased (Fig. 4c and d) in almost all the simulations, indicating that soil stability increased as the soil water content increased (Martínez-Mena et al, 1998). The decreasing discharges of fine material might indicate that its erosion rate is supply-limited (Durnford and King, 1993). The increase in coarse material with time could be due to crust formation, which would make it more difficult to break down the aggregates (Le Bissonnais, et al., 1998; Bajracharya and Lal, 1998). This crust formation was reflected in the decrease in sediment concentration and erosion rate with time. Proffit et al. (1993a) noted a gradual increase in the coarseness of transported sediment with time due to the development of a coarser deposited layer.

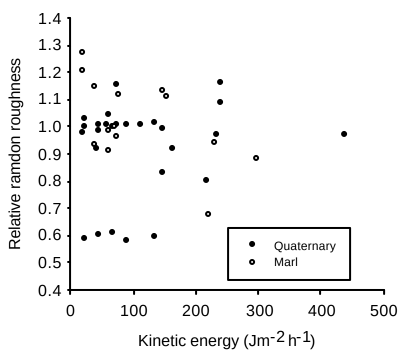
Figure 4. Changes in the effective sediment-size with time



2.2.3. Change in the surface, physical and hydraulic properties within storm

2.2.3.1. Surface roughness

Figure 5. Change in surface roughness with kinetic energy



The roughness index used was: Relative Random Roughness (Zobeck & Onstand, 1987):

$$RRR = RRa/RRb$$

RRa, Random Roughness after the rainfall y RRb: Random Roughness before the rainfall.
In M soils there was a decay with the KE increase but it was not observed in Q soils.

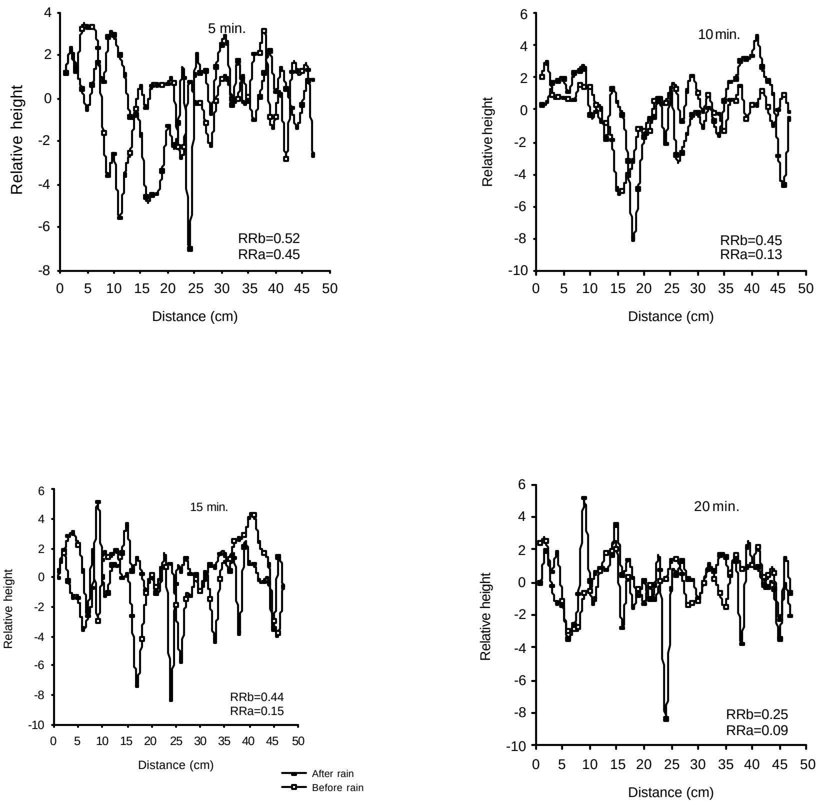
The decrease in surface roughness seems to start after 10 minutes of rainfall in most of the simulations. Figure 6 displays the change in RR in one of the simulations on M soil at 5, 10, 15 and 20 minutes since the rainfall starts.

The greatest changes are observed between 10 and 15 minutes, while in the first 5 minutes, when the total rainfall is still low, the difference between initial and final roughness is practically negligible.

Contrary to the general trend in relation to a RR decay with the rainfall, in some simulations were observed an increase in RR in the first simulation minutes. This increase may be due to the protector stone action on the rain drops impact and the small pedestal erosion formation increasing, in this way, the RR microtopography between protected and bare areas. During the storm the sedimentation of suspended particles lead to a smoother microtopography with a RR decay.

The decrease in soil roughness with rainfall lead to a decrease in the infiltration rate and an increase in surface runoff. It points out the importance of surface conditions in the erosion process.

Figure 6. Change in surface roughness with kinetic energy

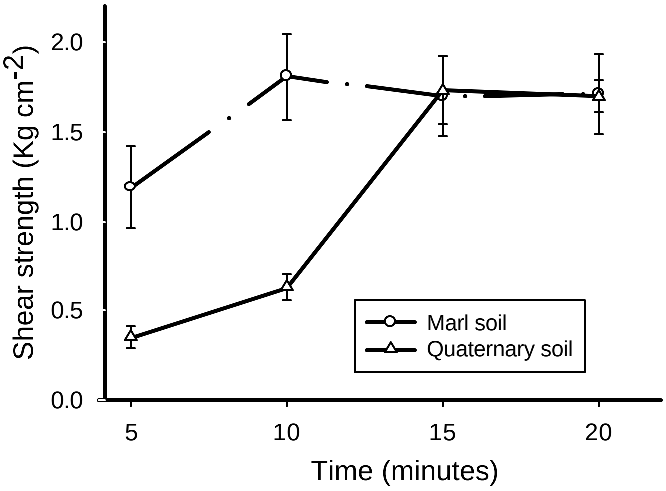


2.2.3.2. Soil shear strength

Slight changes in this parameter were observed in both, Quaternary and Marl soils.

The soil shear strength increased during the first minutes and became constant after that. M soil reached higher values than Q soils. In the same way, the increase in the first minutes was quicker (10 minutes) in M soils than in Q soils (15 minutes).

Figure 7. Change in soil shear strength within simulation.



2.2.3.3. Bulk density

On M soil there was, in general, a slight increase in BD since the rainfall started. This increment was quicker after the first 10 minutes with an increase from 1.28 g cm^{-3} to 1.40 g cm^{-3} until the storm was finished.

There was a greater BD variability during the storm in Q than in M soils. Thus, in several simulations were observed a slight decrease of these values during the storm.

This high variability made impossible to find a significant correlation between BD and rainfall in these soils. On the contrary, a significant statistical correlation between BD and KE was observed on m soils (r=0.60, p=0.018) (figure 10).

Figure 8. Change in soil bulk density with time

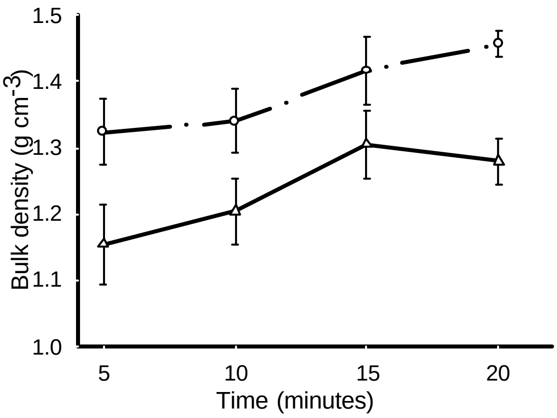
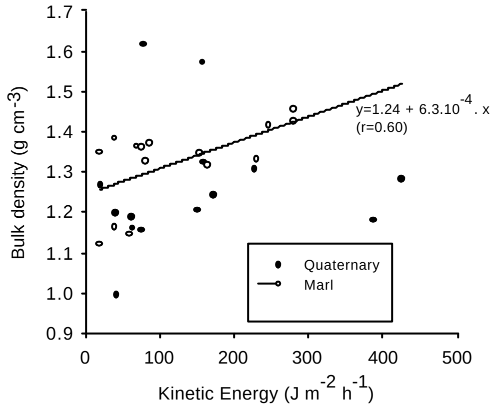


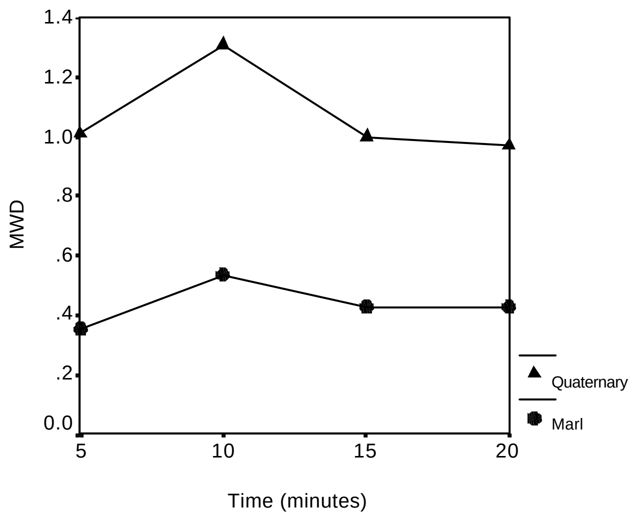
Figure 9. Change in soil bulk density with KE



2.2.3.4. Aggregate stability

An increase of aggregate stability values, measured as MWD, at 10 minutes since the beginning of the storm was observed in both, quaternary and marl soils. After this time the MWD values were stabilised . Q soils displayed higher values of this parameter than M soil (Figure 10).

Figure 10. Change in soil aggregate stability with time



2.2.3.5 Macropores

The macropores (pore >30 micras) percentage decreased about 10% since the beginning to the final of the storm in both soils. On M soils the major decrease was observed from 10 minutes of rainfall, while on Q soils it was observed at the first 5 minutes and it became constant the rest of the time.

Statistically significant correlations were observed between percentage of macroporosity and KE in both soils ($r=-0.61$, $p=0.015$. Q) ($r=-0.78$, $p=0,00$. M) (figure 12).

The decrease in macroporosity with KE reflects the effect of rainfall impact on soil structure (Panini, *et al.*, 1997). The percentage of macropores controls the water infiltration rate on the soil (Bouma, 1992). The decrease of them lead to the reduction of infiltration capacity and then to an increase in runoff.

Figure 11. Change in the macropores with time

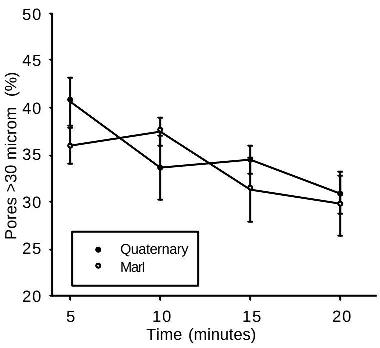
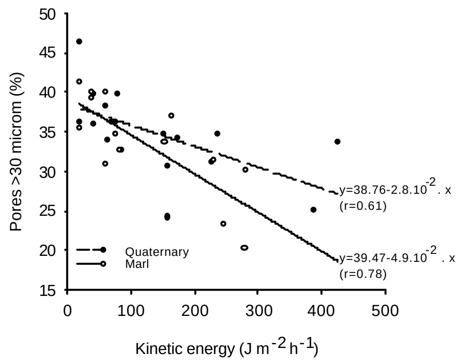


Figure 12. Change in the macropores with KE

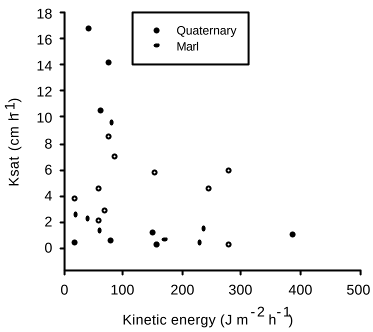


2.2.3.6. Saturated hydraulic conductivity

The mean values of Ks were 3.71± 5.63 cm h^{-1} and 4.53± 2.97 cm h^{-1} for Q and M soils, respectively. It was not found significant relations between Ks and KE due probably to the high spatial variability of this parameter. Any way, a certain negative lineal trend was observed in both soils with a decrease in Ks with the increase in KE.

This result is consistent with the negative correlation found between the macropores percentage and KE commented before.

Figure 13 change in the values in the soil within simulation.



The major changes in most of the soil properties studied were observed at ten minutes from the beginning of the storm. The marl soil showed better relationship between kinetic energy and soil properties changes during the storm than the quaternary soil. The former displayed an increase in the bulk density and a decrease in Ksat values with the increase in rainfall depth and kinetic energy. These changes were consistent with the decrease in the percentage of transmission pores. The change in these properties is an indicator of a surface sealed formation.

3 Work package 2 (WP2) Development and evolution of ephemeral gullies

3.1 Sub task 5 (ST5) Field experiments for validating the algoritm

3.1.1. Field experiment description

The experiment was carried on Marl soil. Each site was supplied with water from a tank. The concentrated water flow was distributed from the tank by means of a sloping flume and spread evenly over the plot surface. The initial velocity and turbulence of the flow was reduced by locating a covered hole with plastic immediately at the end of the flume (Figure 14).

Flow velocity was determined as a mean of at least three dye tracer (potassium permanganate) measurements over 1.5 m. Measurements of gully wide and depth were made on an area of 1.5m long by 0.5 wide situated between 1.5 and 3.5m down slope from the flume. Between two and four transects were measured in each simulation (table 9).

At the down slope end of the plot the runoff was directed into a modified Gerlach through along sides of the plot to prevent lateral flow. The incoming runoff was measured by a calibrated water meter and the runoff passing through the modified Gerlach box was measured volumetrically. These discharges were measured several times during each run.

Figure 14. Experimental simulation plot

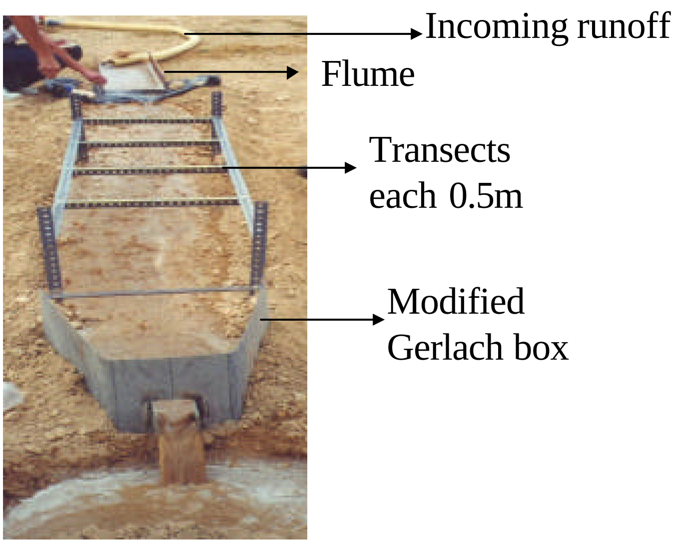


Table 9. Simulation conditions

Simulation	Number of measured transects	Local slope (%)	Inflow discharge ($l\ s^{-1}$)	Simulation time (minutes)
1	4	20	1.37	18
2	2	10	1.29	20
3	2	12	1.67	15
4	3	18	0.91	13.46
5	2	20	2.24	14.35
6	4	10	0.81	15.52
7	3	18	1.72	15.3
8	2	10	1.35	17
9	3	12	2.14	15
10	3	20	1.62	12.55

Table 10. Measurements realised in each simulation

LEVEL		LEVEL	
SOIL	FREQUENCY	FLOW	FREQUENCY
Penetrometric profil	3 (b)	Inflow discharge	6 (d)
Penetrometric resistance	10 wall (a) 10 bottom (a)	Outflow discharge	3 (d)
Moisture	3 (b,a)	Velocity	3 (d)
Bulk density	3 (b,a)	Width and depth	2 (d)
Size particle distribution	3 (a)	Sediment concentration	4 (d)
Rill wide and depth	2 (d)	Temperature	2 (d)

b: before simulation; a: after simulation; d: during simulation

3.1.2. Results

Better relationships were obtained between gully wide, depth and detachment ratio with discharge for a slope higher than 12% . The mean value of the gully wide and depth obtained for different discharges rates were about 25cm wide per 2.09 cm depth in slope lower than 12% and 35cm wide per 2.82 cm wide in a slope higher than 12%. Table 11 and 12 display the results obtained in each simulation for all the measured parameters.

Table 11. Gully and flow results. Mean values of the transects measured in each simulation

Simulation	Gully initial* width (cm)	Gully final width (cm)	Gully final depth (cm)	Flow width (cm)	Flow depth (cm)	Flow velocity (cm s^{-1})	Water temperature (ºC)	Mean sediment concentration (g l^{-1})
1	26	26	3.81	17	2.03	55.47	20.6	32.77
2	20	20	2.13	25	1.78	22.47	20	18.70
3	12.66	14	2.07	12.66	1.19	30.61	20	30.61
4	20	22	1.86	20	1.85	36.85	20.7	20.51
5	41	48	2.90	42	2.23	32.19	19.5	40.84
6	20	30.66	2.87	20	1.46	29.16	19.9	14.21
7	35	39	2.50	34	1.46	47.22	15.5	22.47
8	28.66	32,66	1.62	32.66	1.16	31.45	18.5	14.62
9	31.33	31.33	1.76	32.66	1.50	56.20	13.6	12.13
10	45	45	3.03	48	1.27	58.78	14.1	24.54

* measured between 5 and 10 minutes from the beginning of the runoff simulation

Table 12. Results from the soil properties measured in each simulation.

Simulation	Penetrometric resistance (N cm^{-2})		Soil moisture (%)		BD (g cm^{-3})
	Bottom	Wall	Initial	Final	
1	30.12	21	5.41	16.85	1.36
2	21.39	8.33	5.00	16.70	1.35
3	11.07	10.86	5.48	16.67	1.44
4	24.31	9.5	5.48	15.89	1.35
5	20.57	12.43	4.51	10.43	1.19
6	23.24	14.22	4.51	15.69	1.45
7	21.25	16.28	10.19	16.74	1.53
8	16.95	16.33	10.19	15.55	1.47
9	19.75	9.14	9.66	16.53	1.26
10	42.39	10.32	9.66	16.12	1.32

The higher penetrometric resistance obtained in the rill bottom than in the rill wall for all the simulations (Table 12) might explain the rill geometry of greater width than depth .

The relations obtained between rill geometry and hydraulic flow characteristics (Figure 12) were not as good as those obtained in other studies (Govers, 1985; Merz and Bryan, 1993; Borselli *et al*., 2000) due to the high penetrometric profile resistance presented by these soils and the high surface roughness induced by the presence of stones. Better relations were, however, obtained between rill width and flow stream power (Figure 15) than between rill width and discharge (Figure 16).

A statistically significant linear correlation (R^2 = 0.54; $p<0.05$) was found between rill sediment concentration and flow shear stress (Figure 17) and thus with rill erosion, indicating the dependence of sediment transport on the flow hydraulic characteristics.

Figure 15

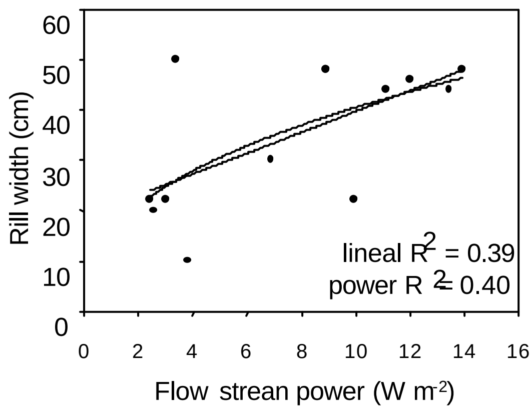


Figure 16

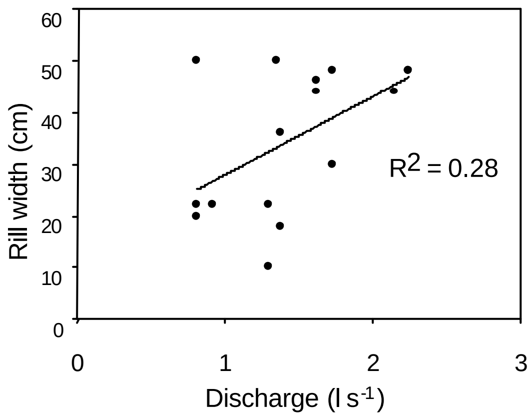
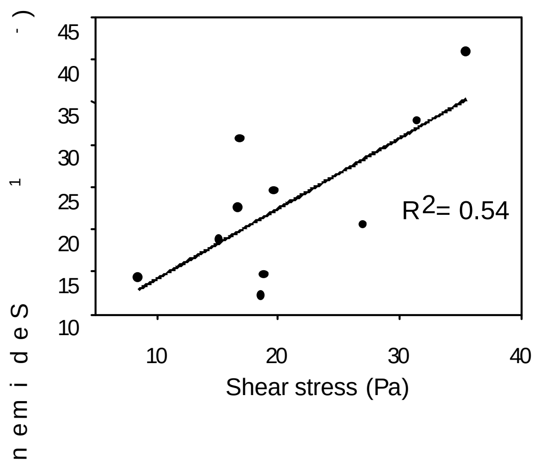


Figure 17



<u>4 Work package 4 (WP4) Simulation of within-storm erosion dynamics</u>

3.1 Sub task 2 (ST2c) Field validations. Arid conditions

Runoff and soil erosion data has been collected from two experimental plot (plot 1, a devegetated plot, and plot 2 with natural plant cover) from April 1998 to April 2001. Because of the drought of these years, only 6 runoff events have been measured. The data are showed in Table 13.

Table 13

Date	Plot	Rain (mm)	I30 (mm h^{-1})	Runoff (mm)	Soil loss (g m^{-2})	Max. Discharge (L s^{-1})	Runoff coefficient (%)
22/05/98	1	n.d.	n.d.	4.3	5.5	n.d.	n.d.
	2			2.6	2.2	n.d.	n.d.
6/11/98	1	35.2	8.4	0.18	0	0.02	0.5
	2			0.31	0	0.005	0.8
2/12/98	1	58.0	9.6	8.57	12.1	0.28	14.7
	2			1.98	1.7	0.06	3.4
23/03/99	1	9.6	7.2	0.214	nd	0.021	2.23
	2			0.148	nd	0.120	1.54
07/09/99	1	82.4	27	25	nd	nd	30.39
	2			13.7	nd	nd	16.7
24/10/00	1	162.9	*	19.75	11.46	1.63	12.12
	2			4.65	7.33	0.79	2.85

b Achievements:

1) The rainfall simulations in the field
2) The analysis of the runoff and sediment dates from the rainfall simulations
3) The analysis of surface roughness
4) The analysis of soil physical properties
5) The data collection for validating EUROEM and EUROWISE models
6) The field simulation of ephemeral gullies on Marl soils.
7) The threshold conditions for ephemeral gully
8) The roughness photographs for RR album

c We failed to obtain:

1) Transfer functions

We estimate that the amount of soil physical data we have got from the field experiments is not enough for a reliable validation of transfer functions.

4- Activity "internal" to the project:

1) We have attended the following internal meetings:

We hosted 1St annual meeting of MWISED Project. 25-26 April 1999
We have attended: Fierenze 2 October 1999.
We have attended: Utrecht meeting 12-16 January 2000.
We have attended: Fierenze meeting June 2000.

5- *Activity "external" to the project:*

• **Publications**:

Martinez-Mena , M., Castillo, V, and Albaladejo, J.
Hydrological and erosional response to natural rainfall in a degraded semi-arid area of Southeast Spain.
Hydrological Processes, 15, 557-571. 2001

Martinez-Mena , M., Garcia Rogel, P, Albaladejo, J. and Castillo, V.
Influence of vegetal cover on sediment size particle distribution under natural rainfall in a semiarid environment.
Catena 38, 175-190. 2000.

Martínez-Mena, M.; Abadía, R., Castillo, V, and Albaladejo, J.
"Diseño experimental mediante lluvia simulada para el estudio de los cambios en la erosión del suelo durante la tormenta".
Cuaternario y Geomorfología (accepted Marzo 2001).

Álvarez Rogel, J.; Martinez-Mena, M.; Albaladejo, J. and Castillo, V.
Organic carbon and nitrogen influenced by vegetation removal in a semiarid Mediterranean soil.
Biogeochemistry (in press).

Martínez-Mena, M.; Castillo, V, y Albaladejo, J.
"Relations between erosion processes and sediment particle size distribution in a semiarid area of SE of Spain"
Geomorphology (in press)

Martínez-Mena, M.; Castillo, V, y Albaladejo, J.
Validation of process-based soil erosion models: a field experimental design
Land degradation and Development (in press)

• Others

Dissemination

• Conferences

Martínez-Mena, M.; Castillo, V. y Albaladejo, J.
"Within storm erosion dynamics in Mediterranean agricultural lands: an experimental design."
Third International Congress of The European Society for Soil Conservation.
Valencia, España. 2000. Oral Communication

Martínez-Mena, M.; Castillo, V. y Albaladejo, J.
"Change in soil and surface properties within-storm in a Mediterranean area of Southeast Spain".
Geographical perspectives on environmental management in Iberia Session. RGS-IBG Annual Conference. Plymouth. England. 2001. Oral Comunication.

Martínez-Mena, M.; Castillo, V. y Albaladejo, J.
“Modelling changes in soil erosion parameters during the storm”
Third International Conference on Land Degradation
Rio de Janeiro 2001. Oral Comunication.

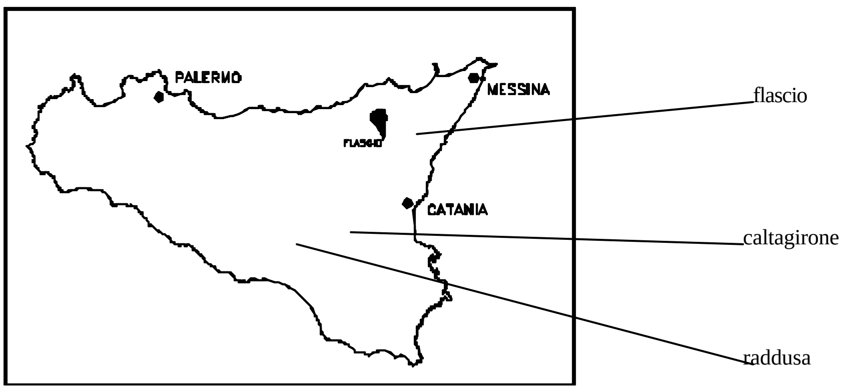
Álvarez Rogel, J.; Martinez-Mena, M.; Castillo, V. and Albaladejo, J.
The effect of vegetation removal on soil organic carbon losses: a 9 years experiment in semiarid SE Spain.
Third International Conference on Land Degradation
Rio de Janeiro 2001. Poster.

ISTITUTO DI IDRAULICA AGRARIA UNIVERSITY OF CATANIA (IIA)

REPORTING PERIOD: 1 APRIL 1998– 30 JUNE 2001

Contractor:	**Istituto di Idraulica Agraria University of Catania(I I A)**
Responsible scientist:	**Prof. Vito sardo**
Address:	*via Valdisavoia, 5 - 95123 Catania*
Telephone:	*++ 39 - 095 - 350401*
Fax:	*++ 39 - 095 - 7311992*
email:	*sardo@ mbox. fa gr unic.-it*

PART 1 - Description of the sites and activities

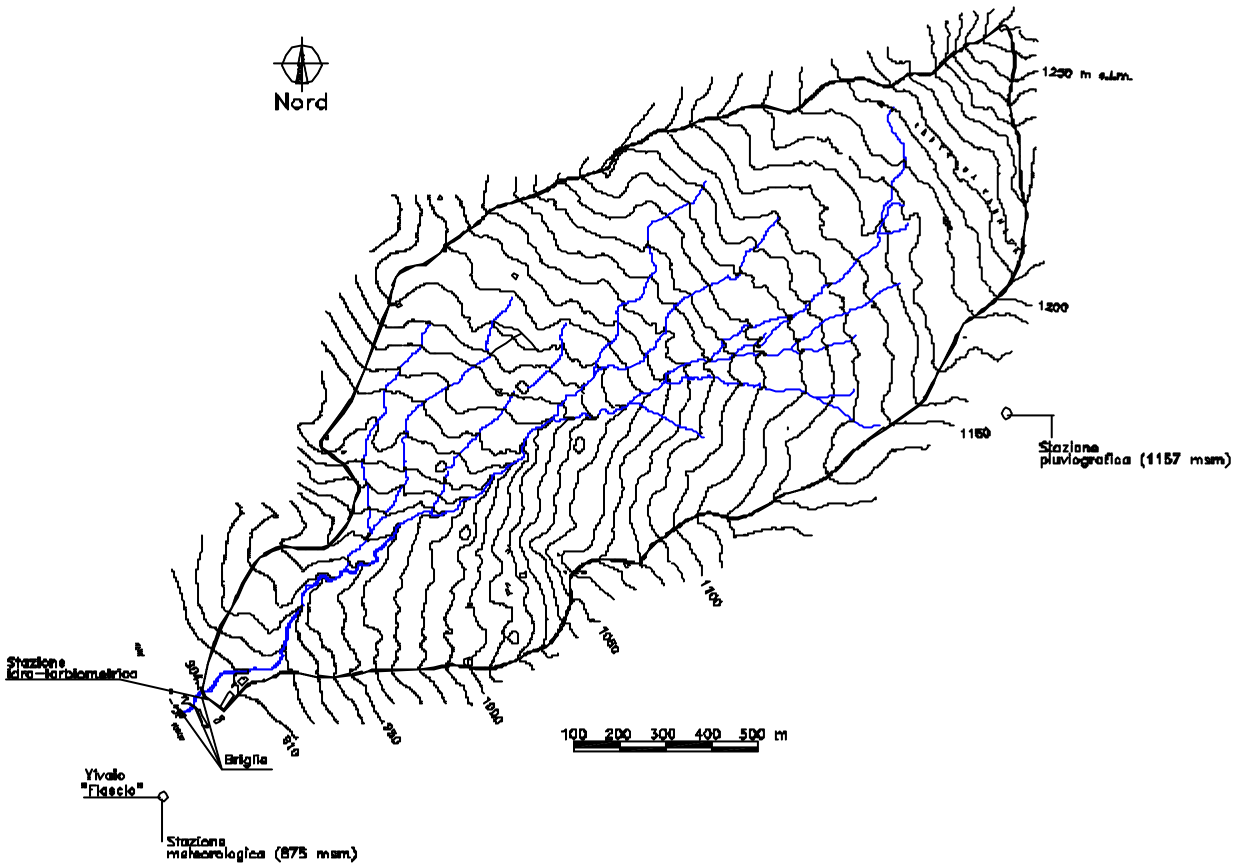


The activity of our group has been addressed to field validate the model (WP4) collecting information and data on spatial and temporal variability in soil and plant cover, in precipitation events, in relationships between land use and management and sheet, gully and rill erosion.

We operated in three different sites in Eastern Sicily, as resulting from the appended map: for an easy reference they were labeled as **Flascio**, **Caltagirone** and **Raddusa** area, respectively. In the **Flascio** area we mapped and analysed the spatial and temporal variability of soil use and characteristics as well as the hydrological response of the watershed as affected by variations in soil use.

The principal soil characteristics as resulting from field sampling and observations and laboratory analysis are reported in table A1; table A2 reports data referring to samples from the canal bed, which generally have a coarser texture and a lower content in organic matter.

Soil use was determined by means of visual estimations in the field and the analysis of aerial photos: this survey evidenced the prevalence of pastureland (about 90%) and a lesser presence of arable land (wheat, beans).



map of the FLASCIO area with contour lines

In order to elaborate the data as thoroughly as possible a digital elevation model (DEM) of the watershed was constructed, based on an aerophotogrammetric survey; the subsequent deployment of the software package WODITEM (Watershed Oriented Digital Terrain Model) permitted the development of a number of thematic maps (elevations, slopes, flow lines).

Meteorological data were obtained by means of two automatic stations, installed at the elevation of 875 and 1175 m. a s.l.; the data recorded at the two sites are reported below.

The comparison between total precipitations and peak intensities in the two stations is reported below.

Flow rates in the channel were monitored by means of a hydrometrograph installed at the closure station.

Periodic samples were taken during water flowing in order to estimate solid transports; the deposits of coarse material downstream the closure section were measured with the use of a tacheometer, after a previous accurate topographic survey of the area.

Watershed land cover.

Cover type (%):	Pasture, dense	Pasture, medium	Pasture, with shrubs	Pasture, tilled	Arable land
Oct 1996 / Aug 1997	61	20	6	0	13
Sep 1997 / Dec 1999	53	11	6	22	8
After January 2000	72	11	0	6	11

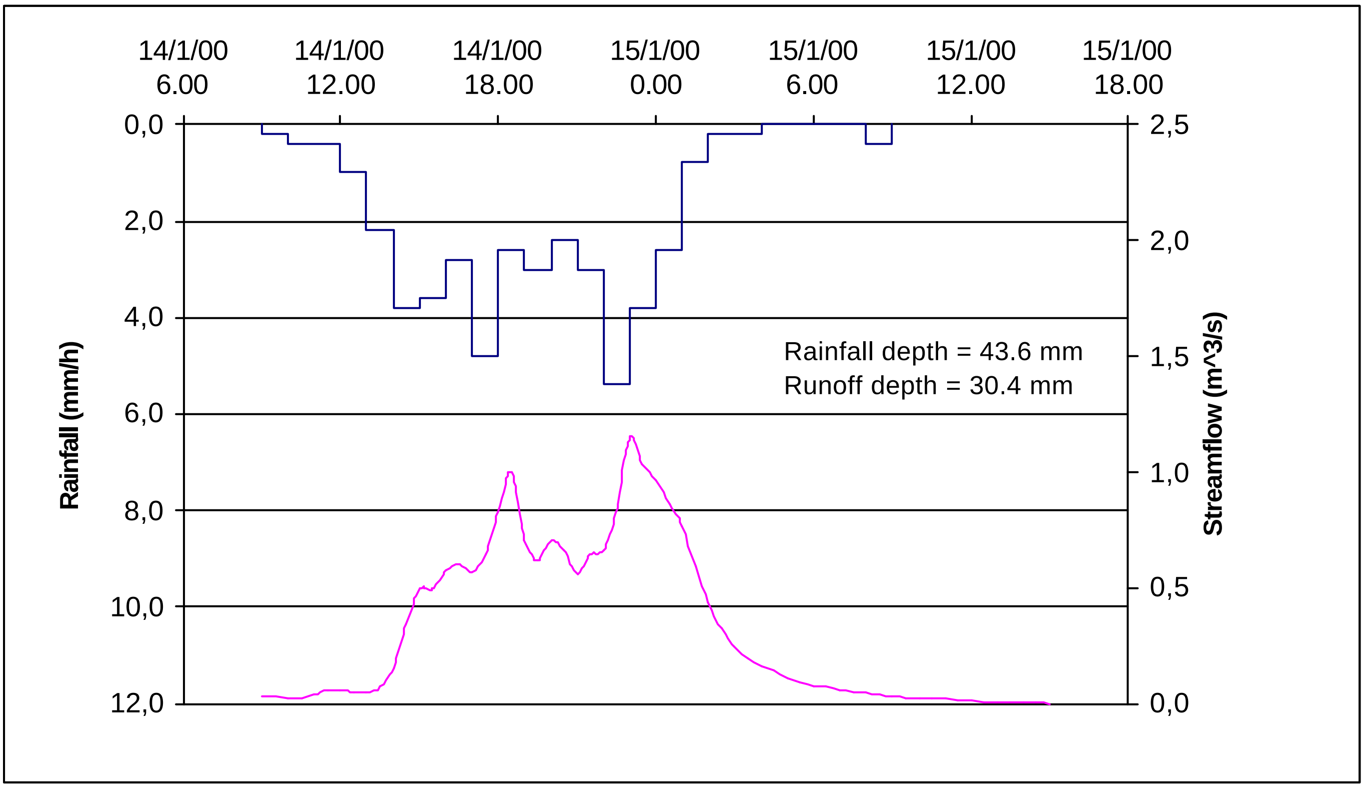
Table 1. Sampling results for soil characterizarion of the watershed.
Each sample is representative of a 200x200 grid element.

Sample	Particle size: Texture (>2mm)	Sand coarse (2-0.1mm)	Sand fine (0.1-0.05mm)	Silt (0.05-0.002mm)	Clay (<0.002mm)	organica matter %	Bulk density (g/cm^3)	USDA texture	Cations K %	Na %	Ca %	Mg %
1	22,7	24,9	12,8	31,6	30,7	2,0	1,33	Clay-loam	0,44	0,79	93,45	5,31
2	32,9	43,8	12,4	24,4	19,5	3,0	1,36	Clay-loam	0,55	0,85	93,48	5,19
3	18,5	24,7	12,2	30,2	32,9	4,0	1,47	Clay-loam	0,56	0,72	92,33	6,39
4	7,3	18,9	9,9	32,6	38,6	4,0	1,48	Clay-loam	0,82	0,88	86,79	11,51
5	8,7	24,4	11,5	35,9	28,2	4,0	1,49	Clay-loam	0,86	0,90	89,67	8,57
6	30,0	41,7	18,3	26,8	13,2	4,0	1,45	Clay-loam	0,56	1,55	80,68	17,21
7	7,7	19,9	12,5	31,0	36,6	2,0	1,41	Clay-loam	0,69	0,68	95,76	2,86
8	15,9	26,3	14,5	29,7	29,5	3,0	1,45	Clay-loam	0,56	0,72	91,68	7,03
9	19,8	24,0	13,0	36,2	26,8	3,0	1,45	Loam	0,80	0,98	91,00	7,00
10	20,7	24,4	12,8	31,8	29,0	4,0	1,33	Clay-loam	0,74	0,70	95,10	3,45
11	21,5	31,0	13,9	30,7	24,4	5,0	1,39	Loam	0,82	0,78	87,04	11,35
12	13,8	23,7	15,6	31,2	29,5	3,5	1,43	Clay-loam	0,61	0,86	91,29	7,24
13	5,5	18,1	10,8	29,5	41,6	2,0	1,50	Clay	0,64	0,76	92,00	7,00
14	10,2	21,7	8,9	25,9	43,5	3,0	1,37	Clay	0,38	0,74	90,00	9,00
15	9,7	17,2	12,1	33,7	37,0	5,0	1,34	Clay-loam	0,66	0,94	90,87	7,54
16	8,5	26,4	8,9	27,6	37,2	1,5	1,37	Clay-loam	0,47	0,82	90,36	8,34
17	2,3	17,3	9,4	35,3	38,0	4,0	1,32	Clay-loam	0,48	0,75	93,83	4,95
18	13,4	30,0	13,3	33,4	23,3	6,0	1,13	Loam	0,78	0,92	88,00	10,00
19	7,6	22,2	11,1	31,6	35,1	4,0	1,42	Clay-loam	0,67	0,66	88,61	10,06
20	7,7	25,3	10,6	32,3	31,9	4,0	1,15	Clay-loam	0,79	0,82	87,89	10,50
21	10,7	23,9	11,0	31,9	33,2	3,0	1,28	Clay-loam	1,47	1,27	92,45	4,81
22	7,4	26,8	13,2	28,2	31,8	2,0	1,29	Clay-loam	0,64	1,01	95,27	3,08
23	13,0	26,3	15,5	36,1	22,1	5,0	1,13	Loam	0,84	1,67	86,36	11,13
24	11,2	24,6	12,5	34,3	28,6	5,0	1,32	Clay-loam	1,08	1,52	84,32	13,07
25	10,7	35,8	11,4	28,9	23,9	2,0	1,32	Loam	0,69	0,75	94,00	4,00
26	12,0	22,6	12,0	35,2	30,2	4,0	1,50	Clay-loam	0,91	1,18	90,20	7,71
27	26,1	31,7	13,1	30,7	24,5	4,0	1,25	Loam	0,96	1,39	88,78	8,87
28	8,5	23,1	13,6	34,2	29,1	5,0	1,14	Clay-loam	0,86	1,26	85,84	12,04
29	17,1	38,1	12,1	27,6	22,2	5,0	1,29	Sandi-clay-loam	0,76	1,30	87,77	10,16
30	23,1	26,5	17,7	36,1	19,7	4,0	1,17	Loam	1,12	1,97	81,87	15,04
31	26,8	37,8	14,2	30,2	17,8	7,0	1,12	Loam	0,78	1,38	88,45	9,39
32	33,8	36,7	19,7	27,7	15,9	4,0	1,18	Sandy-loam	0,75	1,28	88,94	9,02
33	25,1	38,4	15,9	31,3	14,4	6,0	1,31	Sandy-loam	1,26	2,07	76,47	20,20
34	23,6	38,5	20,9	29,4	11,2	6,0	1,27	Sandy-loam	1,57	5,34	72,89	20,20
35	10,8	30,7	18,3	37,7	13,3	3,0	1,18	Loam	1,10	2,26	83,17	13,48
36	10,6	28,8	13,9	29,7	27,6	4,0	1,30	Clay-loam	1,03	0,99	93,18	4,80
37	8,7	30,1	12,1	30,4	27,4	5,0	1,28	Clay-loam	0,88	1,10	94,06	3,95
38	16,1	22,7	13,0	30,8	33,5	3,0	1,28	Clay-loam	0,86	1,08	93,32	4,73
39	5,6	17,8	10,7	32,1	39,4	2,0	1,23	Clay-loam	0,76	0,91	90,78	7,55
40	7,2	16,0	12,3	32,6	39,1	2,7	1,35	Clay-loam	0,80	1,29	86,29	11,62
41	11,2	21,4	13,6	33,3	31,7	4,0	1,10	Clay-loam	0,79	0,47	81,81	16,90
42	9,6	15,6	12,9	31,6	39,9	2,8	1,30	Clay-loam	0,57	0,42	86,94	12,10
43	9,8	30,3	13,2	28,9	27,6	2,6	1,33	Clay-loam	0,36	0,44	90,06	9,10
44	23,5	28,4	12,5	32,1	27,0	4,6	1,17	Clay-loam	0,49	0,39	90,57	8,50
45	9,9	23,5	14,3	32,6	29,6	6,1	1,06	Clay-loam	0,62	0,38	91,56	7,40
46	6,9	15,6	14,5	32,0	37,9	3,9	1,06	Clay-loam	0,75	0,49	87,77	11,00
47	10,4	18,4	13,0	31,6	37,0	4,3	1,33	Clay-loam	0,53	0,42	91,82	7,20
48	16,4	31,7	16,7	34,7	16,9	9,0	1,11	Loam	0,67	1,14	87,50	10,68
49	36,8	34,6	20,6	29,4	15,4	3,0	1,47	Sandy-loam	0,89	1,51	83,03	14,57
50	23,5	22,0	14,0	32,8	31,2	3,0	1,39	Clay-loam	0,60	1,00	87,62	10,77
51	7,0	16,8	14,8	31,1	37,3	3,8		Clay-loam	0,63	0,37	90,06	8,90
52	32,6	27,2	13,8	30,6	28,4	3,3	1,37	Clay-loam	0,71	0,56	89,99	8,80
53	12,4	36,8	9,4	28,8	25,0	4,9		Loam	0,60	0,41	90,44	8,60
54	11,2	24,0	15,4	31,8	28,8	7,3	1,32	Clay-loam	0,75	0,44	90,27	8,50
55	6,8	19,8	15,8	30,1	34,3	3,0	1,21	Clay-loam	0,84	1,09	92,05	6,00
56	14,5	26,4	12,8	27,3	33,5	6,0	1,00	Clay-loam	0,63	0,90	87,83	10,65
57	11,7	33,1	17,6	33,7	15,6	9,3	1,02	Loam	1,31	0,39	85,76	12,50

Table 2. Main characteristics of the observed events used for AGNPS applications.

Event		Rainfall[1]	Erosion index[1]	Runoff		Hydrograph	Sediment	Sediment
Number	Date	Depth (mm)	(MJ mm/ha/h)	Depth (mm)	Peak (m^3/s)	type [2]	yield (10^3 kg)	sample points
1	23/11/97(I)	14.6	64.80	3.8	1.26	Single-peak	-	-
2	23/11/97(II)	7.8	6.40	5.0	1.15	Single-peak	25.69	5
3	24/11/97	19.8	45.81	6.6	1.34	Single-peak	-	-
4	02/12/97(I)	10.8	6.03	3.4	0.28	Multi peak (2)	-	-
5	02/12/97(II)	21.2	34.54	11.5	1.26	Multi peak (3)	-	-
6	27/12/97	24.8	19.47	5.8	0.17	Multi peak (4)	-	-
7	25/01/98	23.0	25.31	12.1	0.33	Multi peak (3)	3.20	12
8	31/01/98	19.0	22.50	4.3	0.28	Multi peak (2)	7.50	16
9	24/03/98	27.2	28.48	1.2	0.07	Single-peak	-	-
10	11/12/98	12.4	7.33	2.8	0.31	Single-peak	4.81	14
11	22/12/98	18.8	21.92	4.2	0.36	Single-peak	2.04	13
12	03/01/99	57.0	64.07	40.5	1.44	Multi peak (5)	50.54	20
13	23/03/99	7.2	4.47	4.8	0.41	Multi peak (2)	-	-
14	11/04/99	9.2	3.91	4.1	0.23	Single-peak	-	-
15	13/01/00	50.2	41.02	15.3	0.48	Multi peak (5)	13.87	29
16	14/01/00	43.6	45.06	30.4	1.19	Multi peak(4)	58.66	20
17	19/01/00	9.6	4.17	2.8	0.22	Single-peak	0.65	12
18	13/01/01	56.8	20.63	2.8	0.21	Multi peak (3)	-	-

[1] Station B. [2] Number of peaks in brackets.



Example of the pluviograph/hydrograph relationships at the watershed Cannata

Based on the data collected, simulations were also run using the model AGNPS (Agricultural Non-Point Source); this model was selected since at the time MWISED was not operative, owing to the numerous bugs.

Accordingly, in addition to reporting the results of the data collection referred to the specific watershed, in fulfillment of our task, we report here also the results of these simulations.

B) - In the **Caltagirone** area a field was installed to observe overland flow and solid transport at plot scale; four square-shaped plots (m 8 x 8) on slopes of 5%, 10%, 15% and 20% (plots A, B, C, D, respectively) were equipped with rain simulators and the necessary appliances to conduct the experiences.
The four plots were hydraulically insulated by means of metal sheets high 40 cm, intruding 25 cm. into the soil.
A metal gutter downstream collected overland flow from each plot conveying it into a 2 m^3 tank; water flowing into the tank was sampled for the solid transports.
In every plot four sprinklers were installed at the four corners of a 10 x 10 square including the 8 x 8 m experimental plots, with a maximum flow rate of about 26,4 l/min (which originated an hourly precipitation intensity of about 50 mm, taking into account the unavoidable water losses outside the borders) at the pressure of about 3 bars; pressure could be cheked by means of a manometer and a hand valve installed in every sprinkler riser.
All the plots were protected against wind with a plastic net surrounding them at the heigth of about 3 m.
The application uniformity as resulting from the Christiansen Uniformity Coefficient was in any case above 85%.
The experiments were conducted, according to the generally accepted protocol, with three distinct runs lasting one hour each, with the interval of 24 hours between the first one ("dry run") and the second ("wet run") and one hour between the second and the third ("very wet run").
A total of 108 runs was conducted.
The parameters considered were the following.
<u>The moisture content</u> in topsoil: it was gravimetrically determined at 1, 5 and 15 cm depth, sampling it ten minutes before each run.
<u>The bulk density</u>: it was determined with soil samples taken in 54 mm wide, 20 mm high rings.
Through the previous measurements it was possible to estimate <u>soil porosity</u> and <u>initial soil moisture</u>

Surface cohesion in the top 8 mm was measured immediately after the very wet runs by means of a torvane.

Plant cover was estimated applying the photographic method.

Water outflow was measured recording the time needed to derive fixed water volumes 1, 3, 5, 7, 10, 15, 20, 25, 30, 40, 50 minutes after outflow initiation and at the end of inflow; hydrographs were elaborated and the resulting total volumes were compared to those collected in the tanks. Differences in volumes averaged 4% and peaked 8%.

Ponding time resulted from the time elapsed between inflow and outflow initiation.

Soil loss measurements were based on the oven-dried outflow samples.

Selected input parameters required for the application of EUROSEM were recorded.

Plant cover percentage ranged within the limits reported below.

Plot	% plant cover
A	0 — 50
B	0 — 65
C	0 — 80
D	0 — 90

Soil bulk density, averaged over 3 samples per plot taken before every run, ranged between 1.09 to 1.29 g/cm^3 , with mean values of 1.12 g/cm^3 in plot A; 1.21 g/cm^3 in plot B; 1.20 g/cm^3 in plot C; 1.18 g/cm^3 in plot D.

Based on an estimated particle density of 2.65 g/cm^3, total soil porosity resulted in the range of 0.44 to 0.60, with mean values of 0.58 in plot A; 0.54 in plot B; 0.55 in plot C, 0.56 in plot D.

Soil cohesion was assessed through ten torvameter readings in each plot immediately before the very wet runs; it ranged between 3.7 to 6.1 kPa, averaging 4.8 kPa.

Water content before the very wet runs ranged between 28.8 to 44.1% in weight.

C) - In the **Raddusa** area a watershed extended 1,35 km^2 was fully characterised through a topographic survey, the analysis of historical rain events, the accurate appraisal of land use and its variations in time.

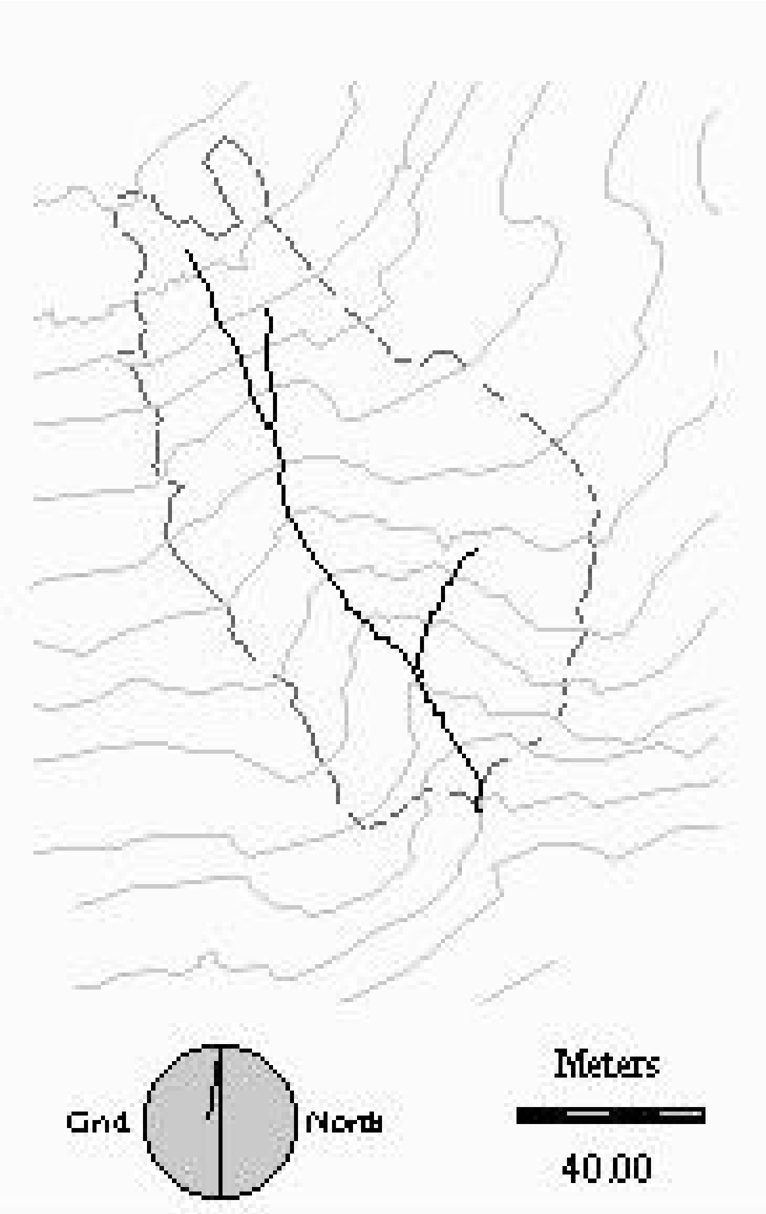
A sub-basin extended about 5 ha was surveyed in detail (2.5 m contour lines) by means of a GPS and equipped at the closure section with a sediment trap as described in the figure.

The evolution in time of the main gully and its branches (in length, width and depth) were recorded and linked to rain events; the possible correlations were found among gully evolution vs rain events and pedological conditions.

The tables below report the main features of precipitations in the site.

Precipitation characteristics

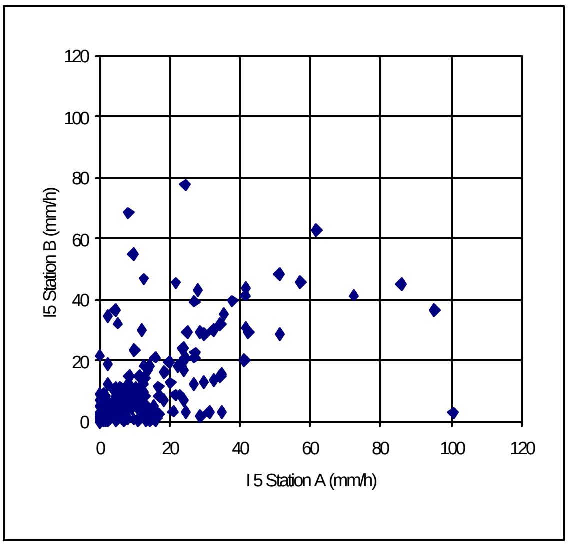
date	Event precipitation*		5 days precipitation	
	total, mm	maximum intensity, mm/h	total, mm	maximum intensity, mm/h
29/8/99	24,5	49	24,5	49
3/9/99	17,9	14	24,3	38
7/9/99	33,6	18	51,9	18
9/9/99	9,4	55	43,4	55
28/11-01/12/1999	194,2	24	194,2	24
12/01-14/01/2000	75,3	7	81,1	7

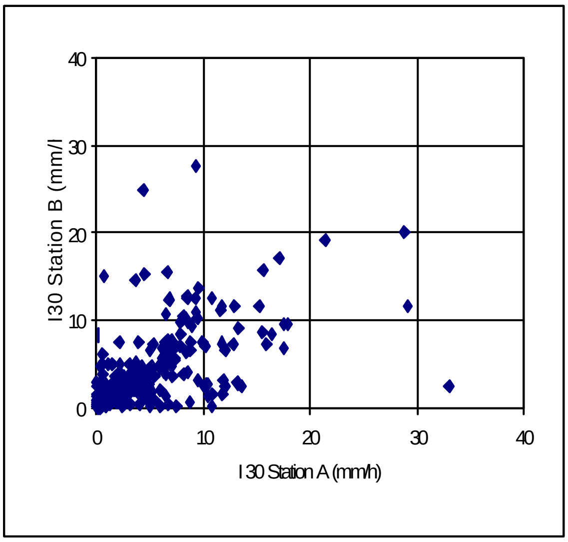


– Ephemeral gully at the end of the rainy season 1999-2000

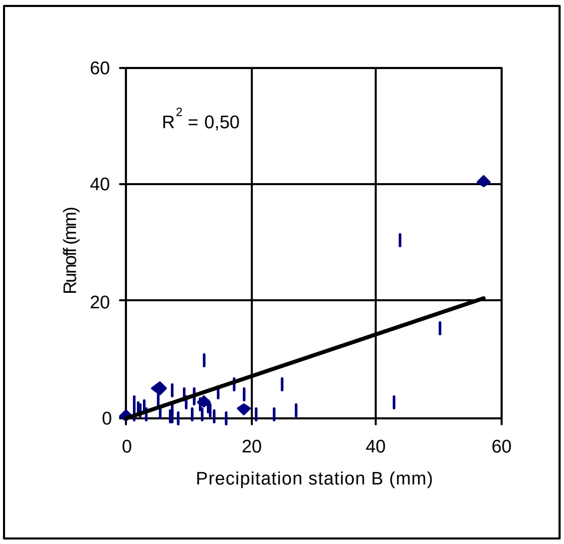
PART 2 - THE MAIN RESULTS

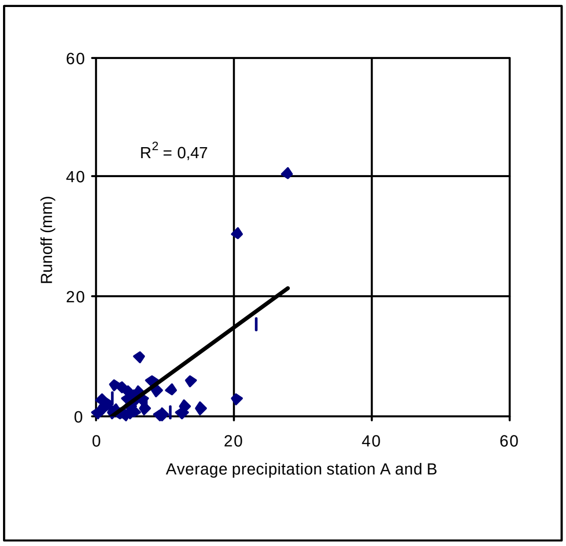
In the Flascio area



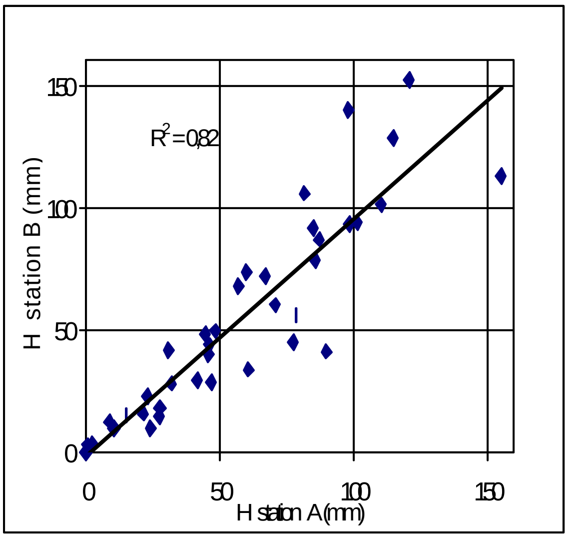


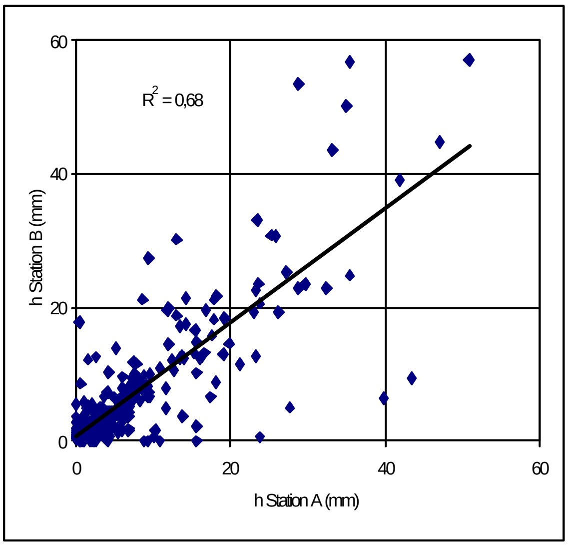
Comparison between precipitation maximum intensity recorded at station A and B in 5 (I5, left, n=258) and 30 minutes (I30, right, n= 258)



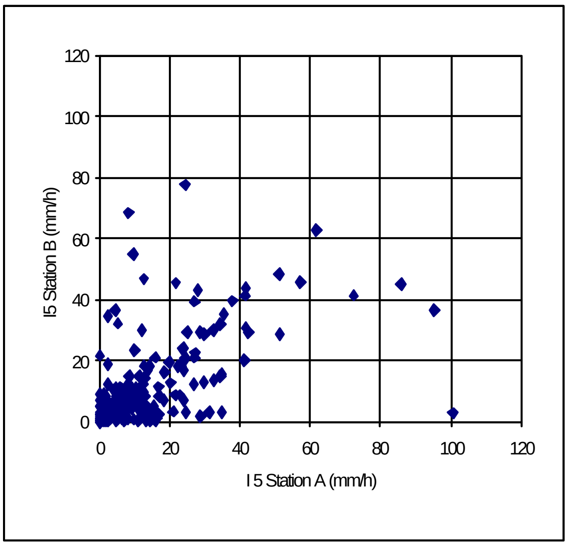


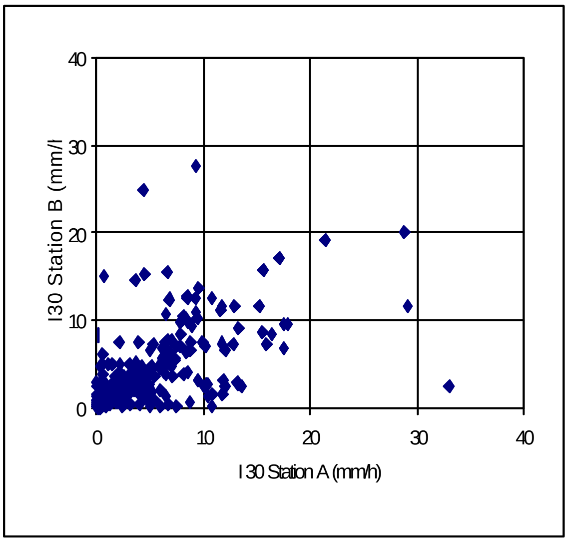
Runoff /precipitation comparisons as recorded at station B (left) or averaged from stations A and B (right)



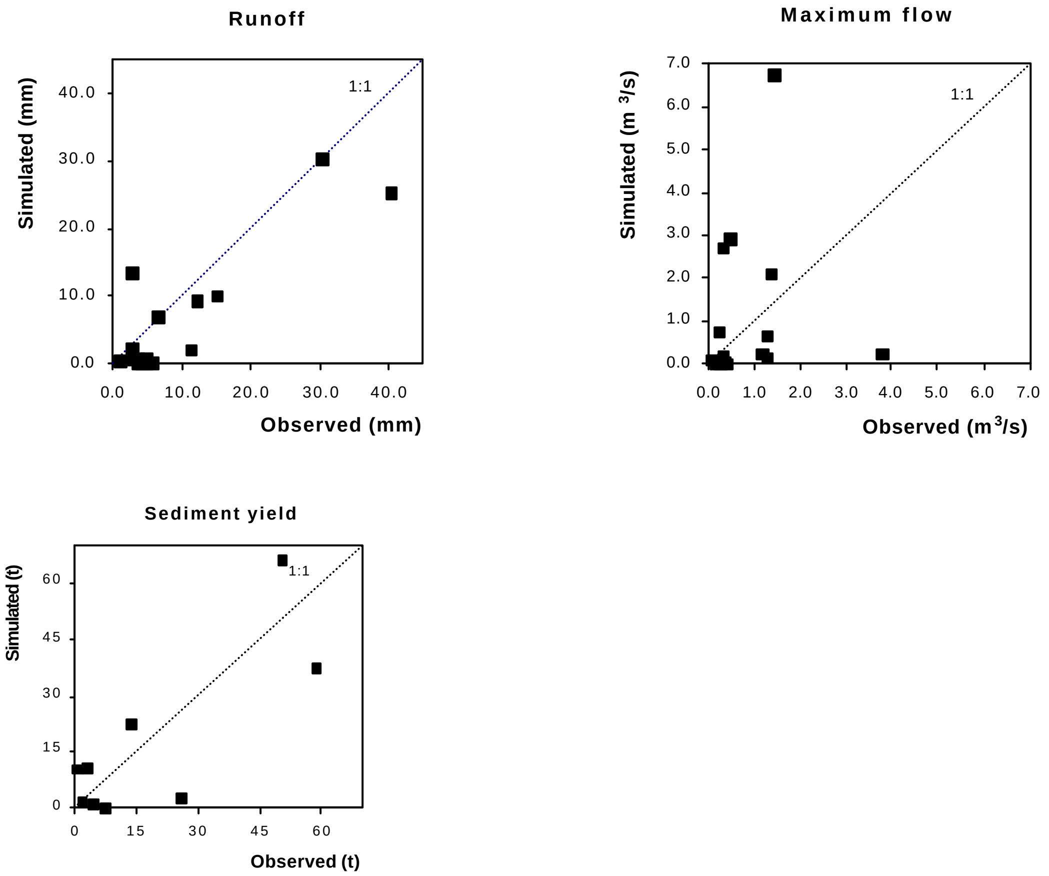


Comparison between precipitation depths recorded at station A and B: single event (h, right, n=336) and monthly totals (H, left, n=39).





Comparison between precipitation maximum intensity as recorded at stations A and B in 5 (I5, left, n= 258) and 30 minutes (I30,right, n=258)



Comparison between observed and simulated runoff (left, n = 18); maximum flow (center, n = 18) and sediment yield (right, n = 9)

	Mean [mm]	Median [mm]	Minimum [mm]	Maximum [mm]	St. dev. [mm]	E* [-]
Measured	8.97	4.55	1.20	40,50	10.46	-
Predicted	5.60	0.51	0,00	30.23	9.08	0.658

* Coefficient of efficiency, Nash and Sutcliffe (1970).

Runoff depth statistics for the selected events.

In the plots with rain simulators (Caltagirone)

The experiments conducted with rain simulators (108 runs in all) highlighted some unexpected results.

Out of the total number of runs, all those from the very wet runs and only those from the wet runs which originated some runoff were selected for the analysis.

Dependent variables were considered runoff and soil transport whereas independent variables were slope, precipitation intensity, soil cover, initial soil moisture content at 1, 5 and 15 cm depth.

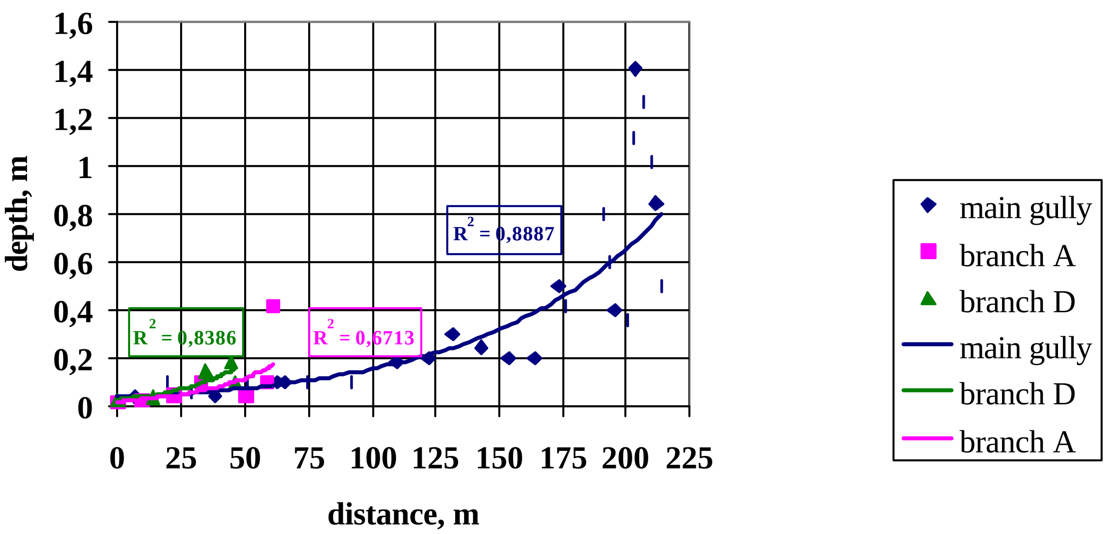
The main results of the statistical analysis are reported below (n = 47).

simple regression - dependent variable: runoff	**R^2**
Independent variables	
Slope	.02
Rain intensity	.11
Plant cover	.11
Soil moisture 1 cm	.06
Soil moisture 5 cm	.09
Soil moisture 15 cm	.26
multiple regression - dependent variable: runoff	
Independent variables	
Rain intensity + plant cover	.18
Soil moisture 1, 5, 15 cm	.27
Rain intensity + soil moisture 15 cm	.27
Rain intensity + plant cover + soil moisture 15 cm	.34
Rain intensity + plant cover + soil moisture 1, 5, 15 cm	.35
simple regression - dependent variable: soil transport	
Slope	.05
Rain intensity	.11
Plant cover	.003
Soil moisture 1 cm	.21
Soil moisture 5 cm	.12
Soil moisture 15 cm	.31
multiple regression - dependent variable: soil transport	
Independent variables	
Rain intensity + soil moisture 15 cm	.32
Soil moisture 1, 5, 15 cm	.37
Slope, rain intensity, soil moisture 1, 5, 15 cm	.37
Plant cover, rain intensity, soil moisture 1, 5, 15 cm	.37

The linear correlation between the two dependent variables, runoff and soil transport, showed a R^2 = .38
The figures above evidence the non-significant influence of slope on both dependent variables, and the limited influence of plant cover and rain intensity, under the experimental conditions.
The consistently rather strong correlation with soil moisture content at 15 cm, higher than that at 1 and 5 cm, cannot be easily explained.
The highest coefficients of determination obtained (R^2 =35 % in the case of runoff and 37 % in that of soil transport) explain only about one third of the variations occurred.
Perhaps the most interesting conclusion which can be drawn is that the initial soil moisture content in the layer 1-15 cm can explain 37 % of the soil transport under the experimental conditions.

In the Raddusa watershed

Gully depth versus distance from the heads



Precipitations h> 9.4 mm

precipitation 1 day		precipitation 5 day		gully erosion	precipitation 1 day		precipitation 5 days		previous precipitation, days	erosion during previous 5 days
h, mm	i max, mm/h	h, mm	imax, mm/h		h class	i max class	h class	i max class		
20,8	7,00	20,8	7,00	N	m	l	m	l	8	N
21,8	6,00	42,6	7,00	N	m	l	m	l	1	N
24,8	5,00	24,8	5,00	N	m	l	m	l	10	N
19,8	10,00	19,8	10,00	N	l	l	l	l	>30	N
24,5	49,00	24,5	49,00	Y	m	h	m	h	14	N
17,9	14,00	24,3	38,40	Y	l	m	m	m	4	Y
33,6	18,00	51,9	18,00	Y	m	m	h	m	4	Y
9,4	55,29	43,4	55,29	Y	l	h	m	h	2	Y
20,8	76,80	24,8	76,80	N	m	h	m	h	>30	N
17,6	16,00	17,6	16,00	N	l	m	l	m	7	N
194,2	24,00	194,2	24,00	Y	h	m	h	m	1	N
15,6	26,40	25,6	26,40	N	l	m	m	m	4	N
10	10,00	10	10,00	N	l	l	l	l	9	N
75,3	7,00	81,1	7,00	Y	h	l	h	l	1	N
27,2	9,00	31,7	9,00	N	m	l	m	l	>30	N
10	4,00	10,2	4,00	N	l	l	l	l	>30	N
15,8	18,96	20	18,96	N	l	l	l	m	>30	N
45,6	29,00	45,6	29,00	N	m	m	m	m	21	N
26	17,20	26	17,20	N	m	l	m	m	15	N
27	8,60	27	8,60	N	m	l	m	l	11	N
19,8	5,80	20,6	5,80	N	l	l	m	l	>30	N
15	6,00	16,2	6,00	N	l	l	l	l	>30	N
18,4	7,00	33,4	7,00	N	l	l	m	l	>30	N

N= not: Y = ves: l=low m=medium

gully erosion

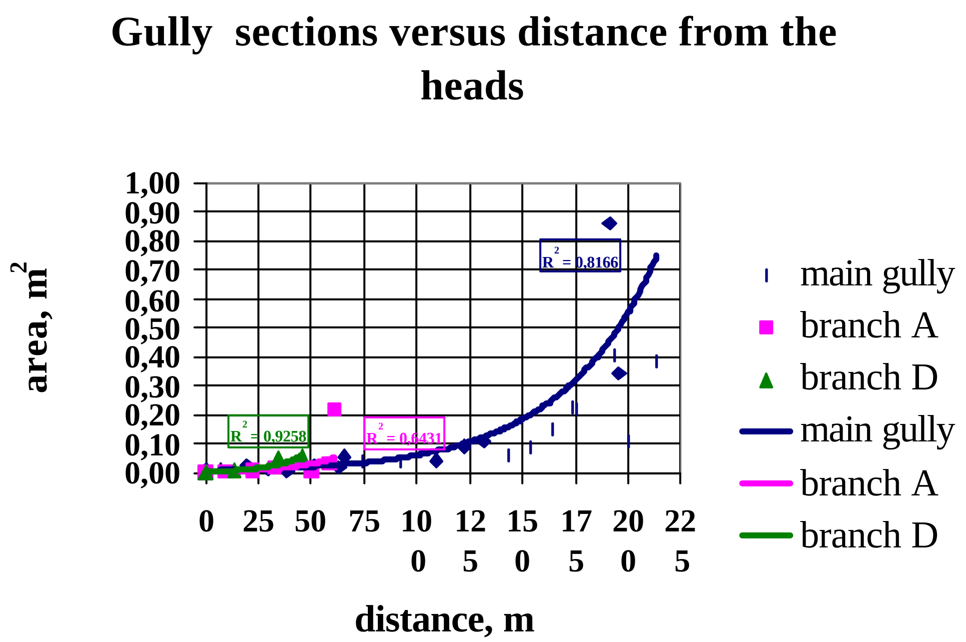
high total precipitation (> 50 mm/h)

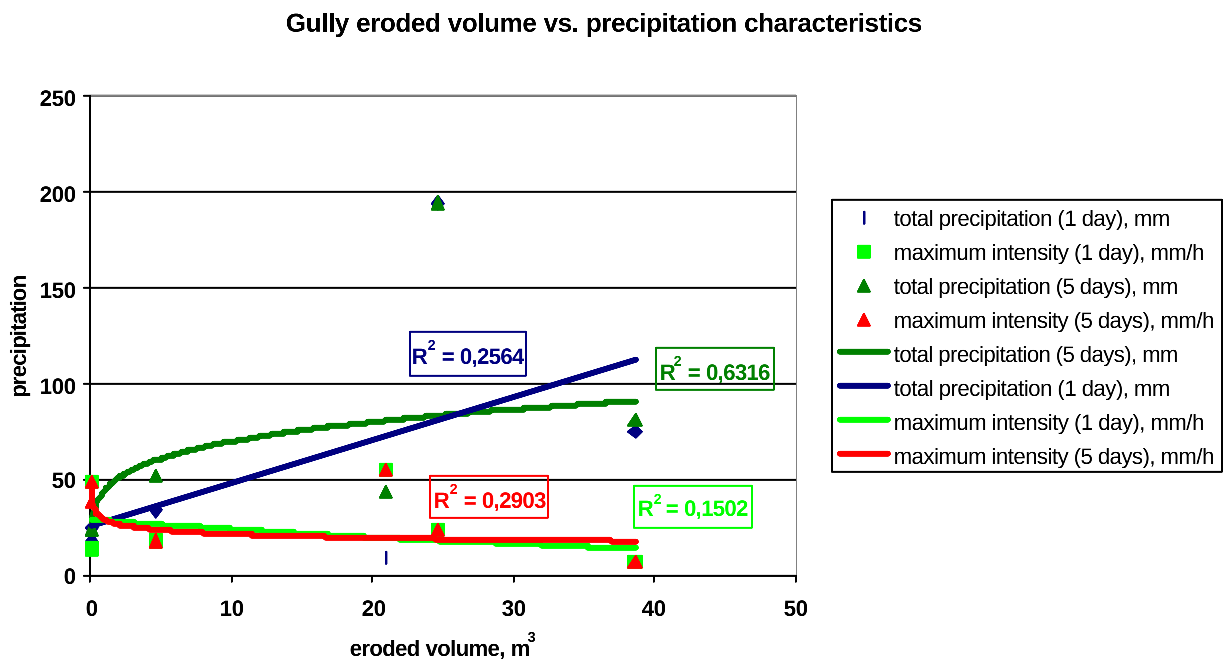
higth intensity precipitation (> 40 mm/h)

precipitation > 5 mm in the previous 5 days

gully erosion in the previous 5 days

total precipitation classification: l= <20 mm; m = 20-50 mm; h = > 50 mm; maximum intensity classification: l = < 12 mm/h; m = 12-40 mm/h; h = >40 mm/h;


Gully sections versus distance from the heads
area, m2
1,00
0,90
0,80
0,70
0,60
0,50
0,40
0,30
0,20
0,10
0,00
R2 = 0,8166
R2 = 0,9258
R2 = 0,6431
0 25 50 75 100 125 150 175 200 225
distance, m
main gully
branch A
branch D
main gully
branch A
branch D


Gully eroded volume vs. precipitation characteristics
precipitation
250
200
150
100
50
0
R2 = 0,2564
R2 = 0,6316
R2 = 0,2903
R2 = 0,1502
0 10 20 30 40 50
eroded volume, m3
total precipitation (1 day), mm
maximum intensity (1 day), mm/h
total precipitation (5 days), mm
maximum intensity (5 days), mm/h
total precipitation (5 days), mm
total precipitation (1 day), mm
maximum intensity (1 day), mm/h
maximum intensity (5 days), mm/h

Institut für Bodenforschung, Universität für Bodenkultur (BOKU)

REPORTING PERIOD: 1 APRIL 1998– 30 JUNE 2001

Contractor:	Institut für Bodenforschung, Universität für Bodenkultur
Responsible Scientist:	Dr. Peter Strauss
Scientific staff:	Mag. Susanne Zach Dr. Franz Konecny, Sabine Brenner,Dietmar Palmetzhofer Thomas Partaj, Erich Steiner
Address:	Gregor-Mendelstrasse 33 A-1180 Wien, Austria
Telephone:	+43 1 7416 52108 17
Fax:	+43 1 7416 52108 3
E-mail:	peter.strauss@baw.at

RESULTS

Work Package 3 (WP3) - Rainstorm Generator

ST1 - Simulation of the effect of different intensity patterns on erosion

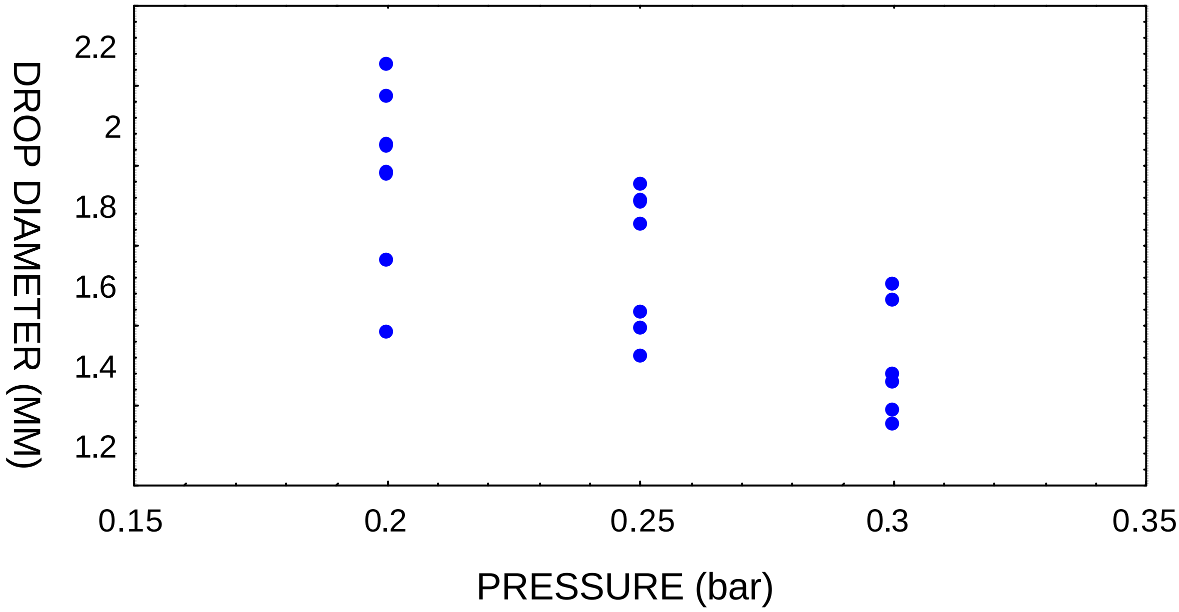
A fully programmable rainfall simulator, capable of simulating varying rainfall intensities within one erosion event has been built and tested. Table 1 gives an overview on the general characteristics of the rainfall simulator. Figure 1 demonstrates the influence of pressure on the drop size characteristics of the rainfall simulator.

Table 1:General characteristics of the fully programmable rainfall simulator

CHARACTERISTICS OF THE RAINFALL SIMULATION UNIT

- rainfall intensity freely variabel between 0 - 220 mm/h
- modular design - 4 modules give a plot size of 12 m by 2 m
- nozzles: HH40WSQ of Spraying Systems
- nozzle distance: 1m
- Christiansen uniformity coefficient about 90 %
- Median volumetric drop size about 2.0 mm

Figure 1: Influence of water pressure on median volumetric drop diameter



This unit has been used for field experiments to study the influence of the location of the rainfall peak intensity on runoff and soil loss. Two different soil types (Cambisol, Phaeozem) were investigated using three different positions of peak intensity (peak intensity at beginning, middle and end of the rainfall event) while all other factors were kept constant. Tables 1 and 2 give a brief summary of the results for this experiment.

Table 1: Selected runoff and soil loss parameters for a rainfall simulation experiment on a Phaeozem, using different locations of peak intensity (beginning, middle, end). Reported values are means of two repetitions.

Treatment	**Total soil loss**	**Total runoff**	**Mean soil loss rate**	**Mean runoff rate**
	g m^{-2}	**l m^{-2}**	**g m^{-2} min**	**l m^{-2} min**
Beginning	2037.5	47.5	34.1	0.8
Middle	1436	46.5	26.5	0.8
End	1503	48.5	28.5	0.8

Table 2: Selected runoff and soil loss parameters for a rainfall simulation experiment on a Cambisol, using different locations of peak intensity (beginning, middle, end). Reported values are means of two repetitions.

Treatment	**Total soil loss**	**Total runoff**	**Mean soil loss rate**	**Mean runoff rate**
	g/m^{-2}	**l/m^{-2}**	**g/m^{-2}/min**	**l/m^{-2}/min**
Beginning	850	23	15	0.4
Middle	1307	22	41	0.6
End	1591	27	42	0.7

Results clearly indicate that an influence of the time until rainfall peak intensity on soil erosion exists. However, the way the two different soil types reacted on the experimental setup was completely different. While runoff and soil loss parameters increased for the Cambisol with later arrival of the rainfall peak intensity, the contrary was observed for the

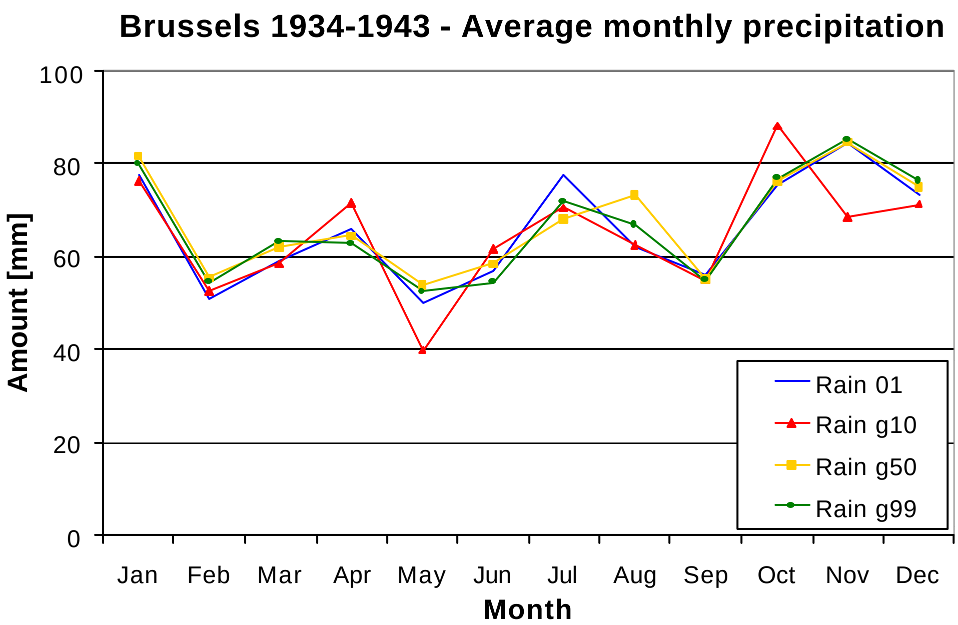
Phaeozem.

ST2 – Temporal variability in rain characteristics

In addition to the pre-existing rainfall data for Austria data for one additional rainfall station (Kremsmünster) were collected. In addition to the Austrian stations, rainfall data from one rainfall station in Belgium (Brussels) and Italy (Vicarello) were obtained for further analysis.

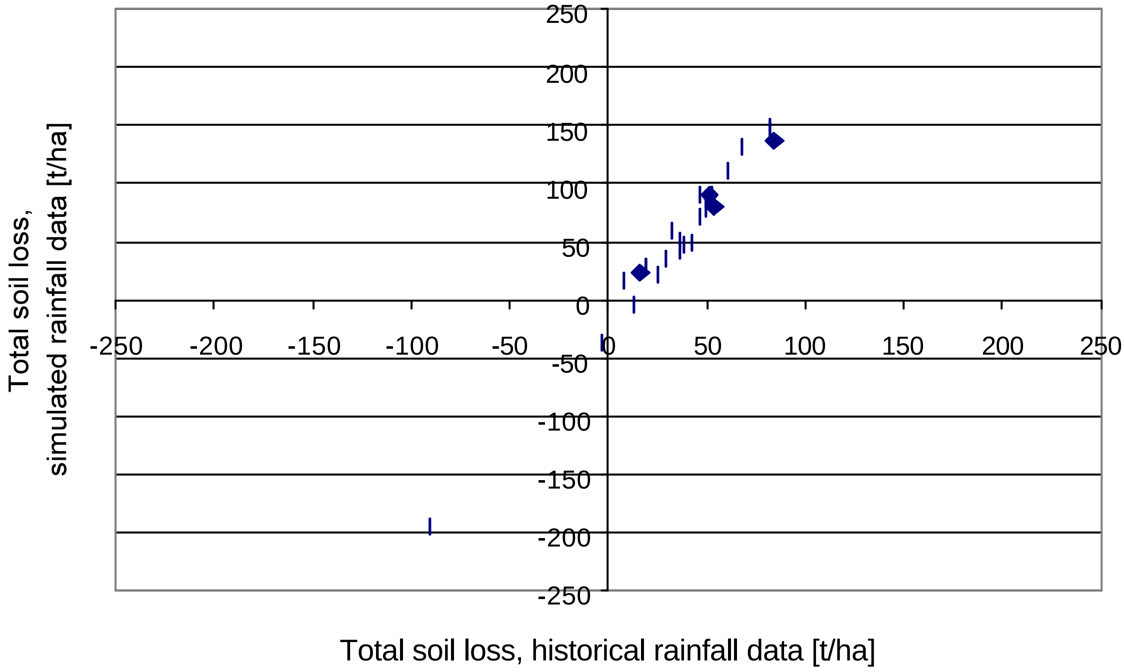
To test the possibility to generate daily rainfall amounts we explored the markov chain methodology using wet day/dry day probabilities. For a given rainy day, the daily rainfall amount can subsequently be calculated according to a fitted distribution. To explore the possibilities and limitations of the markov chain approach, different experiments regarding limitations of the random number generator, optimum simulation periods and others have been conducted. As an example, Figure 2 shows the influence of the simulation period length on monthly rainfall amounts for the station Brussels. It can be concluded, that it is necessary to use long term runs for simulations in order to minimise deviations between actual data and simulation data. In general markov chains could be used satisfactorily for different European stations to simulate daily rainfall amounts.

Figure 2: Comparison of generated monthly rainfall amounts using different evaluation periods (Rain 01 = observed data, Rain g10 = simulation period 10 years, Rain g50 = simulation period 50 years, Rain g99 = simulation period 99 years)



To simulate internal rainfall structure various different approaches have been tested: Bartlett-Lewis-type of model: A Bartlett-Lewis type of model has been tested to be used as input for EUROSEM. Results of a comparison between calculated soil losses using actual rainfall data and soil losses using rainfall data of a Bartlett-Lewis simulation are given in Figure 3. Using this approach simulated soil losses were overestimated to about 50%. In addition, one of the main problems commonly reported of using this type of rainfall simulation remains the laborious parameterisation of the necessary input parameters.

Figure 3: Comparison of total soil losses for a watershed with 28 cells using actual rainfall data and rainfall data which had been generated with a Hybrid Bartlett-Lewis model approach (rainfall station St.Pölten, Austria).



Design storms approach: Rainfall events are being simulated as a series of peaks with double exponential rainfall intensity distribution. The necessary input parameters to derive the double exponential distribution (peak duration, peak intensity, peak rainfall amount) are generated stochastically. Figure 4 demonstrates the concept of this approach. Table 3 shows results of a comparison between soil losses calculated with actual rainfall data and soil losses calculated using design storm rainfall data for a microwatershed of 10 cells. From table 3 it can be seen that design storm rainfall data tend to overpredict soil losses. This effect increases with rising total amounts of soil loss. As the microwatershed was ordered in a way that the cells partly drain into other cells (indicated with different shading in table 3), the overprediction of soil loss is also an effect of routing runoff and sediment along these cells.

Figure 4: Conceptual model to generate design storms for EUROSEM

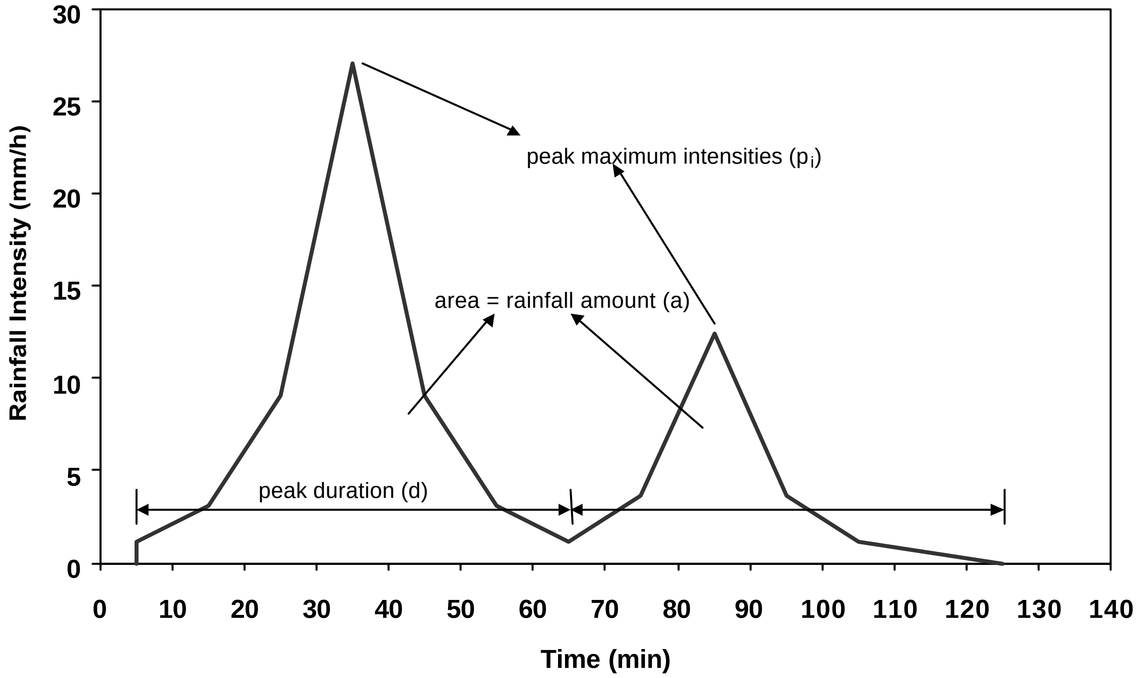
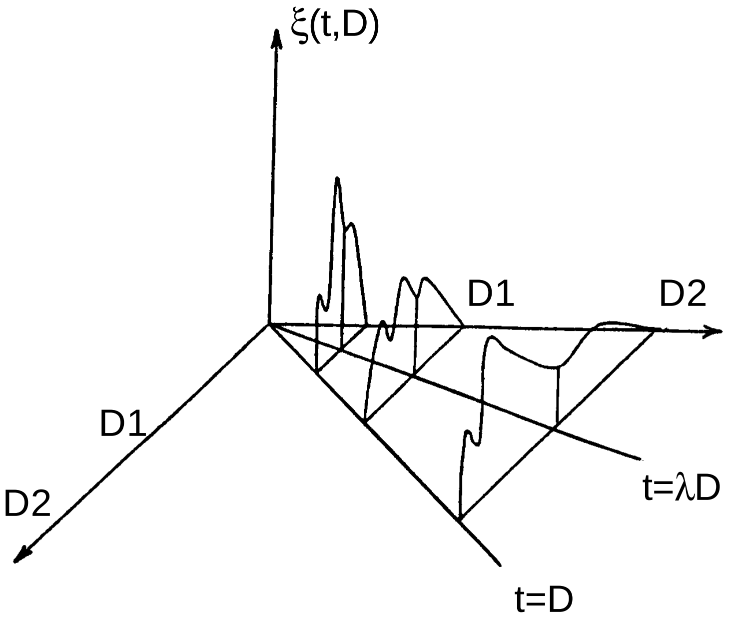


Table 3: Calculated total soil loss (tons/ha/y) for a microwatershed of 10 cells obtained with actual rainfall data and rainfall data generated with the design storm model (two independent simulation repetitions).

Cell No.	Calc. Soil Loss	Sim. Soil Loss 1	Sim. soil loss 2
1	22.3	26.8	24.1
2	20.9	25.8	22.9
3	20.9	25.8	22.9
4	20.9	25.8	22.9
5	22.9	34.3	30.5
6	24.5	36.5	32.6
7	24.5	36.5	32.6
8	27.2	41.7	37.6
9	23.3	36.6	32.7
10	25.5	40.3	36.0

Scaling model: Basis of this approach is the assumption that actual rainfall intensity of storm events is a self-similar stochastic process which can be decribed with a scaling coefficient H and parameters c_1, c_2 and . Figure 5 gives a conceptual presentation of the scaling approach.

Figure 5: Conceptual representation of the simple scaling model



As could be observed this asssumption is only of partial validity. Instead the coefficient H was time dependant for most investigated stations. Therefore it was necessary to fit H using piecewise linear regression (Figure 6).

Characteristics of the scaling model are:

Events are generated

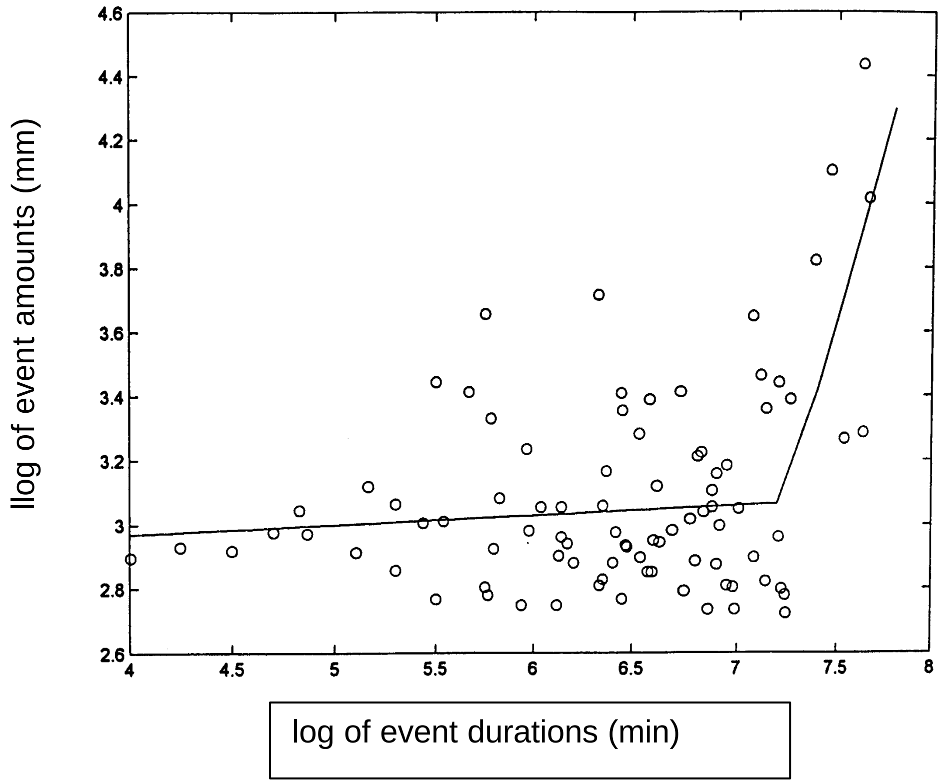
- Event durations are assumed to be Weibull distributed
- Total event depths are assumed to be Hyperexponentially distributed
- Incremental depths of events are assumed to be Gamma distributed
- assumption: rainfall intensity process ξ(t,D) within a storm is a self-similar (simple scaling) process with scaling exponent H:

$$\left\{ x(t,D) \right\} \stackrel{d}{=} \left\{ l^{-H} x(lt,\, lD) \right\}$$

=1/D = normalized to unit duration

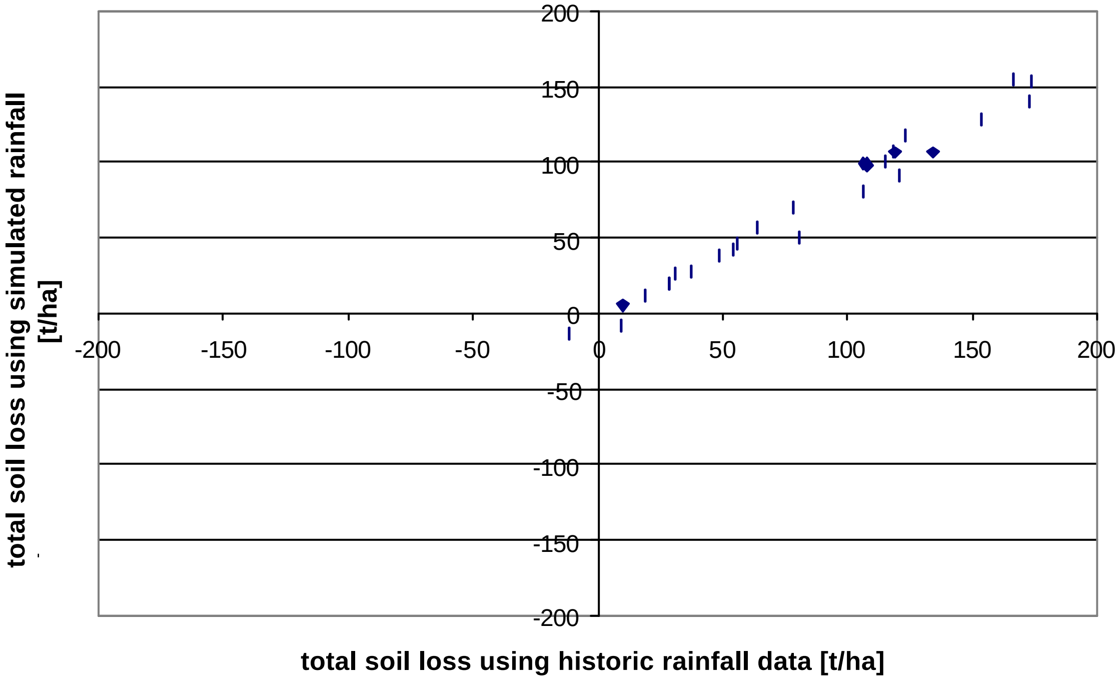
The statistical properties of rainfall intensities in storms of any duration are obtained by appropriate scaling of statistical properties of rainfall intensities in a storm normalized to unit duration.

Figure 6: Relationship between durations and amounts of rainfall events (station Baden)



A comparison of calculated soil losses using observed rainfall events with calculated soil losses using generated rainfall events for a microwatershed consisting of 28 cells shows, that the scaling model underpredicted total soil losses for a period of 20 years slightly (Figure 7).

Figure 7: Comparison of calculated soil losses for a microwatershed of 28 cells using actual rainfall data and rainfall data generated with the scaling model. Soil losses are sums over a period of 20 years (station Baden, Austria).

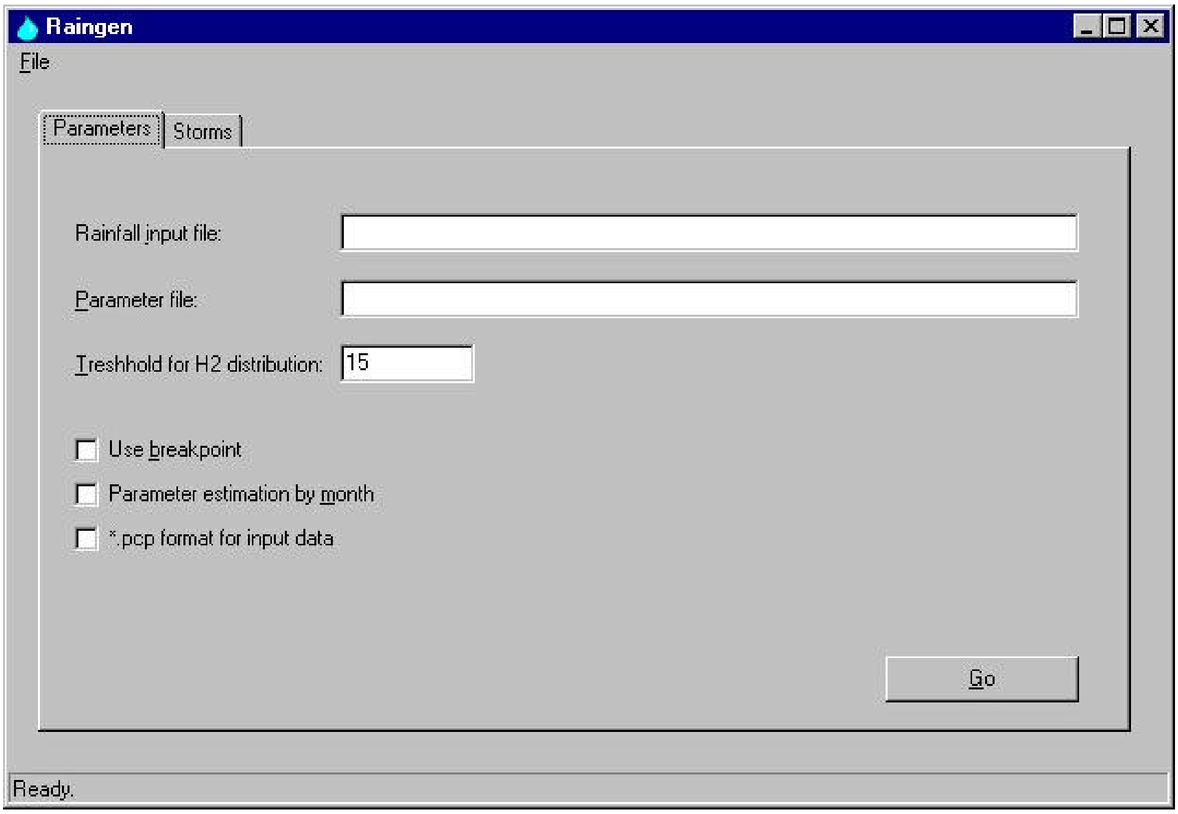


To get a make the described scaling model approachable for users a software module (RAINGEN) has been written. All mathematical routines are written in Fortran 90. They are embedded in a shell written in C++. If desired, the different routines can also be used without the C++ shell. The mathematical routines consist of two parts:

A) Parameterisation: Given an inputfile with rainfall data, all necessary parameters to run the scaling model are generated automatically. The possibility to transform the rainfall data into a format readable by EUROSEM exists in addition.
B) Generation: This module uses the parameter values of the parameterisation module to generate a variable number of rainfall events. The values for the necessary input parameters can also be added or changed manually.

A manual for RAINGEN has been prepared to supply the users with details about program use. Figure 8 gives the main view of RAINGEN 1.0.

Figure 8: Main view for Raingen 1.0



PUBLICATIONS

- Printed papers:

P. Strauss, A. Mentler: Phosphorus transport with sediment particles as affected by the location of rainstorm peak intensity. Proceedings of the OECD workshop on „Practical and innovative measures for the control of agricultural phosphorus losses to water“. Greenmount College of Agriculture and Horticulture, Northern Ireland, 1998.

Strauss P., F.Konecny, W.E.H. Blum: A rainfall generation procedure for the European Soil Erosion model (EUROSEM). Hydrology and Earth System Sciences, 3, 2, 213-222, 1999.

Strauss P., J.Pitty, M.Pfeffer, A. Mentler: Rainfall Simulation for Outdoor Experiments. In: P. Jamet, J. Cornejo (eds.): Current research methods to assess the environmental fate of pesticides. pp. 329-333, INRA Editions, 2000.

Strauss P.: Raingen – A scaling model to generate event based rainfall. Concepts and technical description. Institut fuer Kulturtechnik und Bodenwasserhaushalt, Bundesamt fuer Wasserwirtschaft, Petzenkirchen 2001.

- Papers in press:

P. Strauss, F. Sancho, Ch. Prat, G. Arevalo (accepted for TERRA): Diseño de un sistema de generación de lluvias para la Introducción de datos en el modelo EUROSEM.

Zach S., P. Strauss, F. Konecny, W.E.H. Blum (Mitteilungen des hydrographischen Dienstes): Erzeugung von Niederschlagsereignissen für das Europäische Bodenerosionsmodell EUROSEM unter der Verwendung des Bartlett-Lewis-Hybrid-Modells.

- Submitted papers:

Strauss P., F. Konecny, S. Zach: Simulation zeitlich hochaufgelöster Niederschläge für hydrologische Modelle am Beispiel von EUROSEM (European Soil Erosion Model). Mitteilungen der Deutschen Bodenkundlichen Gesellschaft.

- Papers in preparation:

Strauss P., F. Konecny: Using a simple scaling model to generate synthetic rainfall input data for EUROSEM.

ISTITUTO SPERIMENTALE PER LO STUDIO E LA DIFESA DEL SUOLO (ISSDS)

REPORTING PERIOD: 1 APRIL 1998– 30 JUNE 2001

Contractor:	ISTITUTO SPERIMENTALE PER LO STUDIOE LA DIFESA DEL SUOLO
Responsible scientist:	Dr. Paolo Bazzoffi
Scientific staff:	Dr. S. Pellegrini
Address:	Istituto Sperimentale per lo Studio e la Difesa del Suolo. P.za D'Azeglio, 30 50121 Firenze
Telephone:	+39 55 2491211
Fax:	+39 55 241485
email:	bazzoffi.paolo@iol.it spellegrini@dada.it

WORK CARRIED OUT AND ACHIEVED RESULTS

2 Work package WP1 Within Storm change in infiltration

2.1 Sub task 1 (ST1) In-field monitoring of surface roughness decay.
Level of participation for ST: CC
Surface roughness decay was monitored at Vicarello Experimental centre during the three-years. In the first year, surface roughness decay was monitored during two periods on two different places. The monitoring period on the first site spanned between February to September and from October to November on the second site. The change of site was caused by the necessity of differentiating the measurements according to the two main periods of the agrarian cycle (plant growing and not growing) and by the fact that on the first place it was not possible to restore surface
On 9 sites, surface roughness decay was monitored by using a pin profilemeter after natural rainfall events at Vicarello. Measurements were done both on bare (weeded) and cultivated surfaces (winter wheat).

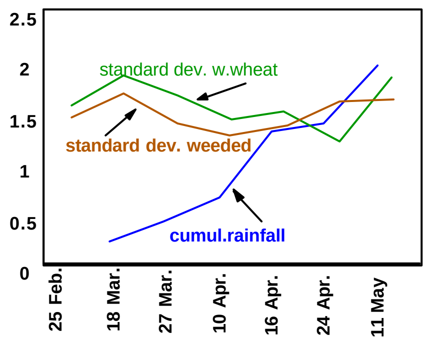


Fig. 1 Roughness decay and cumulative rainfall during 1998

Fig. 1 shows the trends of standard deviation of surface roughness during the period between soil harrowing and wax maturity of winter wheat. These first results made evident the stronger decay of surface roughness of bare soil than the soil covered by winter wheat. In April, an inversion was detected, probably due to the higher self mulching occurred on bare soil, not protected by vegetation, as consequence of a stronger action of dry-wetting cycles.

In the second year, ISSDS started the collection of other data of surface roughness decay by using a different equipment. Survey lasted until the end of the project.

After each natural rainfall event, measurements were done with a profile meter of 40 cm length (fig.2) with sliding pins 2 mm spaced. On each place, 30 sampling sites were randomly monitored, half of them on the maximum slope and the others perpendicular to the slope gradient. Thus, each value of random roughness (RR) shown on figs. 3 represents the mean value of 30 measurements.

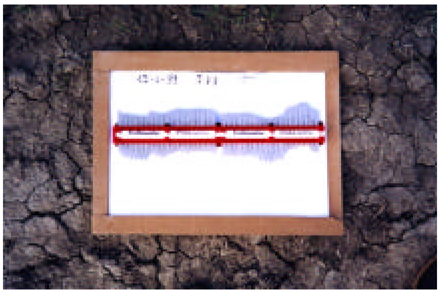


fig. 2. The profile meter used for the second cycle of roughness detection

Each measurement was performed by placing the profilemeter on the soil surface and gently lowering the pins to preserve the natural profile. Then, profile meter was removed and photographed on a white-background frame. Pins profile was acquired from pictures with the use of a tablet digitizer. The entire data set were analyzed for determining the relationship between rainfall energy and roughness decay under natural conditions, including the effects of diurnal termal excursion, incident solar radiation, which have a further effect on roughness dynamics.

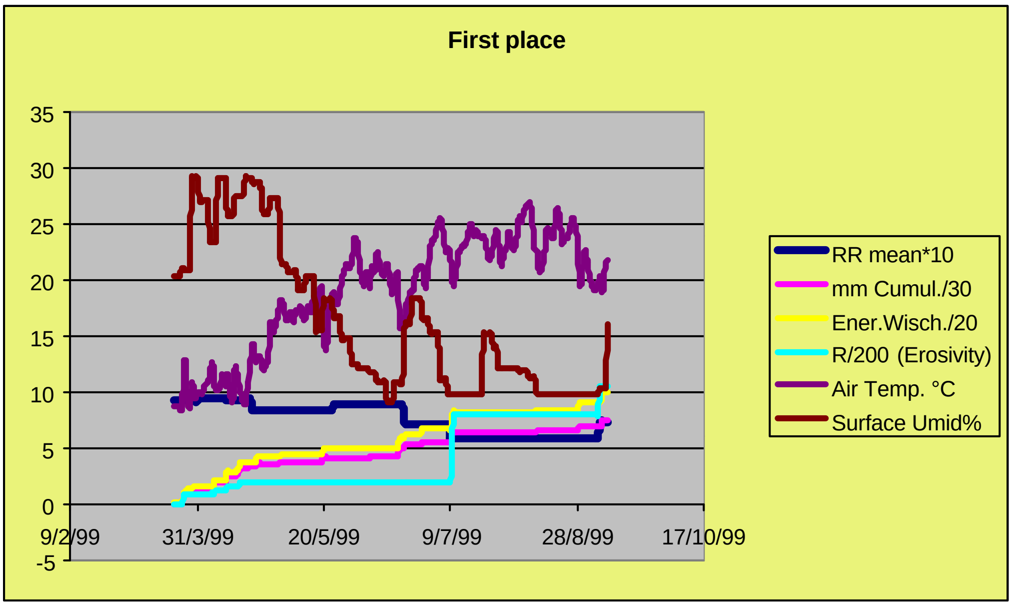


Fig. 3. Surface roughness evolution related to climatic variables (site 1).

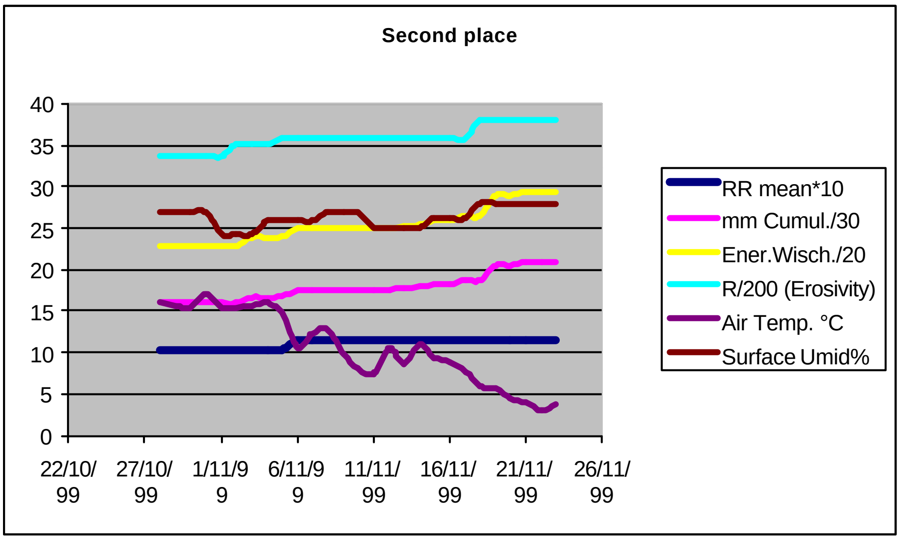


Fig. 4. Surface roughness evolution related to climatic variables (site 2).

The results of roughness analysis, together with climatic data are shown in fig 3 and 4. From the analysis it was found that surface roughness decay may be, to some extent, dependent on rainfall energy and soil wet-dry cycles.
During the project, data of soil moisture were collected twice a week at two different depths (0-20 cm and 20-40 cm) for diferent soil uses (wheat, alfalfa and continuous fallow). Contemporarily, continuous record of rainfall, air temperature, humidity, global solar radiation, wind speed and direction as well had been made with the use of a one-hour recording meteostation.
A model for predicting soil moisture from rainfall and temperature had been developed **in cooperation with CNR-IGES**, by Lorenzo Borselli, which developed a mixed inference system based on both statistical and fuzzy approach and two basic input parameters:

- P_{20} = Cumulate Rainfall in the previous 20 days (mm)
- T_{20} = Average mean daily temperature in the previous 20 days (C°)

Some results and model performances are shown in figures 5, and 6.

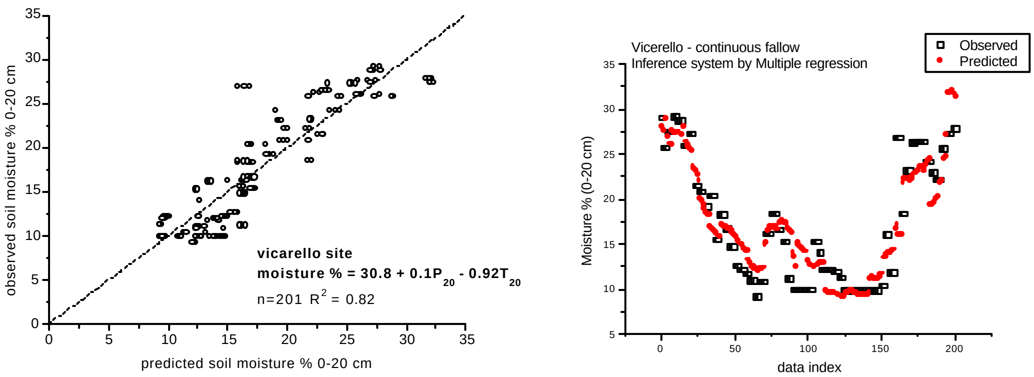


fig. 5 : Multiple regression model for moisture prediction - Vicarello Continuous Fallow

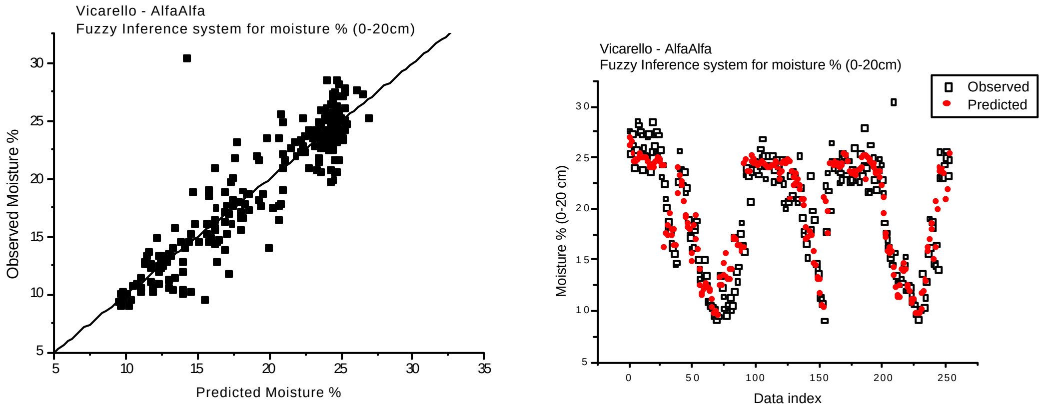


fig. 6 : Fuzzy Inference System for soil moisture prediction
Vicarello AlfaAlfa

In the third year a survey work had been done to prepare of a field guide for the visual estimate of roughness, to help the users of EUROSEM and LISEM models to input realistic values for this crucial parameter.
Different locations, soils and surface conditions were chosen in Tuscany to represent a variety of possible agricultural scenarios. On 20 sites roughness values were taken through a new pin profile-meter which was designed and realised to perform the work

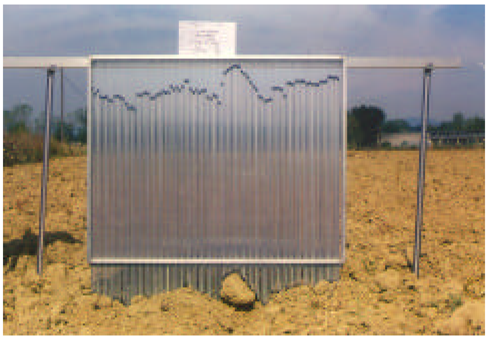


fig. 7. View of the new pin profile meter

Each measurement was performed by placing the profile meter on the soil surface and gently lowering the pins to preserve the natural profile. Then, profile meter was removed and photographed on a white-background frame. Pins profile was acquired from pictures with the use of a tablet digitizer.
Data have been processed and the results have been reported in a field manual for the visual estimating of roughness.

3 Work package WP2 Development and evolution of ephemeral gullies

3.1 Sub task 1 (ST1) Field observation of gully evolution
Level of participation for ST: C

In the firs year, on an area of Tuscany close to San Gimignano, ephemeral gullies were measured by aerial photograph analysis and field measurements with pin profilemeter. A special device was realized for shooting pictures from helicopter. Pictures were then digitized and corrected for distortion with the use of a software realized for this project.
Soil density was also monitoired at the survey time for calculating the ponderal value of erosion. Meteo data of the rainfall events that generated the ephemeral gully pattern on the soil surface had been analyzed and put in relationship with the soil loss.
In the second year, the analysis of rills volume and form continued. 52 cross sections of rills were digitised for determining the area of rills at different location along the slope. This analysis also enabled to know the maximum depth reached by rills and the average depth as well.
In the same second year, experiments of rill formation under simulated runoff were performed at Vicarello Exp. Centre. The flume and the experimental layout were set up during an MWISED meeting devoted to this subject.
In the third year the total length of rills at San Gimignano had been acquired by image analysis with QUANTIMET technology. Results achieved showed a total soil loss of 175.66 ± 14.93 t/ha due to ephemeral gully evolution. Soil compaction on wheel tracks resulted the principal component causing long-distance zigzag pattern of ephemeral gully. Also, soil compaction on harrowed paths was recognised to be the secondary component causing fine-textured zigzag.
In the Vicarello area, where LISEM and EUROSEM were applied, the position, length and dimension of observed real ephemeral gullies were provided to the other project partner contractors to test the effectiveness of models in predicting ephemeral gully evolution.
LISEM model developers used these data and a demonstration of pevisional capacity had been showed during the final MWISED meeting held in Leuven in the spring 2001.

3.2 *Sub task 2 (ST2)* Flume experiments
Level of participation for ST: CC

In the first year, due to the lack of standard protocols, flume experiments had not still initiated.
In the second year the experimental layout were set up during an MWISED meeting at Vicarello devoted to find a common research methodology for determining the threshold conditions for flow erosion. Then experiments of rill formation under simulated runoff were performed at Vicarello Experimental Centre.
In the third year runoff experiment started at Vicarello continued, and other experiment were performed in laboratory at Fagna Experimental centre with the use of a special flume equipped with a device to enable the change of its slope.
For each simulated flow, hydraulic parameters and flow detachment rates have been determined

3.2 *Sub task 4 (ST4)* GIS development
Level of participation for ST: CC

In the first year, a geodetic TRIMBLE 4600 LS-TCS1 GPS was purchased and calibration trials were performed. In the same year the GPS station continuously collected GPS data, to control on a selected point at ISSDS institue the stability of the measured position and the associated experimental error.

In the <u>second year</u> the continuous control survey was prosecuted and the survey of the Vicarello watershed and sub watersheds was started. The survey was finalized to the determination of the locations where critical conditions for ephemeral gully formation were likely to occur during individual storms.
Field survey was completed in the <u>third year</u> by using the same differential GPS and continuous data collection of satellite ephemeredes . In the same year, from spatialized data of elevation of the Vicarello area, different grid-size Digital Terrain Models were produced to perform the simulation of ephemeral gully formation using LISEM model based on PC-raster GIS. These results were compared with the position of the actual gullies that evolved on the Vicarello watershed.
Data were provided to MWISED contractors encharged to develop models.

<u>4 Work package</u> WP3 Modification to a rainstorm generator

4.1 Sub task 1 (ST1) Rainfall data collection
Level of participation for ST: CC

During the <u>first year</u> recorded charts of rainfall of the period spanning 1964-1990 at the experimental center of ISSDS at Vicarello (Volterra-Tuscany) were analyzed and a database was realized.
For building the database an hard work was done. The result consisted of 2220 files each of them corresponding to a rainfall event. Each file contains information of total amount, energy, maximum amount in 30 and 15 min of digitized data of mm of rainfall discretized in quantities of homogeneous intensity.

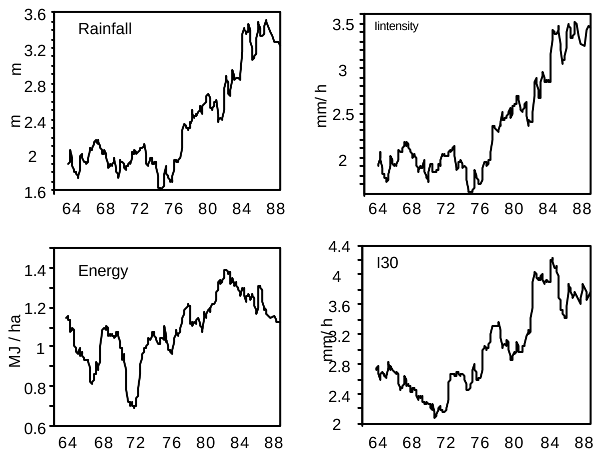


Fig.8 Trends of hydrologic parameters of monthly rainfall.
36^{th} - order mobile means.

A detailed analysis of rain characteristics influencing the erosive process demonstrated a dry up of climate in the short period. This trend was in terms of rain quantity and particularly from the point of view of aggressiveness. In fact the evolution of rain events resulted towards an increasing of energy, I30 and erosivity, meanwhile an increasing of the mean lag between successive events has been found.
In the <u>second year</u>, the dataset of rainfall, spanning 1964-1990, was further analysed for determining maximum erosive rainstorm events. These events were crossed with plot and watersheds runoff events for selecting the most significant ones for calibrating and testing LISEM and EUROSEM.

Further digitised data of each rainfall were given to BOKU partner for RAINGEN model improvement.
A neural networks analysis for predicting the periods of maximum occurrence of extreme events was performed on rainfall energy by using moving mean values. In Fig. 9 the reliability test on 20-years. Rainfall energy trend at Vicarello Exp. Station. Period (yellow area) shows that the observed values of energy are quite in accord with the observed ones. Thus this kind of investigations should be intensified by scientists to confirm the effectiveness of the analysis in other locations of Europe. In case of success, this methodology could be used for predicting the periods of maximum occurrence of extreme events.
In the third year the RAINGEN routine for synthetic rainfall was implemented by BOKU partner with the provided data, to produce a model which also reflects Mediterranean climatic conditions.

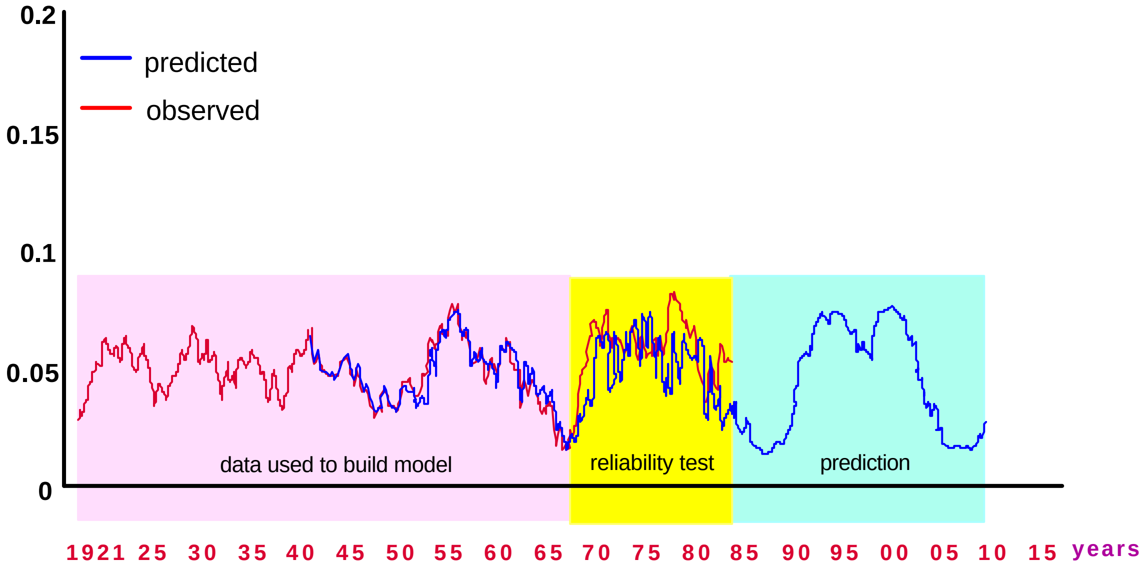


Fig. 9 : reliability test on 20-years. Rainfall energy trend at Vicarello Exp. Station

4.2 Sub task 1 (ST2) Erosion data collection
Level of participation for ST: C

In the first year 10 plots (75 x 15 m) and two watershed of 5 hectares each, for runoff and soil erosion measurements were set up at Vicarello. Collection of data was started in this year in conjunction with calibration tests of the measuring devices.

In the second year Data of reservoir water level recorder, placed at Vicarello, were elaborated for determining the total runoff from a 60 ha watershed. Furthermore, runoff and suspended sediment data of two 5-ha mono crop watersheds (belonging to the same aforementioned 60-ha watershed) were elaborated to test MWISED for its suitability to determine watershed dynamics. Mono crop watershed data were collected with the use of ISCO hydrological electronic units, that record water-level in the flume and collect integrated samples of runoff water.
In the second and third year runoff data form plots and watershed continued to be monitored. In total, during the three year, 155 plot runoff events were measured.

5 Work package WP4 Simulation of within-storm erosion dynamics.

4.1 Sub task 1 (ST2b) Ephemeral gullies evolution on Small catchment
Level of participation for ST: C

No gully-generative runoff events occurred in the first year in the two monitored sub watershed.
Anyway ISSDS collaborated with CNR-IGES for the analysis of a heavy rainfall event occurred in May 1994 with 77.8 mm of rainfall and an estimated frequency of 6.5 years .
On two plots kept in permanent fallow the rainstorm caused the formation of evident rills and a very high soil loss. The mean cross sectional area and the total length of the rill network were utilized to estimate soil loss; using the mean bulk density value of the 0-10 cm layer (1.4 g cm^{-3}), a soil loss of 126.2 t ha^{-1} was calculated, a value which is over 10 times greater than the mean annual erosion rate of this environment. From data analysis it was found that SCS-Curve numbers must vary not only with antecedent moisture content before rainfall event but also with soil surface condition.
The goal of this task was fully achieved in the third year, when the last version of EUROSEM and LISEM model, developed with the data supplied, were provided.
Runoff data from a 60-ha watershed (at Vicarello) were compared with the predictions made with the use of LISEM model. The same model was applied to predict runoff volumes generated from two sub-catchments of about 5 ha each of the same 60-ha watershed and to some plots (dimensions:75x15 meters) down the dam in the Istituto Sperimentale per lo Studio e la Difesa del Suolo's experimental centre.
At watershed scale both the models were applied only for runoff generation, due to the unsuitability of the measures of sediment loaded by runoff. In fact, it was impossible to sample the fraction of sediment (clods) that creeps on the flume bottom placed at the basin outlet.

Table 1 **LISEM application to the 60-ha watershed**

		Observed				**Lisem predictions**			
Event date	**Total rainfall mm**	**Duration min**	**total discharge m^3**	**peak time min**	**peak discharge (l/s)**	**Duration min**	**total discharge m^3**	**peak time min**	**peak discharge (l/s)**
05/18/94	48.9	3215	37270	452	98	41032	2409	40805	499
08/03/95	28.3	320	1335	48	320	64450	1253	64248	140
02/19/96	38.7	6376	168573	6000	187	64927	2576	64926	680
02/04/96	7.71	4203	61498	3953	165	26407	319	26361	91
04/29/96	17.3	720	681	720	67	4260	601	4223	109

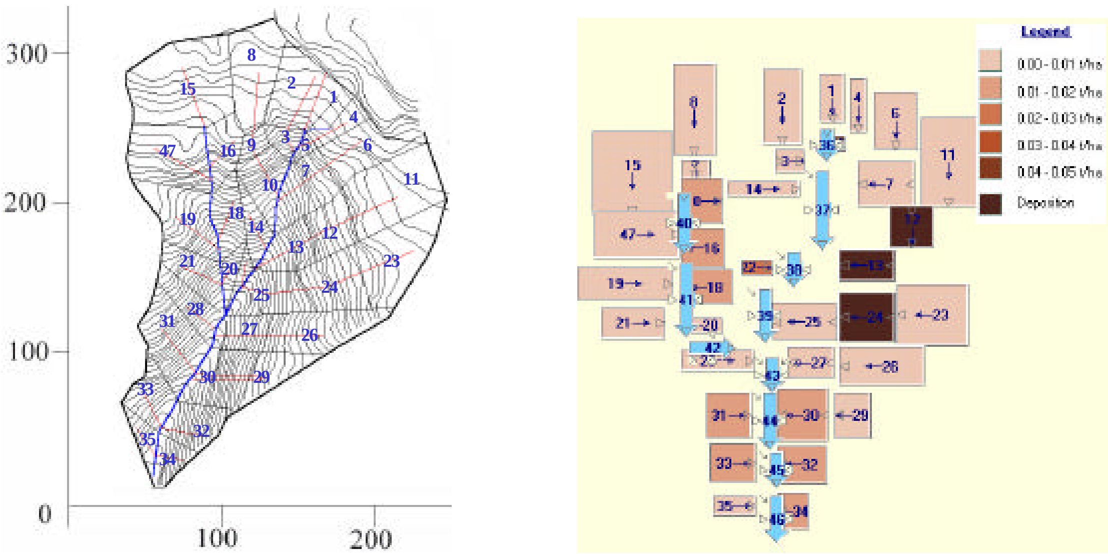


Fig. 10 : Alfalfa subwatershed and EUROSEM fragmentation

EUROSEM model was applied to compare predicted vs. observed runoff values from the two sub-basins and to the same plots were LISEM was used. EUROSEM was not applied to the entire 60-ha watershed due to the excessive complication of the requested watershed's fragmentation, which might have been outside the field of applicability of the model.

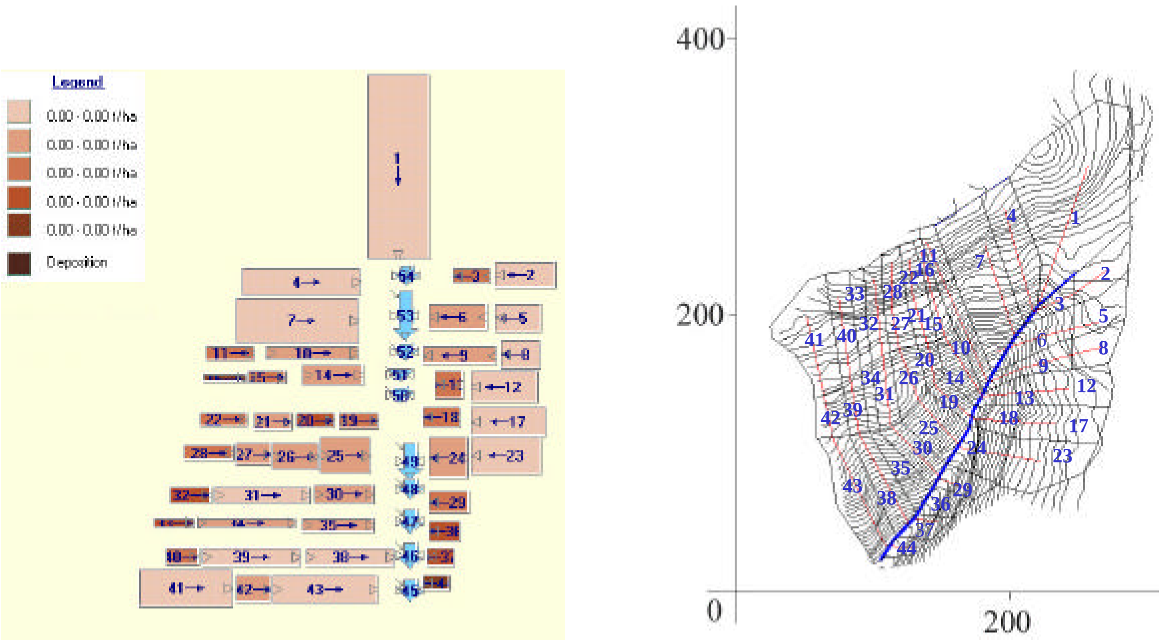


Fig. 11: Winter wheat subwatershed and EUROSEM fragmentation

From table 1 it is possible to see that LISEM simulation applied to the 60-ha watershed did not predicted well runoff parameters; with the exception of total discharge and peak discharge for the runoff event occurred on April 29 1996 which seems to converge with the observed data.

Application of EUROSEM model to the two subwatersheds was also disappointing. In fact the only parameter that was sufficiently well estimated was the time to peak flow rate for the events occurred in the winter-wheat subwatershed on 04/29/96 and on 05/18/94. For the alfalfa subwatershed, the best convergence of time to peak flow rate was observed for the runoff events occurred on 05/18/94 and on 02/19/96.

Table 2 **5-ha subwatersheds Runoff parameters for different events**
Observed and EUROSEM predicted values

		channel outflow m^3		duration runoff min		time to peak flow rate min		peak flow rate mm/h	
Event	Soil use	observed	predicted	observed	predicted	observed	predicted	observed	predicted
04/29/96	wheat	0.05	31.21	38	2608	74	84	24	2.78
05/18/94	wheat	85.48	906.99	108	3872	74	54	7.33	45.92
04/02/96	wheat	0.19	408.67	38	2420	25	700	0.01	7.54
03/08/95	wheat	0	346.6	0	1440	0	186	0	7.14
02/19/96	wheat	2.06	1997.9	61	1904	140	698	0.22	14.99
04/29/96	wheat	0	31.21	0	2608	0	84	0	2.78
04/02/96	alfalfa	0.19	217.73	38	2376	25	902	0.01	4.81
05/18/94	alfalfa	55.91	137.35	108	9654	75	56	5.52	59.05
02/19/96	alfalfa	5.48	641.65	60	1832	180	260	7.33	54.34
04/29/96	alfalfa	0	17.87	0	598	0	176	0	2.61
03/08/95	alfalfa	0	572.68	0	1440	0	148	0	22.57

Also the predicted values of runoff parameters predicted with LISEM for the two subcatchments were very disappointing. In fact, the observed and predicted discharge hydrographs, always looked like in the figures shown herein.

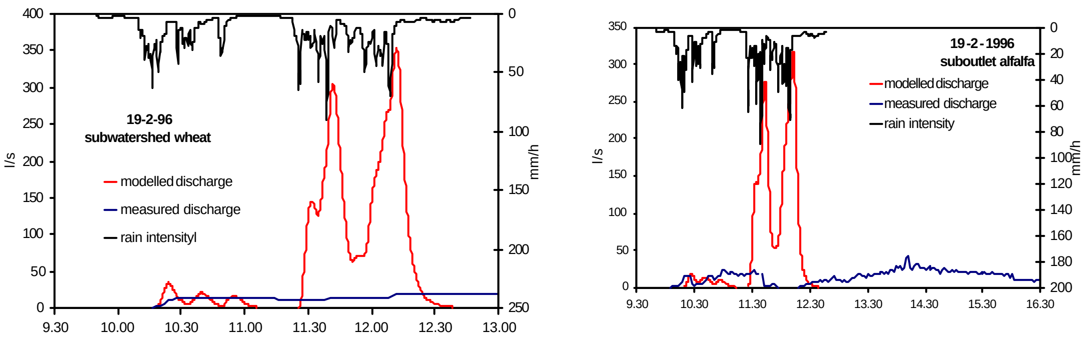


Fig. 12: Example of LISEM simulation on 5-ha subwatersheds.

Table3 Runoff and soil erosion for plots (observed and model-predicted values)

Date and Soil use		Measured					**Predicted EUROSEM**				**Predicted LISEM**			
Date	Soil use	Rainfall depth (mm)	Total discharge (m^3/plot)	Time to peak (min)	Peak flow rate (l/sec)	Net erosion (kg/plot)	Total discharge (m^3/plot)	Time to peak (min)	Peak flow rate (l/sec)	Net erosion (kg/plot)	Total discharge (m^3/plot)	Time to peak (min)	Peak flow rate (l/sec)	Net erosion (kg/plot)
05/18/ 94	wheat	48.9	3.37	31	4.8	278.3	4.96	75	4.76	1417	16.8	53	5.2	278.7
03/08 95	wheat	28.4	17.76	104	1.8	44.9	0.35	172	0.41	10.1	7.95	14	3.1	1561.2
03/08 95	alfalfa	28.4	12.19	94	2.1	20.9	0.18	171	0.15	3.1	9.84	14	4.2	2438.3
02/19/96	wheat	40	27.41	31	2.3	457.6	0.78	140	1.44	15.1	0.79	140	2.4	104.4
02/19/96	fallow	40	54.42	202	5.9	4027.7	10.27	140	10.73	62.6	3.63	140	4.8	590.6
02/19/96	alfalfa	40	26.45	68	6.8	43.8	0.14	140	0.58	3.1	6.39	140	7.8	1207
04/02/96	fallow	25.2	27.69	17	1.2	1592.3	0.43	37	1.88	20.1	0.03	13	0.2	2.4
04/29/96	fallow	15.4	27.75	94	5.1	146.1	0.31	103	1.4	28.1	2020	143	5.2	282.2

When applied to predict runoff and erosion to plot events, EUROSEM and LISEM showed the same uncertainty observed at watershed scale.

Convergence of observed and predicted values was achieved with EUROSEM for the peak flow rate parameter occurred on 18/05/94 an 04/02/96 and time to peak parameter for the event of 04/29/96. The same model did not predicted well soil erosion, with the exception of the event occurred on 08/03/95 (same order of magnitude). LISEM predicted well soil erosion only for the event of 05/18/94 and time to peak for the event of 04/02/96. More interesting results were achieved for the peak flow rate parameter; in fact, five of the eight event values were well predicted.

From these results it might be concluded that processes included in both the models need better mathematical descriptions or new processes need to be added to describe the Mediterranean soil-climate environment of the Vicarello area.

Department Of Physical Geography, Utrecht University (UU)
REPORTING PERIOD: 1 APRIL 1998 –30 JUNE 2001

Contractor:	**Department of Physical Geography, Utrecht University**
Responsible scientist:	**Dr. Victor Jetten**
Scientific staff:	D. Van de Vlag, C. Wesseling
Address:	Heidelberglaan 2
	3508 TC Utrecht, The Netherlands
Telephone:	+31 30 2535773
Fax:	+31 30 2531145
email:	v.jetten@geog.uu.nl

SUMMARY OF THE SCIENTIFIC ACTIVITY AND FINAL RESULTS

The Department of Physical Geography is responsible for construction of the spatial gully erosion model EUROWISE, as defined in tasks: WP2-ST4 and WP4-ST1.

WP2-ST4: Development and evolution of ephemeral gullies in GIS

Objective
Development of a methodology in a Geographical Information System environment to determine the terrain conditions where ephemeral gully erosion is most likely to occur during individual storms.

Background
The modelling of gully formation is based on two steps:
i. the analysis of the landscape to determination likely locations of a gully as a result of one or more rainfall events, called here "critical areas";
ii. the simulation of changes in dimensions of the gully as a result of runoff and erosion.
This task is closely linked to WP2-ST3, in which the algorithms were developed to find the critical areas in a landscape, based on field experiments in this project. A literature review revealed that several gully location algorithms exist, based on field observations in temperate regions (notably Belgium) and semi-arid (Southern Spain and Australia). The algorithms are all based on a combination of two factors: the runoff contributing area above a certain location, and the slope at that location. If the combination of these two passes a given threshold, incision will likely occur. A second threshold is needed to predict the "lower end" of a gully, because the critical area algorithms will predict an unlimited continuation of a gully. It appeared that the lower threshold is best represented by a minimum slope angle of the terrain.
Since the EUROWISE model uses raster maps created with the Geographical Information System PCRaster (Van Deursen and Wesseling, 1998). This GIS combines the regular spatial expression of any GIS with a modelling language that enables the analysis of flow of material over a landscape and is therefore very suitable for this work package. The language follows simple rules that can be combined in a "script", a kind of macro that is executed with a compiler (PCRCALC.EXE).

Five algorithms for critical threshold (Fc) determination were selected based on slope S (m/m), upstream area A (m^2) and grid cell width w (m):

1. Vandaele, 1996: $Fc = S \cdot \left(A/w\right)^{0.4} > 0.5$

2. Moore et al., 1988: $Fc = S \cdot \left(A/w\right) > 18$ and $\ln\left(\frac{A/w}{S}\right) > 6.8$

3. Vandaele et al., 1996: $Fc = S > 0.025 \cdot \left(A/10000\right)^{-0.4}$

4. Desmet and Govers, 1997: $Fc = S \cdot \left(A/w\right)^{0.4} > 0.72$

5. Vandaele et al., 1997: $Fc = S \cdot \left(A/w\right) > 40$ and $\ln\left(\frac{A/w}{S}\right) > 9.8$

The term *ln(A/S)* in these equations is the wetness index (see e.g. Kirkby, 1979) and is a measure for saturation overland flow. Moore et al. (1988) analysed shallow soils when defining their Fc, which are fairly easily saturated and which results in a spatial moisture distribution gives wetter valley floors than water divides. The term $S(A/w)^b$ is explained by O'Loughlin (1986) as being a measure for Hortonian overland flow.
Although these equations are derived from observations, it was seen during the project that a second threshold is needed to determine the end of a gully. The further one moves downslope in an area, the more the upstream area A dominates the threshold values. The result is that while in reality a gully sometimes end in the thalweg because of a change in topography, the equations will continue to delimit that area as a critical zone. A simple rule proved to be effective for the Belgium loess area: the lower threshold is determined by a slope of 4%, below which no gullying occurs. In Spain and Portugal the lower limit was determined by a relation of the type $S = cA^d$, where c is respectively 0.1 to 0.03 and d is -0.20 and -0.54 (see elsewhere in this report).

GIS implementation

In PCRaster a network can be generated from the digital elevation model (DEM) that defines the direction of flow over the landscape. The network is called LDD, the Local Drain Direction. The LDD can be made directly from the DEM by using the steepest angle of flow (see figure 1a). However in an agricultural environment the direction of flow is often the tillage direction (at least for a part of the year). Takken (2000) in her work on the influence of tillage on runoff, created a PCRaster script to generate automatically a valid LDD based on the tillage direction per field, while including features such as headlands, dead furrows and topography where necessary(see Fig. 1b).

To delimit critical zones of likely gully erosion the area draining towards a given point has to be generated. In PCRaster the command to do this is:

```
ups.map =  accuflux(ldd.map, cellarea());
```

This command accumulates the cellarea over the network and gives therefore in each cell of the output map the cumulative area of all cells draining towards that cell, e.g. the value of the outlet of the catchment has the total area of the whole catchment above the outlet. This is the PCRaster equivalent of the variable A in the algorithms above. This is shown in figure 2 a and b for the two situations. It can be seen that the effect is very different: the concentration zones follow the field pattern much more in the right hand image than in the left hand image. The main concentration lines are formed by the four small side valleys. The slope is calculated by taking the difference in elevation between a grid cell and the cell towards it drains, divided by the distance.

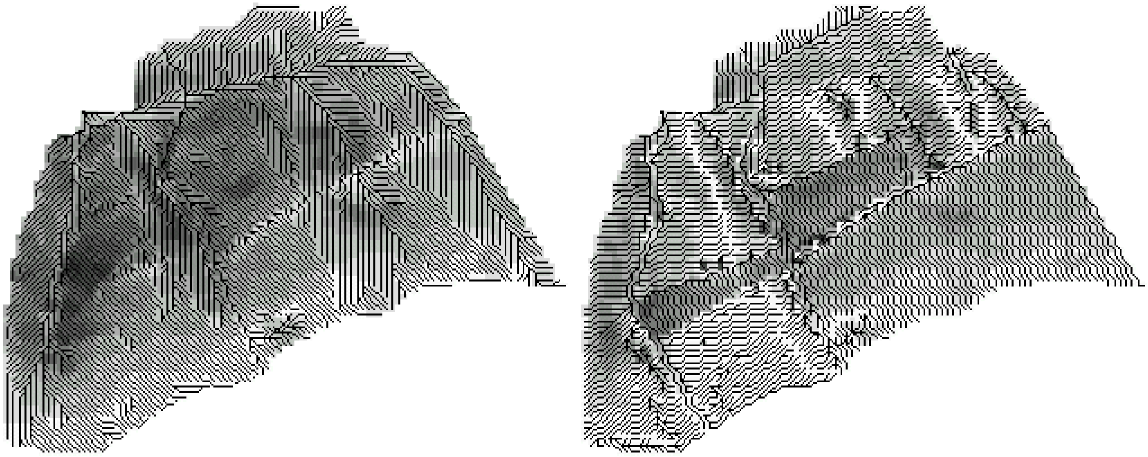


Figure 1. PCRaster LDD maps: a) drainage direction (lines) and slope (grayscales) according to the steepest slope, and b) according to tillage direction. Note that the field boundaries are preserved. The area is a 40ha catchment in Limburg (NL).

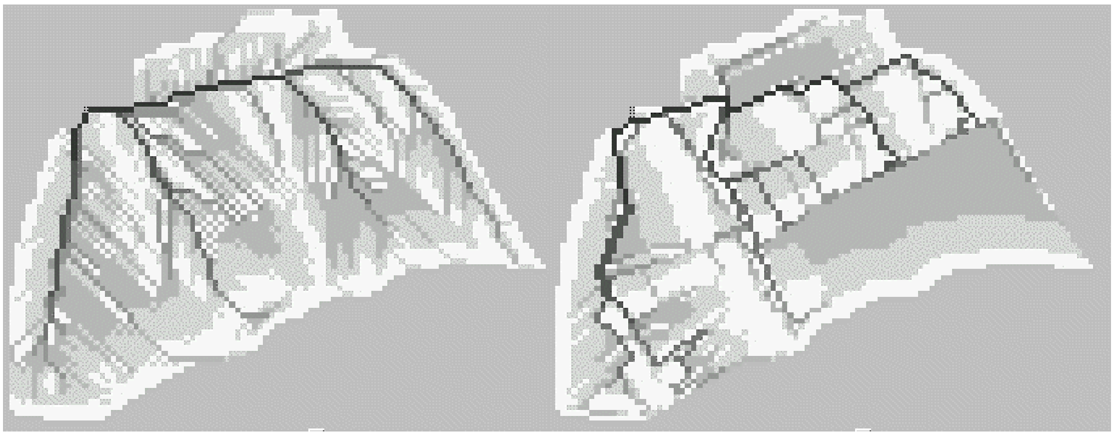


Figure 2. PCRaster contributing area from accuflux (identical to variable A in the critical zone algorithms, see text): a) patterns using the steepest slope, and b) patterns using the according the tillage direction.

However, the implementation of the above algorithms in PCRaster needs a certain interpretation of the thresholds. Firstly, when the algorithms are implemented directly the critical area is calculated on a cell to cell basis. That means that if a cell has a local slope angle that does not meet the criteria, that cell may not be seen as a critical cell. This causes fractioning of the critical zone. It must therefore be assumed that once a gully starts forming it will not stop at a single location and continue downslope of that location simply because the local slope is not sufficient. Therefore a more continuous zone has to created. The implementation in PCRaster is done as follows:

1) a critical zone is made according to the gully initiation algorithms;
2) the map edge is excluded from the zone because the flow path created in PCRaster will consider the map edge as a boundary (so often a gully will form there);
3) this zone is accumulated along the network to give a continuous area;
4) a critical threshold slope angle to end the gully is applied when necessary (depending on the research area);
5) isolated "critical" pixels are removed;
6) isolated "non-critical" pixels are classified as "critical" if the pixels upstream and downstream are also "critical" (repair holes in the critical zone).

.

Results

Critical areas for the Kinderveld test site (BE)

Figure 3 shows 6 images of the Kinderveld test area near Leuven (BE) where gullies where formed during the project time period. The test site has a size of 13.7 ha and a grid cell size of 5x5 m. The measured gullies are shown as a black line while the white areas are the 5 critical areas susceptible to gully erosion. It can be seen that all critical areas include the gullies except for algorithm 5 which begins too far downslope. Also the figure shows that the algorithms 1 and 3 produce too large areas while 2 and 4 are closer to reality. Since the main overland flow process is Hortonian overland flow, criteria 4 seems the to give the best result.

Critical area for the Vicarello test site (Tuscany)

Figure 4 shows 6 images of the Vicarello test area in Tuscany (IT). The size of the area is 60.7 ha and a the grid cell size is 5x5 m. The first image is the DEM with three gully area depressions indicated with arrows. The next 5 images show the critical areas according to the equations above. The results are similar to the Belgium area with critical values 2 and 4 giving the best relation with observed gullying in the area. Unfortunately there were no maps of observed gullies available at the time of this analysis, but the results are confirmed by field observations.

Products

Although the PCRaster script and databases exist to quickly analyse a digital elevation model, the algorithms have been incorporated in the EUROWISE model and appear in the user interface. Thus the user can choose the appropriate threshold method for which EUROWISE will then simulate gullies.

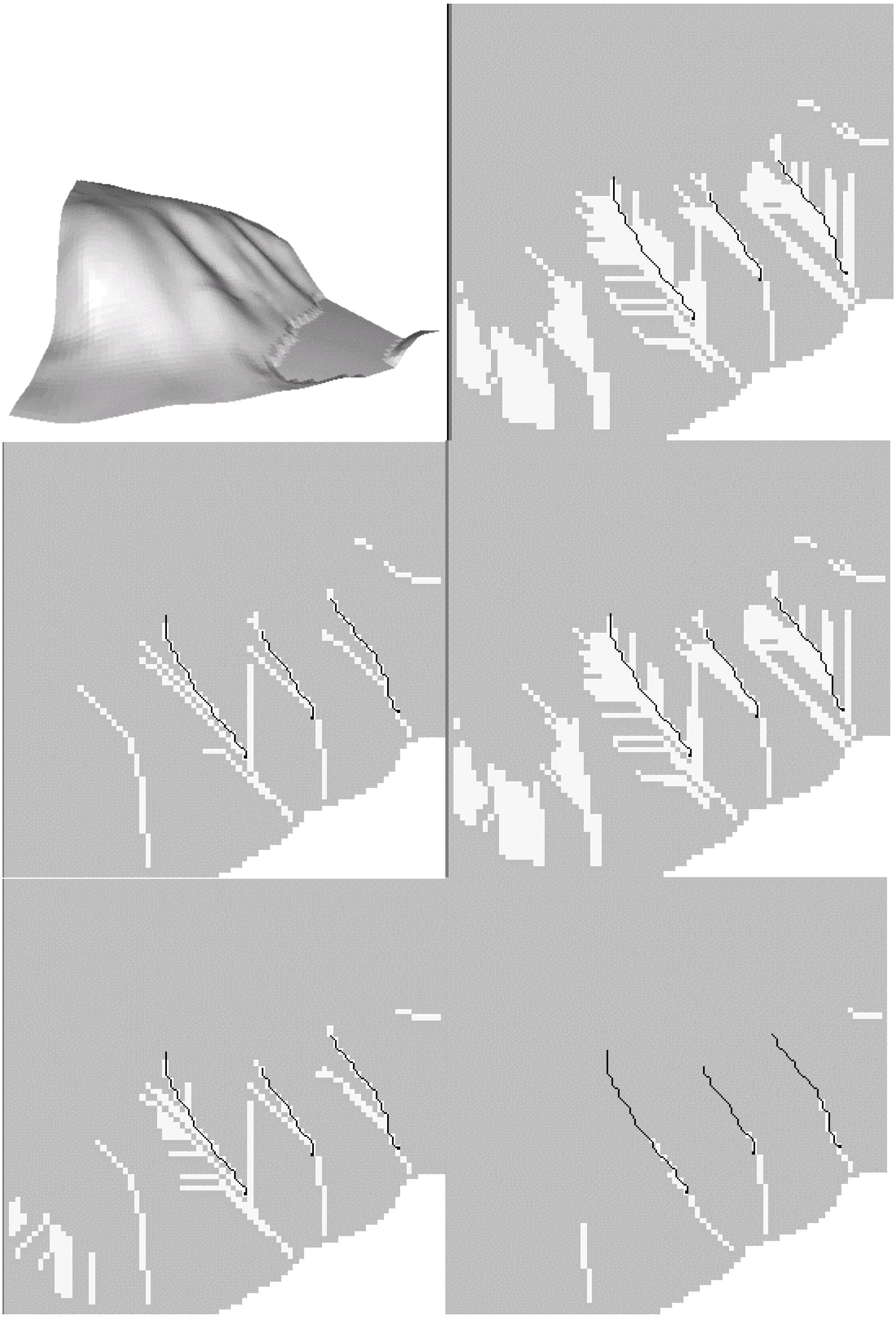


Figure 3. The belgium test area. Top: dem and critical threshold 1, middle: critical thresholds 2 and 3, bottom: critical thresholds 4 and 5.

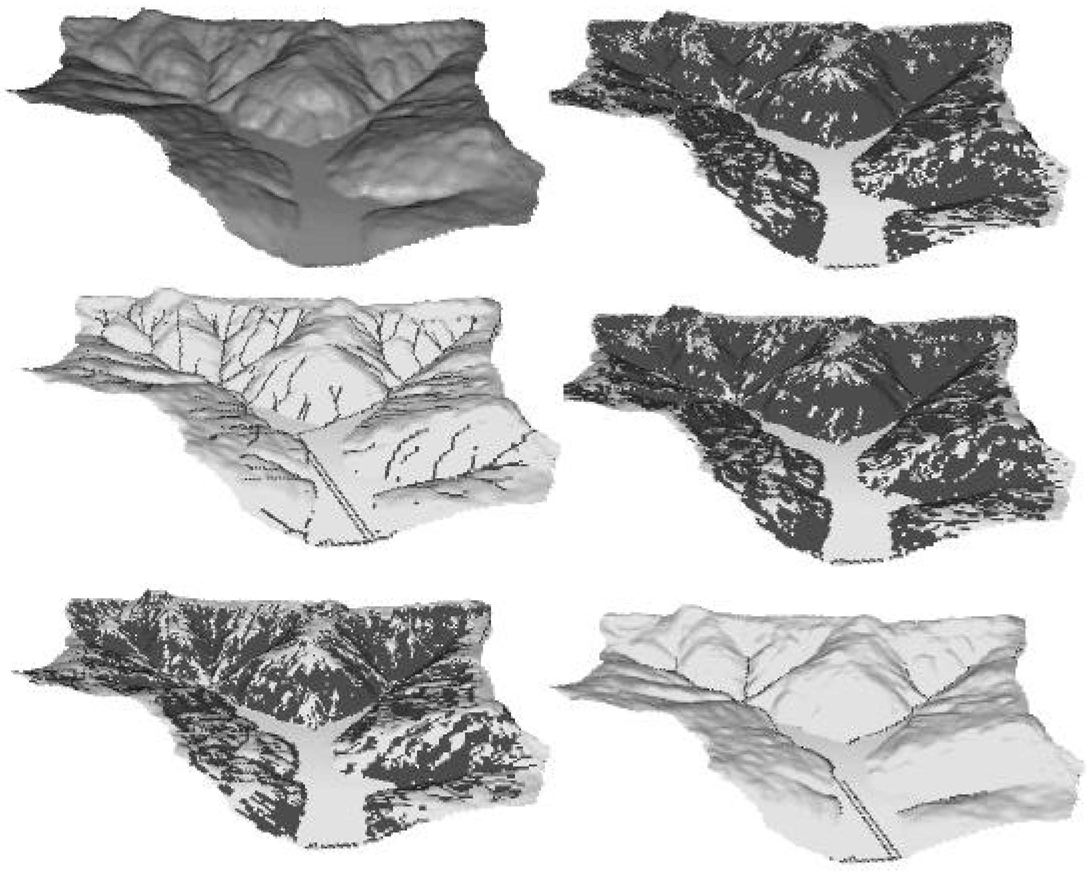


Figure 4. The Vicarello test area (IT). Top: dem and critical threshold 1, middle: critical thresholds 2 and 3, bottom: critical thresholds 4 and 5. Note that the flat area in the centre is actually a lake and should be disregarded.

WP4-ST2: Simulation of within storm erosion dynamics - model construction

Objective

Construction of EUROWISE, an event based erosion model that is capable of simulating gully incision and formation.

Background

The modelling of gully formation is based on two steps:

i. the analysis of the landscape to determination likely locations of a gully as a result of one or more rainfall events, called here "critical areas" (see WP2-ST4);
ii. the simulation of changes in dimensions of the gully as a result of runoff and erosion.

The first part is explained above (task WP2-ST4): the GIS algorithms are integrated into the EUROWISE model and the critical area analysis is done automatically. For the second part, the dynamic simulation of gully dimensions, there are two approaches possible. A physical approach that considers all shear forces applied on the bottom and side-walls of the gully and causes erosion and wall collapse. Although the theoretical framework for such a model was formulated within MWISED by the IGES (IT), the data needed to implement and test it was not available. A second method was therefore chosen that follows a combined physical and empirical approach. The amount of erosion and deposition is calculated on a physically deterministic basis, while the widening and deepening of gullies is based on an empirical width-discharge relationship.

The EUROWISE Model

EUROWISE simulates the incision and formation of ephemeral gullies for various combinations of soil and climate. The model has a physical deterministic basis, but is partly empirical to promote simplicity and avoid the necessity of too large input datasets. In fact the gullies are modelled without the need for additional data above the regular erosion modelling, apart from the definition of a second sub-soil layer with a different cohesion. The gullies are modelled as follows.

Critical areas

The digital elevation model of the landscape is analysed according to empirical functions based on contributing area and slope to delimit "critical" areas that are susceptible to gully incision. The five critical area algorithms as explained in task WP2-ST4 are available in EUROWISE, so that the user can choose between algorithms that are more appropriate for temperate or for Mediterranean circumstances.

Flow detachment and deposition

Runoff is simulated according to a detailed water balance (not explained here, see De Roo et al., 1996; Jetten and De Roo, in press), detachment and deposition are modelled according to the transport capacity T_c (kg.m^{-3}) based on the streampower principle of Govers (1992; see also Morgan et al., 1998). The ability of flowing water to erode its bed is assumed independent of the amount of material it carries and is only a function of the energy expended by the flow. Deposition takes place at a rate equal to wCV_s, where w is the width of flow in m, C is the sediment concentration in the flow in kg.m^{-3}, and V_s is the settling velocity of the particles in m.s^{-1}. The concentration at transport capacity (C_T) represents the sediment concentration at which the detachment rate Df and deposition rate Dp are in balance. In this condition the net rate of erosion is zero and Df equals the deposition rate (wC_TV_s). The equation for soil detachment by flow and deposition during flow, expressed in terms of settling velocity and transport capacity, then becomes:

$$D = Y \cdot (T_c - C) \cdot V_s \cdot w \cdot dx$$

in which D is Df or Dp in kg.s^{-1}, T_c is the transport capacity of the flow in kg.m^{-3}, dx is the gridcell length (m), and Y is a dimensionless efficiency factor. The latter is included to account for the fact that the detachment will be limited by the cohesion of the soil material. The pick-up rate for cohesive soil therefore needs to be reduced by a coefficient whenever C is less than T_c. By definition, Y is 1 when deposition takes place, i.e. when C is larger than T_c, and when erosion takes place it is calculated as (Rauws and Govers, 1988):

$$Y = \frac{u_{min}}{u_c} = \frac{1}{0.89 + 0.56 \cdot Coh}$$

in which u_c and u_{min} are the critical shear velocity and the minimum critical shear velocity in cm.s^{-1}, and Coh is the cohesion of the wet soil determined with a Torvane (kPa). Note that dx is added because the unit length of a spatial element in a raster environment becomes the grid cell size. The simulated water and sediment fluxes at the surface are simulated and distributed over the landscape following a kinematic wave procedure.

Gully width

The gully formation, i.e. the deepening of the critical area, is not necessarily over the whole grid cell width: the gully width depends on the peak discharge of the runoff in a non-linear way: $w = a*Q^b$. The parameters a and b are predefined for Belgium from laboratory and field observations.

For areas which exceeds the critical threshold value, gully width is calculated according to the relation: $W = a \cdot Q_{peak}^b$, with a and b as empirical constants, W is the gully width in meters and Q_{peak} is the peak discharge of the runoff in m^3/s. For the Belgium loess belt these relationships are found by KULEUVEN for different kind of gullies in field and in laboratories: the best relation is (see elsewhere in this report):

$$w = 2.51 \cdot Q^{0.412}$$

Note that the user can define the parameters *a* and *b* in the interface.

The gully width has to be initialized in order for the erosion to start. A sensitivity analysis shows that this value is not very sensitive and an arbitrary value of 0.1 m is chosen. The width of the gullies increases with increasing runoff discharge till the point of the maximum peak discharge (Fig. 5). At that point gully width is assumed to be constant.

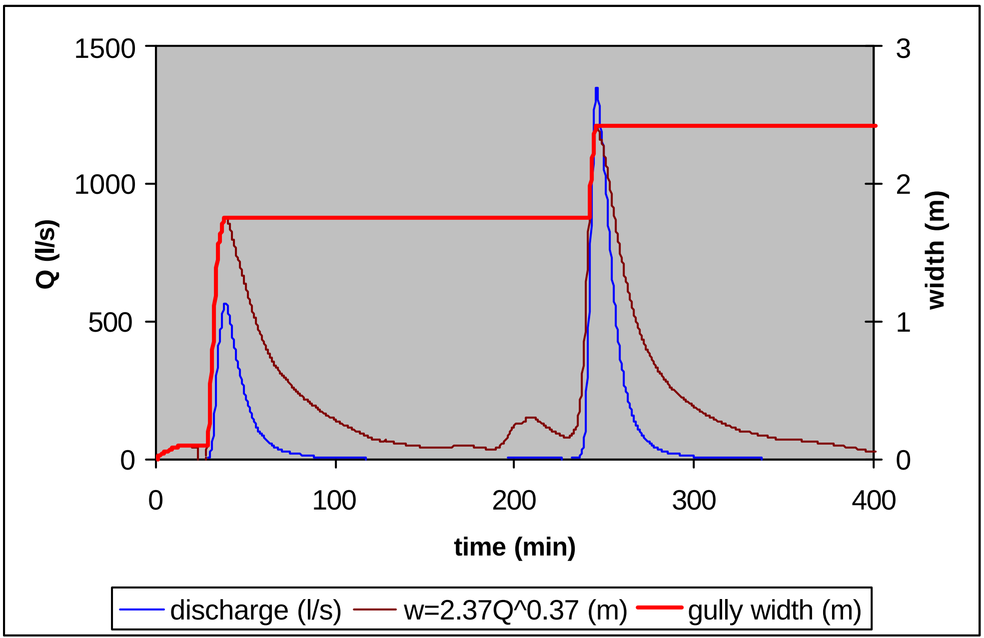


Figure 5. Simulated gully width versus the timestep when the peak discharge is passing a pixel which exceeds the critical threshold.

Gully formation

For each gridcell and timestep the processes above result in the water discharge *Q* ($kg.m^{-3}$), the corresponding gully width *w* (m) and the sediment discharge *Qs* (kg). The eroded mass of the soil is recalculated to a depth depending on the situation:

1. Homogeneous soil: only the depth *d* of the gully increases over the gully width *w* using the amount of flow detachment *Df* and the bulk density *D* of the soil: $d = Df/(w*dx*D)$.

   Note that these parameters are represented by maps that can be spatially variable, only the depth is assumed homogeneous.

2. Two layers: in case the soil has a compacted layer with a higher cohesion (e.g. a plough layer), both the gully width and depth have to be adjusted. In this case the gully often becomes shallow and wide because the sideways erosion is easier than the downward erosion. This effect is not accounted for in the Q-w relationship. Thus the following system is devised: if the depth of the gully reaches the second layer AND the water level in the gully still "touches" the first layer the flow detachment is divided over the walls and bottom of the gully as follows:

$$\mathrm{Df}_x = {}^{2h}\!/_{P_w} \cdot Y_1 \cdot (\mathrm{T_c} - \mathrm{C}) \cdot \mathrm{V_s} \cdot \mathrm{w} \cdot \mathrm{dx}$$

$$\mathrm{Df}_y = {}^{w}\!/_{P_w} \cdot Y_2 \cdot (\mathrm{T_c} - \mathrm{C}) \cdot \mathrm{V_s} \cdot \mathrm{w} \cdot \mathrm{dx}$$

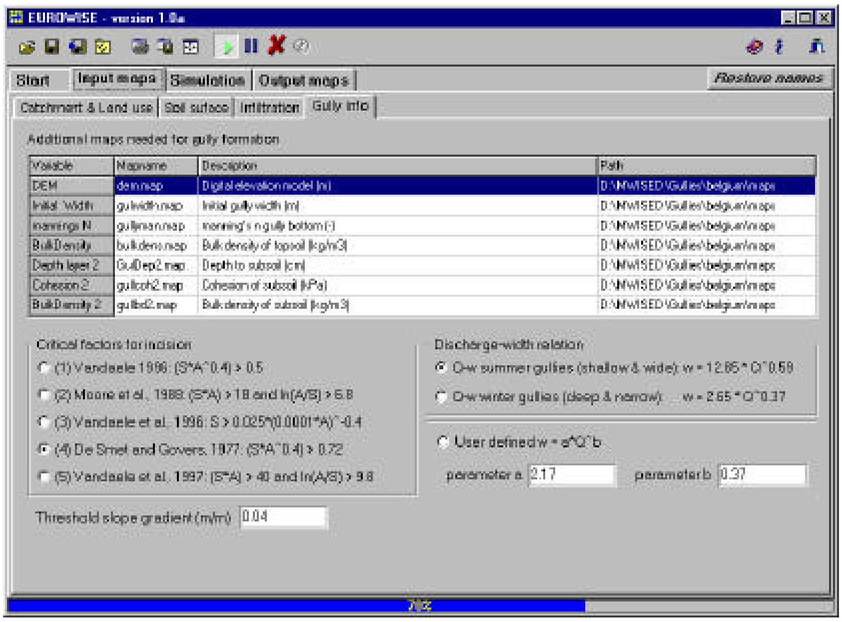
where: h is the water depth (m), P_w is the wet perimeter (m), and Y_1 and Y_2 are the efficiencies based on the cohesions of the 1st and 2nd layer. The gully width w and depth d are increased according to:

$$\mathrm{w} = w + \mathrm{Df}_x / \mathrm{w} \cdot \mathrm{dx} \cdot \tilde{\mathrm{n}}_1$$

$$\mathrm{d} = \mathrm{d} + \mathrm{Df}_y / \mathrm{w} \cdot \mathrm{dx} \cdot \tilde{\mathrm{n}}_2$$

The gully width cannot become larger than the grid cell width. During the calculations the digital elevation model changes. For each time step a new DEM is calculated in the dynamic loop of PC Raster. This new DEM is derived from old DEM with subtraction of the erosion or addition of the sedimentation. Changes in the DEM causes changes in local drain direction (LDD), which allows fluctuations in the stream pattern of the gullies.

Figure 6. Gully parameter input screen of EUROWISE



EUROWISE interface

EUROWISE is created as a stand-alone Windows based program that uses a set of input maps with a PCRaster format. The PCRaster software is still commercial but the basic core programs will soon be free of charge. The interface consists of four screens: a basic input screen with the main choices of directories, program options etc., an series of input screens for the maps that are needed and the gully options (see figure 6) , a screen with output options and a screen with the main erosion and water balance results.

Results

EUROWISE was tested on three gullies that were formed in the Kinderveld area in Belgium, as a result of 5 consecutive rainstorms over a summer season. The gullies were typical "summer" gullies which means that they are wide and shallow, because the soil below the seedbed is fairly compacted compared to the seedbed itself. In that situation the overland flow will more often erode the side walls of a gully than the bottom, simply because the cohesion is less. Thus the recorded depth varied from 5 to 10 cm and the width roughly from 0.5 to 10 meters. Unfortunately, only the location of the gullies and their dimensions where available, as well as a DEM of the area and the rainfall data. All other data needed by EUROWISE was not available (infiltration data, flow resistance, cohesion etc.), but nevertheless a simulation could be done by taking data from other research in the area (see e.g. Takken et al., 2000). Two soil layers were defined with identical hydrological characteristics but a different cohesion of 5-6 kPa for the first layer and 7-8 kPa for the second layer. Different depths of the second layer of 6, 8 and 10 cm were tried.

The goal of this simulation is to see whether EUROWISE can be calibrated to give adequate results in volume, as well as depth and width of the 3 gullies. This is tested in two ways:

1. Compare the volumes, widths and depths of the simulated gullies at the location of the measured gullies directly
2. Compare the simulated gully volumes to the more general relationship between length and volume of summer gullies: $V = 0.048\ L^{1.29}$ (see elsewhere in this report). The measured gullies follow reasonably well this line (see figure 7).

Figure 7 shows the simulation with one deep layer of homogeneous cohesion and bulkdensity. The gully volume is derived from the width and depth. Gully 1 is too narrow with a correct depth and as a result the volume is too small. Apparently the amount of water was Gully 2 has a correct volume but it is too deep and narrow, and gully 3 has a correct width but is too deep so the volume is too large. It is clear that sideways erosion is not accounted for by the Q-w relationship alone and a second layer is needed.

Figure 8 shows the simulation with two layers: the first layer has a cohesion of 6 kPa and a bulk density of 1.3 g/cm^3, the second layer starts at 6 cm and has a cohesion of 8 kPa and a bulkdensity of 1.4 g/cm^3. These calibration values were chosen to obtain the best results but they are realistic for the area. The volumes are quite well simulated, especially gully one is correct in terms of volume, width and depth. Gully 2 is less well simulated as the measured maximum width is 10 m while the maximum simulated width cannot be larger than the cell size of 5 m. It is also a few cm too deep. Gully 3 has a correct depth and a width that is somewhat too large at the beginning of the gully. Compared to the volume-length relationship the simulated volumes are all too large.

The results also show that each gully has different characteristics and that a spatially homogeneous dataset cannot be used to simulate all aspects correctly. Presumably, if more data on the spatial variability are available, EUROWISE is capable of adequately simulating gullies. It should be noted that EUROWISE is very sensitive to the starting depth of the second layer, as this triggers the widening of the gully above the Q-w relationship (not shown here). Cohesion is moderately sensitive while bulk density changes do not have a great effect.

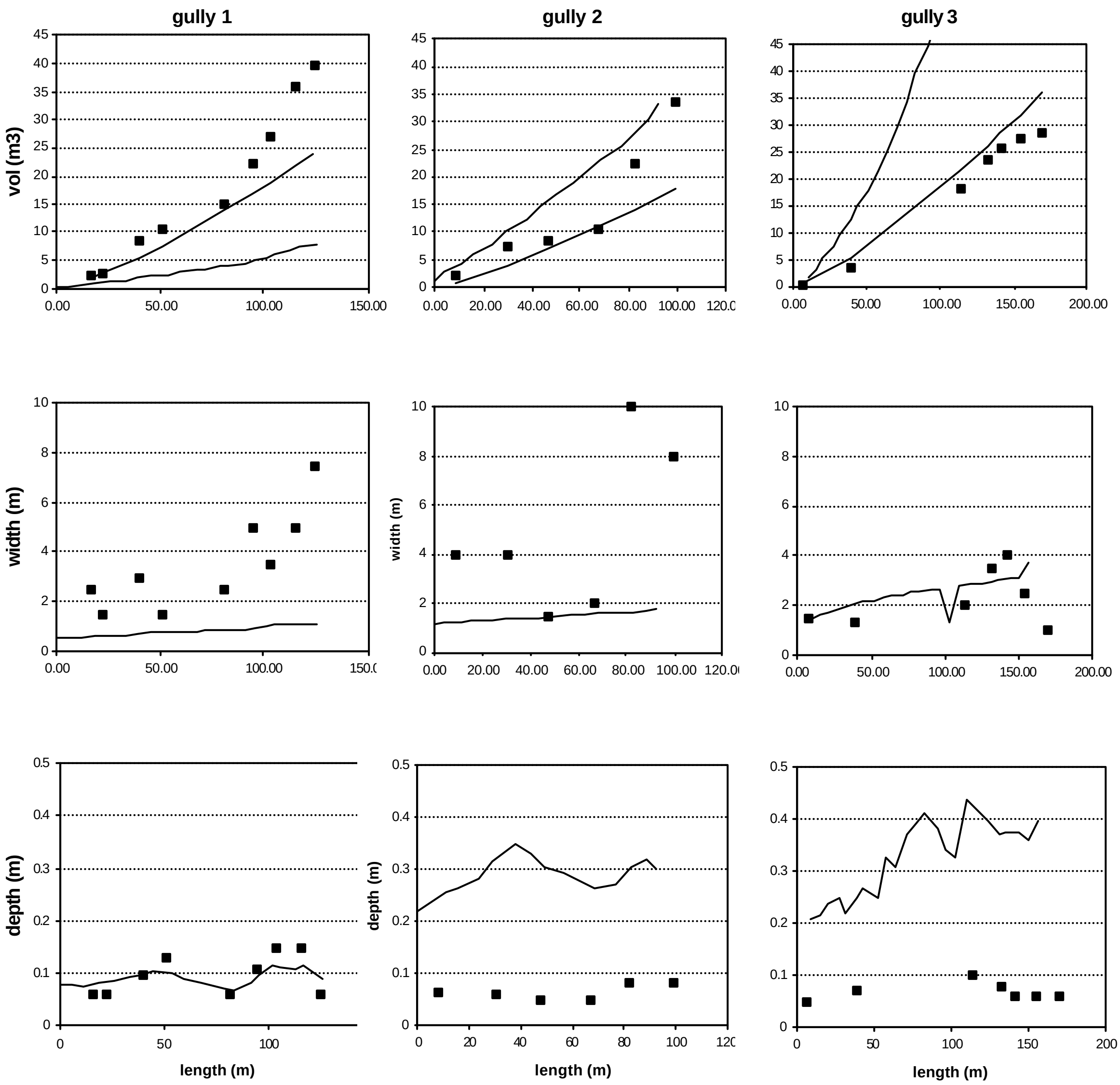


Figure 7. Simulation (lines) versus measured (dots) dimensions of three gullies in the Kinderveld area (BE) using a deep homogeneous soil (cohesion = 6 kPa, bulkdensity = 1.3 g/cm^3). The thin line in the top graphs shows the length volume relationship $V=0.048\ L^{1.29}$. The graphs are the end stage of summer gully development over 5 rainstorms.

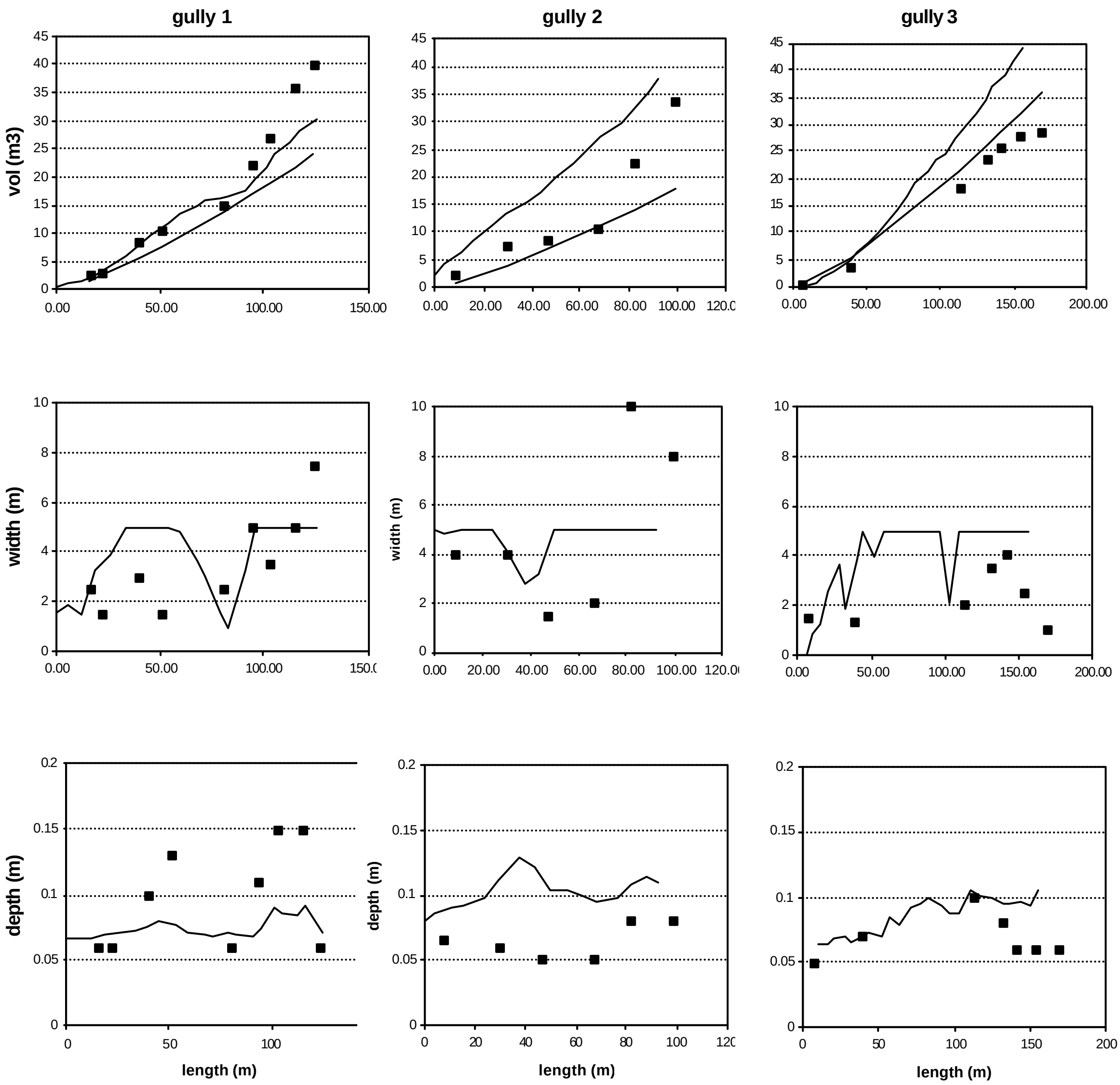


Figure 8. Simulation (lines) versus measured (dots) dimensions of three gullies in the Kinderveld area (BE) using a two layer soil soil (cohesion 6 and 8 kPa, bulkdensities 1.3 and 1.4 g/cm^3). The thin line in the top graphs shows the length volume relationship V=0.048 L $^{1.29}$. The graphs are the end stage of summer gully development over 5 rainstorms.

Spatially, EUROWISE predict incision wherever the critical area is defined. This is a larger area than that with the observed gullies (see figure 3). However, not all erosion inside the critical areas is gully erosion. Some of the incisions will be smaller than a gully and should be classified as rills. A rather arbitrary distinction between rills and gullies is the cross section. Here a cross-section of 1 ft^2 (0.0929 m^2) is used (see Poessen, 1993). Thus if the cross section of the simulated incision than this value, the grid cell is classified as a gully. Figure 9 shows the development of the gully area at three simulation times. Especially during the fourth rainstorm the discharge increases and the (too) large gully area is formed. It appeared that after 280 min the end formation was established and the last rainstorm did not further extend the gully area, which is logical considering the implementation of the Q-w relationship (figure 5).

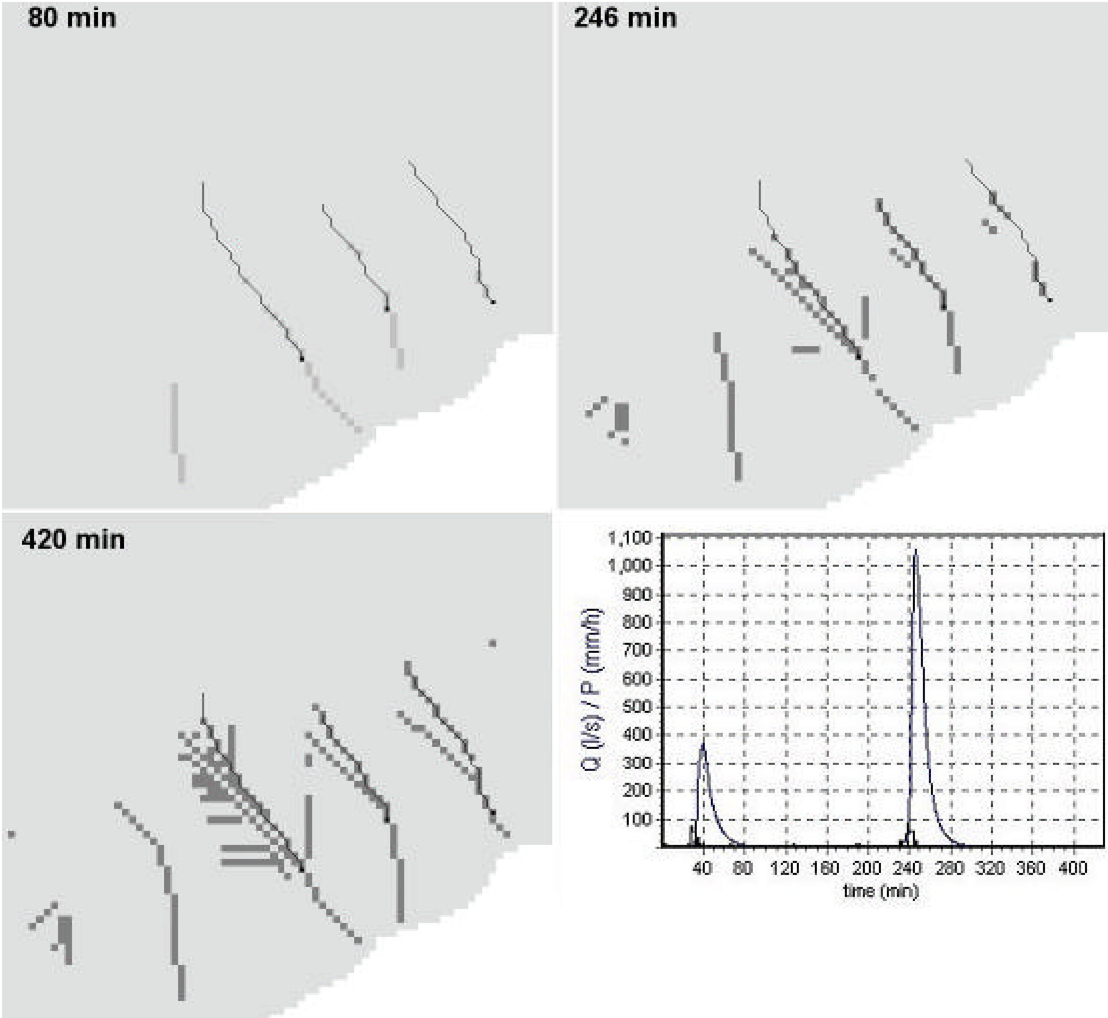


Figure 9. Spatial development of the gully area during five summer rainstorms. Note that the time does not represent the real time as the events were simulated without dry intervals. Gullies are defined as incisions with a cross section larger than 0.0929 m^2 (1 ft^2).

EUROWISE predict incision wherever the critical area is defined. This is a larger area than that with the observed gullies (see above). However, not all erosion inside the critical areas is gully erosion. Some of the incisions will be smaller than a gully and should be classified as rills. A rather arbitrary distinction between rills and gullies is the cross section. Here a cross-section of 1 ft^2 (0.0929 m^2) is used (see Poessen, 1993). Thus if the cross section in the resulting maps is larger than this value EUROWISE incision is classified as a gully in that grid cell. Figure 10 shows the simulated relative cross section values along the measured gullies: average values are in the order of 3 to 4 which would indicate that a cross section limit of 0.0929 m^2 is maybe too small.

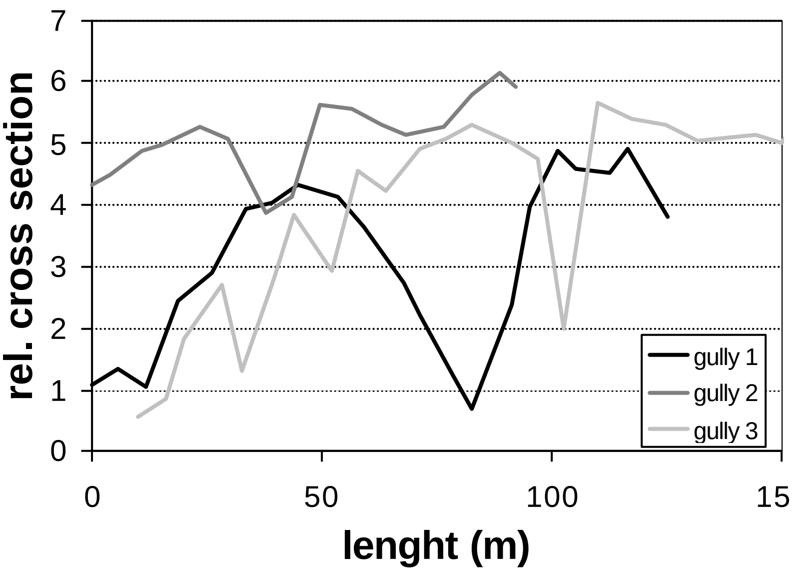


Figure 9. Simulated relative cross section (compared to 0.929 m^2, see text) along the measured gullies.

Conclusions

EUROWISE was tested on a typical set of summer gullies, that are very wide and shallow. A two layer soil was needed to simulate this which corresponds well with the real situation. It appears that EUROWISE performs reasonably well considering these "difficult" circumstance, and a set of calibration parameters could be found to predict all three gullies.

Literature

De Roo, A.P.J., Wesseling, C.G. and Ritsema, C.J., 1996a, LISEM: a single event physically-based hydrologic and soil erosion model for drainage basins. I: Theory, input and output'. *Hydrological Processes* **10**: 1107-1117.

Jetten, V. & A.P.J. de Roo, in press, Spatial analysis of erosion conservation measures with LISEM. Ch 14 in: "Landscape erosion and evolution modelling" Ed. R. Harmon. Kluwer academic press. (2002) pp.___

Govers, G., 1990, Empirical relationships on the transporting capacity of overland flow. *IAHS Publication* **189**: 45-63.

Morgan, R.P.C., Quinton, J.N., Smith, R.E., Govers, G., Poesen, J.W.A., Auerswald, K., Chisci, G., Torri, D., Styczen, M.E., and Folly, A.J.V., 1998, *The European Soil Erosion Model (EUROSEM): documentation and user guide*. Silsoe College, Cranfield University.

Takken, I., Jetten, V.G. , Govers, G., Nachtergaele, J. and Steegen, A., 2001, The effect of tillage-induced roughness on runoff and erosion patterns. *Geomorphology,* **37**, in press.

III Technical Implementation plan (TIP)

TECHNOLOGY IMPLEMENTATION PLAN

PART 1 – Project Identification

A Framework for the further development and exploitation of the results of EC RTD Projects

DOCUMENT TITLE:
Technology Implementation Plan
Part 1 – Project Identification

Part 1 : Project Identification

Mandatory

1.	EC Programme:	Environment 94-98
2.	Project title & acronym:	Modelling within-storm
3.	Project number:	ENV4-CT97-687

4. Consortium details:	**Coordinator: CNR - Istituto per la Genesi e l'Ecologia del Suolo (CNR-IGES)** **Resp. scientist: Dr. Dino Torri** **Address: Istituto per la Genesi e l'Ecologia del Suolo** **Piazzale delle Cascine 15-28 - I-50144 Firenze, Italia** **Telephone: +39 055 3288290** **Fax: +39 055 321148** **email: dbtorri@iges.fi.cnr.it** **Contractor: Katholieke Universiteit Leuven (KULEUVEN)** **Resp. scientist: Prof. Dr. Jean Poesen** **Address: Laboratory for Experimental Geomorphology** **Redingenstraat 16 - B-3000 Leuven, Belgium** **Telephone: +32 16 32 64 25/26** **Fax: +32 16 32 64 00** **email: jean.poesen@geo.kuleuven.ac.be** **Contractor: Cranfield University, Silsoe (CRANFIELD)** **Resp. scientist: Prof. Roy Morgan** **Address: Silsoe College, Silsoe** **Bedfordshire MK45 4DT - United Kingdom** **Telephone: +44 (0)1525 863059** **Fax: +44 (0)1525 863099** **e-mail: r.morgan@cranfield.ac.uk (Prof. Roy Morgan)** **Contractor: Consejo Superior de Investigaciones Científicas (CSIC-CEBAS)** **Resp. scientist: Dr. Juan Albaladejo** **Address: Centro de Edafología y Biología Aplicada del Segura** **Av. Fama. Apartado 4195 - E30080 Murcia. España** **Telephone: +34-968-215717** **Fax: +34-968-266613** **email: jalba@natura.cebas.csic.es** **Contractor: Istituto di Idraulica Agraria (IIA)** **Resp. scientist: Vito Sardo** **Address: via Valdisavoia, 5 - 95123 Catania - Italia** **Telephone : ++ 39 - 095 - 350401** **Fax: ++ 39 - 095 - 7311992** **email : sardo@mbox-fa.gr.unict.it** **Contractor: Institut für Bodenforschung, Universität für Bodenkultur (BOKU)** **Responsible Scientist: Dr. Peter Strauss** **Address: Gregor-Mendelstrasse 33** **A-1180 Wien, Austria** **Telephone: +43 1 7416 52108 17** **Fax: +43 1 7416 52108 3** **E-mail: peter.strauss@baw.at** **Contractor: Istituto Sperimentale per lo Studio e la**

5.	**Number of results submitted :**	4

TECHNOLOGY IMPLEMENTATION PLAN

PART 2 – Project Results

A Framework for the further development and exploitation of the results of EC RTD Projects

DOCUMENT TITLE: Technology Implementation Plan PART 2 – Project Results		
DATE: 01/04/00	**VERSION FP4 2.2**	**ORIGINATOR: European Commission**

Part 2a: Description of result 1 **Project Number:** ENV4-CT97 0687

Please give information on each of the results chosen for a specific exploitation route. Refer to the guidelines for further details.

Table 6. Summary of exploitable result

Mandatory

This information is for administration purposes only and will not be published.

Summarise exploitable result, identify the partners (result owners) involved and describe the exploitation intentions

Title of Result	EUROSEM rel.4		
Partners involved	Cranfield - Cranfield University		
Exploitation intention	Transmission of the model to users		
Category	☒ Exploitable result used only within consortiums	☐ non exploitable result	☐ exploitable result of interest for third parties

(you can use free text in each table cell, but be as short and to the point as possible. In the **Category** cell tick the appropriate box, one box only)

7. Summary (200-300 words maximum)

Mandatory

CONFIDENTIAL
No
Select Yes/No from dropdown menu

Provide an overview of the result which gives the reader an immediate impression of the nature of the result and its relevance and potential!

EUROSEM rel.4 is a model permitting users to deal with soil erosion on the basis of extreme, critical, intense rainstorms. The model permit to foresee effects of gully-generating rainstorms. Hence the model is an ideal instrument for designing prevention and control measures.

*** - insert the number of the specific exploitable result**

8. Description of result

Mandatory

CONFIDENTIAL
No
Select Yes/No from dropdown menu

EUROSEM rel.4 is based on previous version of EUROSEM, which is model developped using European funding, within European projects. The main characteristics of the model are as follows:
1) the model is distributed and the catchment is described through cascading planes and channels
2) the transport of eroded material and surface runoff is garanteed by the application of the mass conservation law through a kinematic wawe equation approximation
3) interril soil erosion is based on an new model where surface ruoghness is modified while sealing and hydraulic saturated conductivity vary accordingly. Erosion and stoniness can cause a local increase in roughness.
4) flow is allowed to concentrate excavating large channels (gullies) during the event. This causes elements of the cascading planes to transform into (or to contain) evolving channel elements once some thresholds conditions are overcome.
5) the model is complemented by a series of tables for estimating values of input variables.
6) a manual for users complements the model.

Categorise subject description using codes from Annex 4.

Subject descriptor codes	c14	c07	c19	c08

9. Current stage of development

CONFIDENTIAL
No
Select Yes/No from dropdown menu

STAGE OF DEVELOPMENT	Select one category only (tick the box)
Basic research	☐
Applied research	☐
Experimental development stage (Laboratory prototype)	☐
Prototype/demonstrator available for testing	☒
Results of demonstration trials available	☒
Other: (Please specify!)	☐

Briefly describe the current status/applications of the result!

The model has been applied to the data collected in Italy and in Spain (3 sites).

10. Documentation and information on exploitable result

Add here a list of the **most important and relevant** information and documentation, indicating the confidentiality status of each document. The "document status" box indicates whether the document being referred to is confidential (and might be made available to third parties only after the signing of a confidential disclosure agreement). The "confidentail" box indicates, whether the knowledge that a document exists is in itself confidential.
Add promotional material that can be used for illustrating the result in dissemination services such as photographs, items of artwork, video clip, interviews, piece of animation, etc.

Documentation type	Document Status **PU**=Public **CO**=Confidential	Details (Title, ref. number, general description, language)	CONFIDENTIAL Select Yes/No from dropdown menu
Model description	PU	EUROSEM4Win model description. Cranfield University, Silsoe. Downlaodable from the EUROSEM website. www.silsoe.cranfield.ack.uk\soil	No
			No
			No
			No
			No
			No
			No
			No
			No
			No
			No
			No
			No
			No
			No
			No

Part 2b: Exploitation of result

11. Exploitation strategy for the specific result

Mandatory

11.1 Using the table below, indicate the intellectual and industrial property rights being exploited (all foreground and possible background rights)

CONFIDENTIAL
No
Select Yes/No from dropdown menu

Type of IPR		**Details (what is covered, reference numbers, countries covered) for all IPRs indicated in the Foreground (FG) and/or Background (BG) fields.**	**Number Fore-ground IPR's**	**Number Back-ground IPR's**
Patent applied for	**FG**			
	BG			
Patent search carried out	**FG**			
	BG			
Patent obtained	**FG**			
	BG			
Registered design	**FG**			
	BG			
Trademark Applications	**FG**			
	BG			
Copyrights	**FG**			
	BG			
Secret know-how	**FG**			
	BG			
Other – Please specify	**FG**			
	BG			

Please enter in the "Details" field the information for **all** the IPR's. If you have more than one IPR per type (e.g. more than one patent), indicate in the "Nr of Foreground IPR's" and/or in the "Nr of Background IPR's fields" the respective numbers.

11.2 Define the role of each partner and the co-operation between the partners involved in the exploitation

CONFIDENTIAL
No
Select Yes/No from dropdown menu

Cranfield will act as depositary of the model. It will keep the model, i.e. remove bugs, distribute it, maintain EUROSEM rel.4 web page.
All the other institutions listed in table 6 (called 'partners' in the following) will contribute in organising training courses and seminars in English as well as in other languages.
Cranfield will also act as treasurer administering the forsee income for both keeping the model (contract or part-time personnel) and, in some cases, organising courses (e.g. paying expenses to partners to lecture in the courses).

11.3 Collaboration sought

CONFIDENTIAL
No
Select Yes/No from dropdown menu

If you are looking for support by third parties, please indicate by using the keys or boxes below

KEY "Collaboration Sought"

R&D	☐	: Further research or development	JV	☐	: Joint venture
LIC	☐	: Licence agreement	MKT	☐	: Marketing agreement
MAN	☐	: Manufacturing agreement	FIN	☐	: Financial support
C	☐	: Venture Capital/spin-off funding	PPP	☐	: Private-public partnership
INFO	☐	: Information exchange	Other	☐	: (Please specify below)

Other:			

Describe the exploitation opportunity that you can offer your potential partner.

Future cooperations for research and further development of EUROSEM will be sought as a group or separately by the different partners. The model can be used, coupled with other complementary models or alone as an instrument for studying effects of rainstorm and/or landuse characteristics in a global change scenario analysis of field-scale effects. Cooperations will be sought with these aim in view.

12. Exploitation activities and timetable

Mandatory

CONFIDENTIAL
No
Select Yes/No from dropdown menu

Describe the exploitation activities, the milestones involved and give a timetable (what will be done by whom and when?)

(1) Organisation of training workshops for users. These could be either European wide or held within country in the local language to targetted local users. They would be run by the most appropriate partner institution but lecturers could be drawn from any of the partners. They would operate at the costs normally charged by the institution for their short course and training programmes. If they are run in the local language it may be necessary to run training programmes for local lecturers - these would have to be in English.

(2) The model would be available to all users at a small charge (amount to be decided) which would be levied annually to cover costs, including an amount to support for managing the code and providing some technical support on either a contract or part-time basis. Separate provision would be necessary for code maintenance for EUROSEM and EUROWISE. To encourage use, a version of EUROSEM with some limitations on functions (to be decided) will be downloadable from the EUROSEM web address. After being able to trial this version, users would be able to register, pay their fee and obtain a fully executable version. The fee would cover some technical support and the provision of updates to Version 4.

Users in countries from which it would be difficult to extract a fee would be permitted to have an executable version free for research purposes only. They would have to agree not to pass the model on to others or to use it in any way for commercial gain (e.g. consultancy or advisory work).

(3) There is some interest from users to have the model for incorporation within other products, e.g. to combine the erosion part of EUROSEM with their own hydrological model. Such users, once registered, would be distributed with a Dynamically Linked Library (DLL) containing all EUROSEM core functions supplemented by a manual on function calls. Alternatively, in some circumstances, such users may given a copy of the code. There would be a small charge for either option (to cover costs as in (2) above) but where the user intends to sell the product which contains EUROSEM, they will pay a royalty on all sales to the EUROSEM partners.

(4) The EUROSEM partners will establish a small committee to discuss initiatives and activities based on the monies accruing from the implementation plan, as well as on monies from other funds (where tpo apply as EUROSEM committee. Use would be limited to the promotion and development of EUROSEM.

ALTERNATIVELY:
4) The EUROSEM partners would establish a small committee to adminster the monies accruing from the implementation plan, monitor the account and decide how any money should be used. Use would be limited to the promotion and development of EUROSEM

Timetable:

Activity	Partner(s) involved	starting from ... to ...
seminars	all?	end of project to 3 years after
schools		to
further development	all	to 3 years from now
		to
		to
		to

		to
		to
		to
		to

13. Exploitation potential*

CONFIDENTIAL
No
Select Yes/No from dropdown menu

When describing the exploitation potential, you might want to consider one or all of the following factors:

- What are the potential applications for this result?
- Who are the users of this result?
- What are the main innovative features and benefits (technical/commercial success factors)?
- Analysis of the market sector
- Potential barriers

** for PROSOMA users and those providing commercially relevant results, please concentrate on describing the business opportunity of your result*

Future cooperations for research and further development of EUROSEM will be sought as a group or separately by the different partners. The model can be used, coupled with other complementary models or alone as an instrument for studying effects of rainstorm and/or landuse characteristics in a global change scenario analysis of field-scale effects. Also Best Management Practices can be examined using the model. Water quality (pollution linked to sediment), modification of flood occurrence (according to land use and land management changes) can also benefit from EUROSEM technology.

Categorise market application sector using codes from Annex 5.

Market application sectors	c23	c12	c07	c16

14. Ability of partners to carry out the exploitation

CONFIDENTIAL
No
Select Yes/No from dropdown menu

When describing this part, you might want to consider one or all of the following factors:

- Estimate the investment and describe the skills which will be required for exploitation of the result
- How do you intend to finance these investments?
- What is the expected return on investment?
- What risks are involved?

If you seek additional partners, clearly describe your input and the expected input from the external partner(s)!

15. Contact person for this exploitable result

Mandatory

CONFIDENTIAL
No
Select Yes/No from dropdown menu

Name	Dr John Quinton
Position	Senior Lecturer
Organisation	Cranfield University at Silsoe
Address	Silsoe, Bedford MK45 4DT, UK
Telephone	44 (0) 1525 863 000
Fax	44 (0) 01525 86 33 44
E-mail	EUROSEM@cranfield.ac.uk

16. Organization information

Mandatory

CONFIDENTIAL
No
Select Yes/No from dropdown menu

Provide a short description of your organization and if necessary, provide contact details on persons who are more involved in the exploitation aspects and/or the technical aspects.

Cranfield University at Silose provides the Environmental and Life Sciences focus for the University, and has a log history of resrch in soil erosion and its control. This history is backed by world class laboratory facilities and one of the largesst groups working on erosion in Europe.

We also provide post graduate education and continuing professional development.

17. Authorisation

Mandatory

I confirm that the information contained in the Technology Implementation Plan which is marked **CONFIDENTIAL / NO** may be disseminated by the Commission :

Name: Prof R.P.C. Morgan

Date: 6 A ugust 2001

Organisation: Cranfield University

TECHNOLOGY IMPLEMENTATION PLAN

PART 2 – Project Results

A Framework for the further development and exploitation of the results of EC RTD Projects

DOCUMENT TITLE: Technology Implementation Plan PART 2 – Project Results		
DATE: 01/04/00	**VERSION FP4 2.2**	**ORIGINATOR: European Commission**

Part 2a: Description of result 2 Project Number: CT97-0687

Please give information on each of the results chosen for a specific exploitation route. Refer to the guidelines for further details.

Table 6. Summary of exploitable result

Mandatory

This information is for administration purposes only and will not be published.

Summarise exploitable result, identify the partners (result owners) involved and describe the exploitation intentions

Title of Result	EUROWISE raster model
Partners involved	Dept. of Physical Geography, Utrecht University (UU); Laboratory for Experimental Geomorphology, Catholic University of Leuven (LEG)
Exploitation intention	The EUROWISE model (raster version) is a free research and application tool that can be downloaded from the LISEM website (www.geog.uu.nl/lisem). It is a scientific application that will not be exploited commercially, nor can anybody do so.
Category	☒ Exploitable result used only within consortiums ☐ non exploitable result ☐ exploitable result of interest for third parties

(you can use free text in each table cell, but be as short and to the point as possible. In the **Category** cell tick the appropriate box, one box only)

7. Summary (200-300 words maximum)

Mandatory

CONFIDENTIAL
No
Select Yes/No from dropdown menu

Provide an overview of the result which gives the reader an immediate impression of the nature of the result and its relevance and potential!

EUROWISE, the EUROpean model for Within storm Simulation of erosion, is a physically based model that simulates the occurence and incision of ephemeral gully erosion as a result of one or more rainfall events. It is integrated into the raster GIS PCRaster (www.pcraster.nl) and is developed for small scale catchments (up to 200 ha). Processes incorporated in the model are rainfall, interception, surface storage in micro-depressions, infiltration and percolation, overland flow, channel flow, splash and flow detachment. This is done in most erosion models, the difference of EUROWISE is in the simulation of incision of ephemeral gullies based on simple empirical relations:
- the landscape is analysed to determine 'critical areas' where gully formation is likely to occur, with algorithms based on the contributing area above a given point in the landscape and the local slope;
- inside this area incision takes place over the width of the gullies, whereby the width is determined by an empirical discharge-gully width relationship;
- the gully depth is changed according to the amount of erosion/deposition calculated by the transport capacity of the flow;
- when 2 layers with different cohesions are present, additional widening takes place.

In order to operate EUROWISE, only commonly available data are needed (such as a digital terrain model, infiltration characteristics and soil cohesion and bulkdensity). EUROWISE has a user friendly interface that enables the user to select all the input maps, the criteria for landscape analysis (pre-defined as 5 different sets of algorithms) and the discharge -wdth algorithms.
The algorithms for critical area analysis and the discharge-wdth relationships were developed and tested in cooperation with the Laboratory for Experimental Geomorphology, Catholic University of Leuven

*** - insert the number of the specific exploitable result**

8. Description of result

Mandatory

CONFIDENTIAL
No
Select Yes/No from dropdown menu

EUROWISE is a stand alone program that works under windows 95, 98 and ME. It has a comprehensive user interface to specify input and output data and gives the total values of the variables simulated onscreen. It saves a series of maps that show the development of the gullies over time during a rainstorm (changes in depth, width, volume, location, total erosion and deposition, e.g. with a timestep of 1 minute). These maps can be shown as a "film" using the associated GIS software PCRaster (www.pcraster.nl). Note that at present the core modules of PCRaster can be obtained free of charge.
EUROWISE has been tested on two sets of data and has been proved to function satisfactoporily. The first set of data is the central belgian loess plateau, which is typical of large parts of north west Europe. Four shallow and wide gullies were formed as a result of five rainstorms. EUROWISE was able to adequately simulate these, whereby the total volume was estimated correctly, while the depth and width were not always correct. Given the right input data (especially on soil cohesion) the model performs well. The second dataset was from Sicily and was typical for parts of the mediterrenean. The gullies were narrow and deep and also these were simulated correctly.

EUROWISE is fairly easy to operate by a user that has a sound knowledge of erosion.

Categorise subject description using codes from Annex 4.

Subject descriptor codes	A01	C07	C14	C19

9. Current stage of development

CONFIDENTIAL
No
Select Yes/No from dropdown menu

STAGE OF DEVELOPMENT	Select one category only (tick the box)
Basic research	☐
Applied research	☐
Experimental development stage (Laboratory prototype)	☐
Prototype/demonstrator available for testing	☒
Results of demonstration trials available	☐
Other: (Please specify!)	☐

Briefly describe the current status/applications of the result!

The EUROWISE model is freely available and tested on two datasets with good results. These will be reported in a scientific article. The model is public domain and cannot be used for commercial purposes, nor be incorporated in commercial software.
EUROWISE will give good results when it is calibrated properly by someone with a solid understanding in erosion and a working knowledge of GIS is advisable. The model and manual are freely available from the website.
EUROWISE is under a constant state of development: new scientific findings will be incorporated in it which means that the results may differ between versions.

10. Documentation and information on exploitable result

Add here a list of the **most important and relevant** information and documentation, indicating the confidentiality status of each document. The "document status" box indicates whether the document being referred to is confidential (and might be made available to third parties only after the signing of a confidential disclosure agreement). The "confidentail" box indicates, whether the knowledge that a document exists is in itself confidential.
Add promotional material that can be used for illustrating the result in dissemination services such as photographs, items of artwork, video clip, interviews, piece of animation, etc.

Documentation type	Document Status **PU**=Public **CO**=Confidential	Details (Title, ref. number, general description, language)	CONFIDENTIAL Select Yes/No from dropdown menu
website	PU	www.geog.uu.nl/lisem	No
manual	PU	available as pdf document from the website	No
article	PU	Jetten,V., Vlag, D. van de, Nachtergaele,J. and Poesen.J., in prep. Event based modelling of gully incision and development in the Belgian loess belt. CATENA.	No
			No
			No
			No
			No
			No
			No
			No
			No
			No
			No
			No
			No
			No

Part 2b: Exploitation of result

11. Exploitation strategy for the specific result

Mandatory

11.1 Using the table below, indicate the intellectual and industrial property rights being exploited (all foreground and possible background rights)

CONFIDENTIAL
No
Select Yes/No from dropdown menu

Type of IPR		Details (what is covered, reference numbers, countries covered) for all IPRs indicated in the Foreground (FG) and/or Background (BG) fields.	Number Fore-ground IPR's	Number Back-ground IPR's
Patent applied for	FG			
	BG			
Patent search carried out	FG			
	BG			
Patent obtained	FG			
	BG			
Registered design	FG			
	BG			
Trademark Applications	FG			
	BG			
Copyrights	FG			
	BG			
Secret know-how	FG			
	BG			
Other – Please specify	FG			
	BG			

Please enter in the "Details" field the information for **all** the IPR's. If you have more than one IPR per type (e.g. more than one patent), indicate in the "Nr of Foreground IPR's" and/or in the "Nr of Background IPR's fields" the respective numbers.

11.2 Define the role of each partner and the co-operation between the partners involved in the exploitation

CONFIDENTIAL
No
Select Yes/No from dropdown menu

Utrecht University, Dept. of Physical Geography (NL), construction of the model and extensive testing with the data of 2 catchments, contact point for questions about EUROWISE and maintainance of the model, manual and the website;

Laboratory of Experimental Geomorphology, Catholic University Leuven (BE): provided and tested the necessary algorithms to develop EUROWISE, provided one of the test datasets.

11.3 Collaboration sought

CONFIDENTIAL
No
Select Yes/No from dropdown menu

If you are looking for support by third parties, please indicate by using the keys or boxes below

KEY "Collaboration Sought"

R&D	☐	: Further research or development	JV	☐	: Joint venture
LIC	☐	: Licence agreement	MKT	☐	: Marketing agreement
MAN	☐	: Manufacturing agreement	FIN	☐	: Financial support
C	☐	: Venture Capital/spin-off funding	PPP	☐	: Private-public partnership
INFO	☐	: Information exchange	Other	☐	: (Please specify below)

Other:			

Describe the exploitation opportunity that you can offer your potential partner.

12. Exploitation activities and timetable

Mandatory

CONFIDENTIAL
No
Select Yes/No from dropdown menu

Describe the exploitation activities, the milestones involved and give a timetable (what will be done by whom and when?)

September 2001: EUROWISE website online: model and manual will be freeware and can be downloaded. Further revisions are scheduled for the end of 2001.

If the website cannot be freely maintained a small fee will be asked for the maintenance and the updates of the manual.

Timetable:

Activity	Partner(s) involved	starting from ... to ...
1	Utrecht University	01-08-01 to 01-08-02
		to
		to
		to
		to
		to
		to
		to
		to
		to

13. Exploitation potential*

CONFIDENTIAL
No
Select Yes/No from dropdown menu

When describing the exploitation potential, you might want to consider one or all of the following factors:

- What are the potential applications for this result?
- Who are the users of this result?
- What are the main innovative features and benefits (technical/commercial success factors)?
- Analysis of the market sector
- Potential barriers

** for PROSOMA users and those providing commercially relevant results, please concentrate on describing the business opportunity of your result*

Applications:
- Analysis of the landscape to pinpoint sensitive areas for erosion;
- Better soil and land management; environmental protection; prediction of erosion and onsite damages (gullies) that may result in loss of agricultural production (e.g. by lodss of fertile soil, seedlings and trafficability).

Users:
EEA, consultants, local administrations, environmental protection agencies, farmers.

Innovative features:
- the first model to actually simulate the development of gullies
- landscape analysis

Potential barriers:
- Can only be used by trained people with a sound knowledge of erosion processes
- some training in the use of the software is probably advisable
- the model needs a more extensive interface

Application sectors:
- Desicion support systems for erosion control. The software forms a sound scientific basis for the development of an expert system, that takes care of the potential barriers listed above
- Environmental management tools

Categorise market application sector using codes from Annex 5.

Market application sectors	C04	C07	C12	C23

14. Ability of partners to carry out the exploitation

CONFIDENTIAL
No
Select Yes/No from dropdown menu

When describing this part, you might want to consider one or all of the following factors:

- Estimate the investment and describe the skills which will be required for exploitation of the result
- How do you intend to finance these investments?
- What is the expected return on investment?
- What risks are involved?

If you seek additional partners, clearly describe your input and the expected input from the external partner(s)!

The partners involved in this result are fully qualified to continue its development. All necessary skills are present within the institutes involved in MWISED.
The finances are covered internally or by new national research funds or EU funds in projects concerning erosion.
A new project proposal under the FP5 program Quality of Life is prepared that explores the use of EUROWISE in an expert system application, dveloped in close cooperation with end-user groups

15. Contact person for this exploitable result

Mandatory

CONFIDENTIAL
No
Select Yes/No from dropdown menu

Name	Dr. V. Jetten
Position	Researcher/lecturer
Organisation	Faculty of geographical Sciences, Utrecht University
Address	Heidelberglaan 2, 3508 TC, Utrecht, The Netherlands
Telephone	+31 30 2535773
Fax	+ 31 30 2531145
E-mail	v.jetten@geog.uu.nl

16. Organization information

Mandatory

CONFIDENTIAL
No
Select Yes/No from dropdown menu

Provide a short description of your organization and if necessary, provide contact details on persons who are more involved in the exploitation aspects and/or the technical aspects.

The department of physical geography, faculty of geographical sciences has a long standing reputation both in the development and application of Geographical Information Systems and spatial analysis and modelling, and in fundamental and applied research of land degradation in the widest sense, in many parts of the world (Western and Southern Europe, Southern Africa, China, South America).
The department combines three research groups:
- Landscape modelling, including GIS and RS and hydrology
- River research management
- Coastal zone management

17. Authorisation

Mandatory

I confirm that the information contained in the Technology Implementation Plan which is marked **CONFIDENTIAL / NO** may be disseminated by the Commission :

Name: V. Jetten Date: 23-07-01

Organisation: Department of Physical geography, faculty of Geographical Sciences, Utrecht University

TECHNOLOGY IMPLEMENTATION PLAN

PART 2 – Project Results

A Framework for the further development and exploitation
of the results of EC RTD Projects

DOCUMENT TITLE: **Technology Implementation Plan** **PART 2 – Project Results**		
DATE: 01/04/00	**VERSION FP4 2.2**	**ORIGINATOR: European Commission**

Part 2a: Description of result 3 Project Number: ENV4-CT97-0687

Please give information on each of the results chosen for a specific exploitation route. Refer to the guidelines for further details.

Table 6. Summary of exploitable result

Mandatory

This information is for administration purposes only and will not be published.

Summarise exploitable result, identify the partners (result owners) involved and describe the exploitation intentions

Title of Result	Software for simulation of rainfall intensity (RAINGEN)
Partners involved	UBW-UBB
Exploitation intention	Further R&D
Category	☐ Exploitable result used only within consortiums ☒ non exploitable result ☐ exploitable result of interest for third parties

(you can use free text in each table cell, but be as short and to the point as possible. In the **Category** cell tick the appropriate box, one box only)

7. Summary (200-300 words maximum)

Mandatory

CONFIDENTIAL
No
Select Yes/No from dropdown menu

Provide an overview of the result which gives the reader an immediate impression of the nature of the result and its relevance and potential!

The provided piece of software calculates two things:
1) Values for the input parameters of a scaling model
2) Rainfall hyetographs according to a scaling model approach

*** - insert the number of the specific exploitable result**

8. Description of result

Mandatory

CONFIDENTIAL
No
Select Yes/No from dropdown menu

Result is a software for the fields of science C04 and C23. It allows to calculate rainfall hyetographs for single rainfall events with high temporal resolution

Categorise subject description using codes from Annex 4.

Subject descriptor codes	C24	C14	C06	

9. Current stage of development

CONFIDENTIAL
No
Select Yes/No from dropdown menu

STAGE OF DEVELOPMENT	Select one category only (tick the box)
Basic research	☐
Applied research	☒
Experimental development stage (Laboratory prototype)	☐
Prototype/demonstrator available for testing	☐
Results of demonstration trials available	☐
Other: (Please specify!)	☐

Briefly describe the current status/applications of the result!

Software is fully functionable - anyway before any application to selected rainfall stations, basic checks to prove the general applicability of the proposed model are necessary

10. Documentation and information on exploitable result

Add here a list of the **most important and relevant** information and documentation, indicating the confidentiality status of each document. The "document status" box indicates whether the document being referred to is confidential (and might be made available to third parties only after the signing of a confidential disclosure agreement). The "confidentail" box indicates, whether the knowledge that a document exists is in itself confidential.
Add promotional material that can be used for illustrating the result in dissemination services such as photographs, items of artwork, video clip, interviews, piece of animation, etc.

Documentation type	Document Status **PU**=Public **CO**=Confidential	Details (Title, ref. number, general description, language)	CONFIDENTIAL Select Yes/No from dropdown menu
Technical manual	PU	Raingen 1.0: A system for generating internal rainfall structure of rainfall events	No
			No
			No
			No
			No
			No
			No
			No
			No
			No
			No
			No
			No
			No
			No
			No

Part 2b: Exploitation of result

11. Exploitation strategy for the specific result

Mandatory

11.1 Using the table below, indicate the intellectual and industrial property rights being exploited (all foreground and possible background rights)

CONFIDENTIAL
No
Select Yes/No from dropdown menu

Type of IPR		Details (what is covered, reference numbers, countries covered) for all IPRs indicated in the Foreground (FG) and/or Background (BG) fields.	Number Fore-ground IPR's	Number Back-ground IPR's
Patent applied for	**FG**		0	
	BG			0
Patent search carried out	**FG**		0	
	BG			0
Patent obtained	**FG**		0	
	BG			0
Registered design	**FG**		0	
	BG			0
Trademark Applications	**FG**		0	
	BG			0
Copyrights	**FG**		0	
	BG			0
Secret know-how	**FG**		0	
	BG			0
Other – Please specify	**FG**		0	
	BG			0

Please enter in the "Details" field the information for **all** the IPR's. If you have more than one IPR per type (e.g. more than one patent), indicate in the "Nr of Foreground IPR's" and/or in the "Nr of Background IPR's fields" the respective numbers.

11.2 Define the role of each partner and the co-operation between the partners involved in the exploitation

CONFIDENTIAL
No
Select Yes/No from dropdown menu

The Institut fuer Bodenforschung, University for Agricultural Sciences, Austria will distribute the model on demand. Initially CNR-IGES will put the software and manual on the MWISED web site for free download of the executables

11.3 Collaboration sought

CONFIDENTIAL
No
Select Yes/No from dropdown menu

If you are looking for support by third parties, please indicate by using the keys or boxes below

KEY "Collaboration Sought"

R&D	☐	: Further research or development	JV	☐	: Joint venture
LIC	☐	: Licence agreement	MKT	☐	: Marketing agreement
MAN	☐	: Manufacturing agreement	FIN	☐	: Financial support
C	☐	: Venture Capital/spin-off funding	PPP	☐	: Private-public partnership
INFO	☐	: Information exchange	Other	☐	: (Please specify below)

Other:			

Describe the exploitation opportunity that you can offer your potential partner.

12. Exploitation activities and timetable

Mandatory

CONFIDENTIAL
No
Select Yes/No from dropdown menu

Describe the exploitation activities, the milestones involved and give a timetable (what will be done by whom and when?)

Exploitation will be carried out by further research an development of the software by the responsible partner. This will be carried out in medium-term.

Timetable:

Activity	Partner(s) involved	starting from ... to ...
		to
		to
		to
		to
		to
		to
		to
		to
		to
		to

13. Exploitation potential*

CONFIDENTIAL
No
Select Yes/No from dropdown menu

When describing the exploitation potential, you might want to consider one or all of the following factors:

- What are the potential applications for this result?
- Who are the users of this result?
- What are the main innovative features and benefits (technical/commercial success factors)?
- Analysis of the market sector
- Potential barriers

** for PROSOMA users and those providing commercially relevant results, please concentrate on describing the business opportunity of your result*

Categorise market application sector using codes from Annex 5.

Market application sectors				

14. Ability of partners to carry out the exploitation

CONFIDENTIAL
No
Select Yes/No from dropdown menu

When describing this part, you might want to consider one or all of the following factors:

- Estimate the investment and describe the skills which will be required for exploitation of the result
- How do you intend to finance these investments?
- What is the expected return on investment?
- What risks are involved?

If you seek additional partners, clearly describe your input and the expected input from the external partner(s)!

15. Contact person for this exploitable result

Mandatory

CONFIDENTIAL
No
Select Yes/No from dropdown menu

Name	Peter Strauss
Position	Researcher
Organisation	UBW-UBB
Address	Gregor-Mendel-Str. 33, A-1180 Vienna
Telephone	0043-1-47654-3100
Fax	0043-1-4789110
E-mail	peter.strauss@baw.at

16. Organization information

Mandatory

CONFIDENTIAL
No
Select Yes/No from dropdown menu

Provide a short description of your organization and if necessary, provide contact details on persons who are more involved in the exploitation aspects and/or the technical aspects.

Institut fuer Bodenforschung is part of the University for Agricultural Sciences in Austria. we do research work in the fields of water and soil science with respect to their protection and maintenance of quality.

17. Authorisation

Mandatory

I confirm that the information contained in the Technology Implementation Plan which is marked **CONFIDENTIAL / NO** may be disseminated by the Commission :

Name: Peter Strauss Date: 21/07/2001

Organisation: Institut fuer Bodenforschung, University for Agricultural Sciences, Austria

TECHNOLOGY IMPLEMENTATION PLAN

PART 2 – Project Results

A Framework for the further development and exploitation
of the results of EC RTD Projects

DOCUMENT TITLE: Technology Implementation Plan PART 2 – Project Results		
DATE: 01/04/00	**VERSION FP4 2.2**	**ORIGINATOR: European Commission**

Part 2a: Description of result 4 Project Number: ENV4-CT97-0687

Please give information on each of the results chosen for a specific exploitation route. Refer to the guidelines for further details.

Table 6. Summary of exploitable result

Mandatory

This information is for administration purposes only and will not be published.

Summarise exploitable result, identify the partners (result owners) involved and describe the exploitation intentions

Title of Result	Transfer functions for estimating soil hydraulic and erosion characteristics
Partners involved	CNR-IGES MiPAF-ISSDS CSIC-CEBAS KULeuven
Exploitation intention	Results will be kept in the public domain
Category	☐ Exploitable result used only within consortiums ☐ non exploitable result ☒ exploitable result of interest for third parties

(you can use free text in each table cell, but be as short and to the point as possible. In the **Category** cell tick the appropriate box, one box only)

7. Summary (200-300 words maximum)

Mandatory

CONFIDENTIAL
No
Select Yes/No from dropdown menu

Provide an overview of the result which gives the reader an immediate impression of the nature of the result and its relevance and potential!

Based on data collected within this European project and in other projects a set of transfer equations and algorithms has been developped. They are presented as documents and are included within a software. The program will allow fast estimates of parameters that are important for running hydrological and erosion models. As the data requirement of last generation models can be fairly high and direct measurements expensive and difficult, the program will help users.

*** - insert the number of the specific exploitable result**

8. Description of result

Mandatory

CONFIDENTIAL
No
Select Yes/No from dropdown menu

The program is an aplet Java (Pedon - The Soil Equation Interface) which will be consultable from one or more web sites. It will allow the estimate of saturated hydraulic conductivity (of the soil matrix), water retention pressure, soil bulk density and related properties, net capillary rise, parameters for modifying saturated hydraulic conductivity with sealing, soil detachabilities, soil erodibility, parameters driving soil surface roughness dynamics.

Categorise subject description using codes from Annex 4.

Subject descriptor codes	C07	C08	C14	C19

9. Current stage of development

CONFIDENTIAL
No
Select Yes/No from dropdown menu

STAGE OF DEVELOPMENT	Select one category only (tick the box)
Basic research	☐
Applied research	☐
Experimental development stage (Laboratory prototype)	☐
Prototype/demonstrator available for testing	☒
Results of demonstration trials available	☐
Other: (Please specify!)	☐

Briefly describe the current status/applications of the result!

SEI is presently based on algorithms tested on public domain datasets and of the soil datasets of the Italian Region Emilia Romagna. The erosion part is mainly (not totally) based on data collected within MWISED project

10. Documentation and information on exploitable result

Add here a list of the **most important and relevant** information and documentation, indicating the confidentiality status of each document. The "document status" box indicates whether the document being referred to is confidential (and might be made available to third parties only after the signing of a confidential disclosure agreement). The "confidentail" box indicates, whether the knowledge that a document exists is in itself confidential**.**
Add promotional material that can be used for illustrating the result in dissemination services such as photographs, items of artwork, video clip, interviews, piece of animation, etc.

Documentation type	Document Status **PU**=Public **CO**=Confidential	Details (Title, ref. number, general description, language)	CONFIDENTIAL Select Yes/No from dropdown menu
WEB pages	PU	the already available part of SEI is described in documents (in English) available at http://www.area.fi.cnr.it/iges/pedone/Pedon_introd.htm	No
			No
			No
			No
			No
			No
			No
			No
			No
			No
			No
			No
			No
			No
			No
			No

Part 2b: Exploitation of result

11. Exploitation strategy for the specific result

Mandatory

11.1 Using the table below, indicate the intellectual and industrial property rights being exploited (all foreground and possible background rights)

CONFIDENTIAL
No
Select Yes/No from dropdown menu

Type of IPR		**Details (what is covered, reference numbers, countries covered) for all IPRs indicated in the Foreground (FG) and/or Background (BG) fields.**	**Number Fore-ground IPR's**	**Number Back-ground IPR's**
Patent applied for	**FG**			
	BG			
Patent search carried out	**FG**			
	BG			
Patent obtained	**FG**			
	BG			
Registered design	**FG**			
	BG			
Trademark Applications	**FG**			
	BG			
Copyrights	**FG**			
	BG			
Secret know-how	**FG**			
	BG			
Other – Please specify	**FG**			
	BG			

Please enter in the "Details" field the information for **all** the IPR's. If you have more than one IPR per type (e.g. more than one patent), indicate in the "Nr of Foreground IPR's" and/or in the "Nr of Background IPR's fields" the respective numbers.

11.2 Define the role of each partner and the co-operation between the partners involved in the exploitation

CONFIDENTIAL
No
Select Yes/No from dropdown menu

The partner CNR-IGES will keep the aplet and maintain it on its web-site. The other partners will have, if possible, a link to the CNR-IGES page on their web-page. The code has been developed at CNR-IGES while the data on erosion have been provided by all the partner involved. Results will be kept in the public domain.

11.3 Collaboration sought

CONFIDENTIAL
No
Select Yes/No from dropdown menu

If you are looking for support by third parties, please indicate by using the keys or boxes below

KEY "Collaboration Sought"

R&D	☒	: Further research or development	JV	☐	: Joint venture
LIC	☐	: Licence agreement	MKT	☐	: Marketing agreement
MAN	☐	: Manufacturing agreement	FIN	☐	: Financial support
C	☐	: Venture Capital/spin-off funding	PPP	☐	: Private-public partnership
INFO	☐	: Information exchange	Other	☐	: (Please specify below)

Other:			

Describe the exploitation opportunity that you can offer your potential partner.

statistical/empirical relationships become more reliable if the data sets on which they are based are larger, hence whoever has data of the type we have used for the program SEI can help merging its own dataset with ours.

12. Exploitation activities and timetable

Mandatory

CONFIDENTIAL
No
Select Yes/No from dropdown menu

Describe the exploitation activities, the milestones involved and give a timetable (what will be done by whom and when?)

A reduced version of SEI is already available on the web. The final version will made avilable by January 2002. Since then it will be kept by CNR-IGES personnel. Modifications will be made based on suggestions by users and on the availability of new datasets and new algorithms.

Timetable:

Activity	Partner(s) involved	starting from ... to ...
SEI completion	CNR-IGES, MiPA-ISSDS, CSIC-CEBAS, KULeuven	now to 31 Jan 2002
SEI maintainance	CNR-IGES	Jan. 2002 to Dec. 2004
		to
		to
		to
		to
		to
		to
		to
		to

13. Exploitation potential*

CONFIDENTIAL
No
Select Yes/No from dropdown menu

When describing the exploitation potential, you might want to consider one or all of the following factors:

- What are the potential applications for this result?
- Who are the users of this result?
- What are the main innovative features and benefits (technical/commercial success factors)?
- Analysis of the market sector
- Potential barriers

** for PROSOMA users and those providing commercially relevant results, please concentrate on describing the business opportunity of your result*

SEI can be used everytime data on soil and soil behaviour are needed. It is simple to use and general background on the matter is given in the web manuals. It is innovative because it is based on a large data set (water retention curves) the only one at the moment available for humid Mediterranean conditions. It is innovative for the part (still under implementation) regarding the soil erosion. It is unique also from this point of view.Moreover, algorithms and tables are not given for a particular model. This makes the model useful also to people not involved with EUROSEM or EUROWISE.

Categorise market application sector using codes from Annex 5.

Market application sectors	C12	C23	C14	C04

14. Ability of partners to carry out the exploitation

CONFIDENTIAL
No
Select Yes/No from dropdown menu

When describing this part, you might want to consider one or all of the following factors:

- Estimate the investment and describe the skills which will be required for exploitation of the result
- How do you intend to finance these investments?
- What is the expected return on investment?
- What risks are involved?

If you seek additional partners, clearly describe your input and the expected input from the external partner(s)!

15. Contact person for this exploitable result

Mandatory

CONFIDENTIAL
No
Select Yes/No from dropdown menu

Name	Dino Torri
Position	permanent staff
Organisation	Consiglio Nazionale delle Ricerche - Istituto per la Genesi e l'Ecologia del Suolo
Address	Piazzale Cascine 15
Telephone	+39 055 3288 290
Fax	+39 055 321148
E-mail	dbtorri@iges.fi.cnr.it

16. Organization information

Mandatory

CONFIDENTIAL
No
Select Yes/No from dropdown menu

Provide a short description of your organization and if necessary, provide contact details on persons who are more involved in the exploitation aspects and/or the technical aspects.

CNR is the larger research institution in Italy. IGES is a reasearch institute working in the field of soil science, geomorphology and slope hydrology. The expertise of D. Torri, C. Calzolari (calzolari@iges.fi.cnr.it), L. Borselli (borselli@iges.fi.cnr.it) and F. Ungaro (Ungaro@iges.fi.cnr.it) goes from soil erosion through soil science and geomorphology to slope hydrology. Mathematics, geostatistics and knowledge of several programming languages are also part of the expertise.

17. Authorisation

Mandatory

I confirm that the information contained in the Technology Implementation Plan which is marked **CONFIDENTIAL / NO** may be disseminated by the Commission :

Name: dino torri

Date:

Organisation: cnr-iges