Applicability of Various Erosion Risk Assessment Methods for Engineering Purposes

Ivan Blinkov[1], Stanimir Kostadinov [2]
[1] University Ss.Ciryl and Methodius, Faculty of forestry – Skopje, Dept. of Land and Water - , bul."Alexandar Makedonski "bb. 1000 Skopje, Republic of Macedonia ,fax: +389 2 3164560 ;
E-mail: blinkov@sf.ukim.edu.mk; ivanblinkov@yahoo.com
[2] University of Belgrade, Faculty of Forestry, Dept. of Ecological Engineering in Soil and Water Resources Protection" ul.Kneza Viseslava 1, 11030 Belgrade, Serbia,
E-mail: Kost@EUnet.rs

Abstract:

Various methods for erosion risk assessment are used by various countries in Europe. Generally, three types of approaches exist to identify areas at risk (Eckelmann et al., 2006): qualitative approach, quantitative approach, and model approach, All these methods vary in their characteristics and applicability. All already developed methods and approaches are improved in the recent period through use of geospatial databases developed using GIS technology. The most spread erosion type in the East and Southeast Europe as well as in whole continent is water erosion.

Aim of this study is to evaluate applicability of these methods for various engineering purposes for water erosion control measures per sector. CORINE approach (EEA-1985); the RIVM (1992); "the Hot Spots" approach (EEA - 2000, based on previous maps by Favis-Mortlock and Boardman, 1999; de Ploey, 1989, and other data); USLE method (Universal Soil Loss Equation - Wischmeier & Smith, 1978). The INRA, PESERA approach (Gobin et al. -1999), the European Soil Erosion Model – EUROSEM - (Morgan et al., 1998), Limburg Soil Erosion Model – LISEM - (De Roo et al., 1996a and 1996b; Takken et al., 1999), WEPP (Water Erosion Prediction Project), KINEROS and Erosion Potential Model (EPM) established by Gavrilovic (1972), CREAMS (Knisel,1980; Foster et al., 1981), etc. After preliminary assessment, further analyses were aimed only to 6 methods: USLE, PESERA, KINEROS, WEP, WEPP and EPM. The elements for evaluation were scale and outputs (maps and values) and qualitative research method was used. Evaluation was separated for purpose per task, scale, erosion type and sector: agro-engineering, bio-engineering and watershed management. The first output of these methods is map that is useful for preparation erosion control strategies. According to the numeric output and scale, applicability for engineering purposes vary from sector to sector. Some of the methods are developed in a very small scale and are interest only for general view of the state and general planning (CORINE, GLASOD, INRA..) and couldn't be used for solving engineering problems.

Key words: erosion risk assessment method

Introduction

Soil erosion is considered as one of the major threats to European soils, particularly in the Mediterranean areas *(Communication on Soil Protection – "Towards a Thematic Strategy for Soil Protection", CEC, 2002).* In order to effectively formulate mitigation strategies and implement conservation measurements to counteract soil erosion, it is essential to objectively identify and quantify (areas at) risk. Erosion is understood to be a physical phenomenon that results in the displacement of soil and rock particles by water, wind, ice and gravity. Numerous aspect and processes contribute to erosion, of which the most direct and generally acknowledged are: land cover/use changes. The degree of erosion is in the first place determined by physical factors, i.e. soil characteristics, rock formation, topography and climate. The amount of edaphic material available for transport (potentially erodible) is depending on soil erodibility, stone content and characteristics. The transport capacity, i.e. the amount of energy available in the form of rain splash or runoff (volume and velocity) is determined by climatic factors and establishes whether and at what rate erosion can take place (Morgan and Quinton, 2001, cited in L. Geraedts, L. Recatala-Boix, C. Ano-Vidal, C.J. Ritsema, 2006). The transport capacity is also influenced by topography, soil characteristics determining hydraulic processes in the soil (e.g. permeability and soil depth) and vegetation cover. During an extreme event, more than 100 t/ha can be lost, although losses of 20 to 40 t./ha give a better indication of erosion volumes during extreme events (Van der Knijff et al., 2000. The anthropogenic influence is essentially reflected in the land cover, where land use changes and intensity and cultivation practices – such as tillage and implementation of conservation strategies – determine the susceptibility to erosion (Batjes, 1996; Drake and Vafeidis, 2004; Boardman, 2006; Lesschen et al., 2007 citated in RAMSOIL report 2.1.- 2006).

Consequently, erosion affects a large proportion of the earth's population. Direct (onsite effects) of erosion are for most people clear, e.g. soil loss (soil depth reduction),water loss, gully development, decreasing soil fertility with consequent productivity decline as well as disturbance of the water regime. However, erosion also includes less obvious or indirect effects, such as environmental pollution, enhanced flood risks due to river sedimentation and reduced water reservoir capacity and damage to buildings and infrastructure especially reservoirs, consequently affecting areas located on a further distance from the location where actual erosion is taking place (offsite effects).

One of the (most effective) means of doing this is the incorporation of erosion models to identify areas at risk, supporting policy making (Evans and Brazier, 2005 citation in RAMSOIL report 2.1). In the last years there has been a huge development in the use of GIS in spatial analysis of the various aspects including erosion risk aspects. Various methods for erosion risk assessment are used by various countries in Europe. Generally, three types of approaches exist to identify areas at risk (Eckelmann et al., 2006): qualitative approach, quantitative approach, and model approach,

Aims and objectives

The aim of this study is to evaluate applicability of these methods for various engineering purposes especially for water erosion control measures..

The objective of this study are as follow:

- to evaluate scale and outputs of the methods
- to evaluate applicability by sector.

Methodology

According the aims and objectives were analyzed the following methods and approaches: CORINE approach (EEA-1985); the RIVM (1992); "the Hot Spots" approach (EEA - 2000, based on previous maps by Favis-Mortlock and Boardman, 1999; de Ploey, 1989, and other data); USLE method (Universal Soil Loss Equation - Wischmeier & Smith, 1978). The INRA, PESERA approach (Gobin et al. -1999), the European Soil Erosion Model – EUROSEM - (Morgan et al., 1998), Limburg Soil Erosion Model – LISEM - (De Roo et al., 1996a and 1996b; Takken et al., 1999), WEPP (Water Erosion Prediction Project), KINEROS and Erosion Potential Model (EPM) established by Gavrilovic (1972), CREAMS (Knisel,1980; Foster *et al*., 1981), etc. After preliminary assessment, further analyses were aimed only to 6 methods: USLE, PESERA, KINEROS, WEP, WEPP and EPM. Some of the methods are developed in a very small scale and are interest only for general view of the state and general planning (CORINE, GLASOD, INRA..) and couldn't be used for solving engineering problems.

The elements for evaluation were scale and outputs (maps and values). The Erosion risk assessment methods are evaluated depend on: fulfilling various erosion related tasks; working scale; determination of various erosion types and finally per sector.

Qualitative research method was used. For this purpose were analyzed a lot of text as follow: descriptions of the methods from their official web-sites, description of the methods in literature, comments for various methods in other scientific papers. Evaluation was separated for purpose sector: agro-engineering, forestry-engineering water management and watershed management. The first output of these methods is map that is useful for preparation erosion control strategies.

Theoretical background

Erosion damages and interest of various sectors. Water erosion, along with its general consequences (soil loss, water loss, disturbance of runoff regime, torrential floods, reservoir siltation, irrigation and drainage systems siltation, etc.) causes great dam ages which can be classified as ecological effects. Ecological effects can be divided into two groups: on-site effects and off-site effects. On-site effects cause environment degradation due to intensive erosion processes and soil loss.
Off-site effects, by erosion, sediment transport through the watershed drainage pattern, is less visible and less studied. In the process of runoff on eroded slopes, along with soil particles (erosion sediment), all the other substances contained in the eroded soil layer are also removed. These substances can be natural (organic and inorganic) and artificial. Natural substances vary depending of geologic and pedologic properties of the slope or eroded region. Most often they are various fertilizers and pesticides applied in agricultural production and they reach the hydrographic network together with erosion sediment. After reaching the streams and reservoirs, erosion sediment has the following ecological (and other) adverse effects: a) mechanical pollution of stream and reservoir water, b) chemical pollution of water by manures and fertilizers c) chemical pollution by pesticides. (Kostadinov,S., 2002)

The main interest of **agricultural engineering** are soil losses including losses of organic matter and nutrient. Based on it, Agricultural engineer (AE) could plan and optimize fertilization. Next item of interest for agriculture are damages on agriculture land located in the valleys caused by flooding and covering by fertile sediments. Agricultural engineering can provide measures for reducing soil loss (including losses of organic matter and nutrients) through carrying out appropriate soil and water conservation measures. In a case of flooding by rivers AE couldn't provide solution except measures for avoiding risk. Flash floods usually origin from the mountain and like in a case of regional floods, agricultural engineering could provide only measures for risk avoidance. Related to Erosion risk assessment methods, the main interest for AE are methods that as output gave erosion rates as on-site damage and soil erodibility.
Forestry engineering (FE) consist of several main activities: silviculture, harvesting, forest protection and forest management planning. FE previously interest for on-site erosion damages. Erosion cause various damages on the forest land: sheet, mix or deep erosion on: bare forest land, on burned forest land, on forest land after logging and forest road network. Consequences of damages are different. On uncovered forest land, erosion cause soil losses, losses of organic matter and nutrients and all of this reduce even defeat growing of new forest. Engineers who work in the field of harvesting especially designing, construction and maintenance of forest road network interest of possible damages on the road infrastructure because it temporary disable their main activity - logging. Forest management planners pay attention on erosion with aim to avoid risk of it. However FE generally previously interest for erosion risk methods which output are erosion rates and soil erodibility.
Water management is previously the planned development, distribution and use of water resources.
Water management pay more attention on on-site damages as a result of fluvial erosion (especially on the stream banks), abrasive erosion and off -site damages (annual intensity of sediment load into the stream net, intensity of siltaion of the reservoirs, quantity of sediments that deposed in the downstream parts. For this type of erosion problems, are relevant methods that involve cinematic aspects especially transport capacity.
Watershed management is the planned use of drainage basins in accordance with predetermined objectives. Watershed management consist of: analysis, protection, development, operation or maintenance of the land, vegetation, & water resources of a drainage basin for the conservation of all its resources for the benefit of its residents. This is the most comprehensive sector that interest for all erosion types.

Description of erosion risk assessment methods

The assessment of erosion risk is specialized form of land resources evaluation , the objective of which is to identify those areas of land where the maximum sustained productivity from a given land use is trhreatened by excessive soil loss.
Soil erosion risk depends on many factors of which the most important are:

- rain erosivity
- soil erodibility.

Rain erosivity actually determines the total energy of rainfall impact on the unprotected soil. Rain drops act as mini bombs and, by their impact, cause soil destruction and enable the transport of detached soil particles by overland flow down the slope. For this reason, the term “soil bombardment by rain drops“ can be found in the professional literature.
Rain erosivity is expressed in different ways by different authors. The most frequently accepted is the so-called rainfall factor - R introduced by Wischmeier and Smith (Wischmeier, W.H., and Smith, D.D., 1958). Later on, rainfall factor became one of the parameters of (universally applied) Universal Soil Loss Equation – USLE (Morgan, R.P.C., 1986 citation in RAMSOIL, project report 2.1, 2006). F. Fournier expressed rain erosivity by the index of the rainfall aggressiveness – Rp (Kostadinov, S., 1996).

Soil erodibility depends on the soil physical characteristics and soil management (land management and organisation plus land use). The above parameters are also the components of the equation USLE.
Soil erosion risk can be expressed by the calculation of the mean annual sediment yield (Gavrilović, S., 1972) or by the calculations of soil loss caused by water erosion, by USLE. (Kostadinov,S., 2004)

In order to predict and also prevent soil erosion it is necessary to assess the potential and also the actual risk of soil erosion. For assessing soil erosion risk, various approaches have been adopted especially in the recent period. All these recent methods use geospatial databases developed using GIS technology. A problem with most methods based on scoring is that the results are affected by the way the scores are defined. In addition to this, classifying the source data in e.g. slope classes results in information loss, and the results of the analyses may depend strongly on the class limits and the number of classes used. Moreover, unless some kind of weighting is used each factor is given equal weight, which is not realistic. If one decides to use some weighting, choosing realistic values for the weights may be difficult. The way in which the various factors are combined into classes that are functional with respect to erosion risk (addition, multiplication) may pose problems also (*Grimm, Jones, Montanarela , 2002*).
A wide variety of models are available for assessing soil erosion risk. Erosion models can be classified in a number of ways. All methods could be divided as *expert*-based and *model*-based methods. One may make a subdivision based on the time scale for which a model can be used: some models are designed to predict long-term annual soil losses, while others predict single storm losses (event-based). Alternatively, a distinction can be made between lumped models that predict erosion at a single point, and spatially distributed models. Another useful division is the one between empirical and physically-based models. The choice for a particular model largely depends on the purpose for which it is intended and the available data, time and money (Grimm, Jones, Montanarela , 2002).
All of these methods require validation and calibration, appropriate for each category. Some of the models assess an already degraded soil resource, whereas others evaluate the risk of future erosion under different scenarios (Boardman and Poesen, 2006).

A large number of <u>empirically based models</u> are developed in the world.
The most wide empirically based model in the world is USLE method (Universal Soil Loss Equation - Wischmeier & Smith, 1978) and it’s variants: RUSLE and MUSLE, *PESERA approach (Gobin et al. - 1999),* KINEROS The INRA (Institut National de la Recherche Agronomique, France) approach is considered as an intermediate step towards a "state-of-the-art erosion modeling at the European scale", subsequent to the USLE approach and it is empirically based model too. The European Soil Erosion Model – EUROSEM - (Morgan et al., 1998) or the Limburg Soil Erosion Model – LISEM - (De Roo et al., 1996a and 1996b; Takken et al., 1999, cited in RAMSOIL 2.1 - 2006), one of the first models using GIS.

The most exposed <u>physically based models</u> contain are: CREAMS (Knisel,1980; Foster *et al*., 1981), ANSWERS (Beasley *et al*., 1980), and WEPP (1985,…, 2006).

The most exposed - an expert based erosion risk methods (approaches) in the recent period are: CORINE approach (EEA-1985); GLASOD (project Global Assessment of Soil Degradation - 1988, updated by Van Lynden 1994); the RIVM approach (developed by the Holland National Institute for public health and environment - 1992); “the Hot Spots” approach (EEA - 2000, based on previous maps by Favis-Mortlock and Boardman, 1999; de Ploey, 1989, and other data, cited in *Knijff van der J.M., R.J.A.Jones, Montanarella L., 2000:*). These approaches were previously used for development of erosion map of Europe or erosion maps of various parts of Europe.

Beside the up-mined world known methods, a large number of not exposed methods are developed In the world. Some of them use more specific mathematical tools as an artificial neural network **(**WANG Xie kang, FANG Duo - China), method of varying weights **(**WANG Xie kang, FANG Duo - China), Green's function Monte Carlo method (L. Mitas, H. Mitasova - USA) , *Erosion, Debris Flows and Environment in Mountain Regions* (Edited by D. E. WALLING, T. R. DAVIES, B. HASHOLT) IAHS Publication No. 209,

On the territory of ex- USSR, were developed methods based on various approach as follow: empirical approach (Bogoliubova and Karaushev -1979, Bobrovitskaya -1979, 1986); logical and mathematical models (Schwebs - 1974, 1981, 1991); hydromechanical models (Mirtskhoulava, 1966, 1970, 1989); mathematical models (Kondratjyev (1989) and other (all cited in *Bobrovitskaya N.N. (2002)*

On the territory of ex-SFR of Yugoslavia, Erosion Potential Model (EPM) was established by Gavrilovic.(Gavrilovic,S., 1972).

For some od these methods is developed appropriate software (KINEROS, WEPP…) and authors permanently upgrade it. In the recent period, software is upgraded to work in GIS environment. Other methods are useful in GIS environment. Some IT companies that produce GIS software develop special tool especially for erosion modeling as follow: ARC/INFO GIS-based flood Water modeling package, GRASS GIS-based hydrological modeling etc. There are some related software packages. Here should be mentioned HEC-RAS (software designed to perform one-dimensional hydraulic calculations for a full network of natural and constructed channels including flow simulation and sediment transport).

Basic facts of part of these methods are presented in the bellow text. Texts in Italic are citations from the official web-sites of the methods or site where they are presented.

The Universal Soil Loss Equation (USLE) predicts the long term average annual rate of erosion on a field slope based on rainfall pattern, soil type, topography, crop system and management practices. USLE only predicts the amount of soil loss that results from sheet or rill erosion on a single slope and does not account for additional soil losses that might occur from gully, wind or tillage erosion. This erosion model was created for use in selected cropping and management systems, but is also applicable to non-agricultural conditions such as construction sites. The USLE can be used to compare soil losses from a particular field with a specific crop and management system to "tolerable soil loss" rates. Alternative management and crop systems may also be evaluated to determine the adequacy of conservation measures in farm planning. (http://www.omafra.gov.on.ca/english/engineer/facts/00-001.htm).

The kinematical runoff and erosion model KINEROS is an event oriented, physically based model describing the processes of interception, infiltration, surface runoff and erosion from small agricultural and urban watersheds. *The watershed is represented by a cascade of planes and channels; the partial differential equations describing overland flow, channel flow, erosion and sediment transport are solved by finite difference techniques. The spatial variation of rainfall, infiltration, runoff, and erosion parameters can be accommodated. KINEROS may be used to determine the effects of various artificial features such as urban developments, small detention reservoirs, or lined channels on flood hydrographs and sediment yield. KINEROS uses one-dimensional kinematic equations to simulate flow over rectangular planes and through trapezoidal open channels, circular conduits and small detention pond. Multi-gage rainfall input is distributed by assigning rain gages to overland flow planes. The infiltration algorithm is dynamic, interacting with both rainfall and surface water in transit. Rain splash and hydraulic erosion are an option for overland flow planes; hydraulic erosion for channels .Eroded sediment may be routed through any type of element, even those with noneroding surfaces. (http://www.tucson.ars.ag.gov/kineros/)*

The European Soil Erosion Model (EUROSEM) is a dynamic distributed model, able to simulate sediment transport, erosion and deposition over the land surface by rill and interill processes in single storms for *both individual fields and small catchments. Model output includes total runoff, total soil loss, the storm hydrograph and storm sediment graph. Compared with other erosion models, EUROSEM has explicit simulation of interill and rill flow; plant cover effects on interception and rainfall energy; rock fragment (stoniness) effects on infiltration, flow velocity and splash erosion; and changes in the shape and size of rill channels as a result of erosion and deposition. The transport capacity of runoff is modeled using relationships based on over 500 experimental observations of shallow surface flows. EUROSEM can be applied to smooth slope planes without rills, rilled surfaces and surfaces with furrows* *http://www.es.lancs.ac.uk/people/johnq/EUROSEM%20ESPL.pdf*

The Water Erosion Prediction Project (WEPP) was developed by the USDA-ARS as a replacement for empirically based erosion prediction technologies, the WEPP model simulates many of the physical processes important in soil erosion, including infiltration, runoff, raindrop and flow detachment, sediment transport, deposition, plant growth, and residue decomposition. The WEPP model can be used for common hillslope applications or on small watersheds. Because it is physically based, the model has been successfully used in the evaluation of important natural resources issues throughout the U.S. and in many other countries. Upgrades to the modeling system since the 1995. DOS-based release include Microsoft Windows operating system graphical interfaces, web-ased interfaces, and integration with Geographic Information Systems. Improvements have been made to the watershed channel and impoundment components, the CLIGEN weather generator, the daily water balance and evapotranspiration routines, and the prediction of subsurface lateral flow along low-permeability soil layers. A combined wind and water erosion prediction system with easily accessible databases and a common interface is planned for the future. The current version available for download is applicable to hillslope erosion processes (sheet and rill erosion), as well as simulation of the hydrologic and erosion processes on small watersheds. http://www.ars.usda.gov/Research/docs.htm?docid=10621

CREAMS (Chemicals, Runoff and Erosion from Agricultural Management Systems) is a field scale model for predicting runoff, erosion, and chemical transport from agricultural management systems. It is applicable to field-sized areas. CREAMS can operate on individual storms but can also predict long term averages (2-50 years). This model estimate runoff, percolation, erosion, and dissolved and adsorbed plant nutrients and pesticides. It could be used for: a single land use, relatively homogeneous soils, spatially uniform rainfall, and single management practices, such as conservation tillage or terraces. *http://ecobas.org/www-server/rem/mdb/creams.html*

The CORINE programme is an example of an expert-based approach and was established in 1985 The CORINE soil erosion risk maps are the result of an overlay analysis by a geographical information system, enabling the evaluation of the soil erosion risk category. The main source of information used was the soil map of the European Communities (CEC, 1985). Potential soil erosion risk was defined as the inherent risk of erosion, irrespective of current land use or vegetation cover (CORINE, 1992). The CORINE soil erosion assessment has the great advantage of simplicity, in that it provides a clear forecast, on an objective basis, for the whole of the area studied. The CORINE methodology is based, at least in principle, on the Universal Soil Loss Equation (USLE), a well-established technology that has been very widely used, both in north America and elsewhere in the world. Being based on a factorial method using a 1km x 1km grid, the method can be applied, using a GIS, at a resolution that allows discrimination within regional areas. Conventional wisdom suggests that the method correctly identifies areas of the Mediterranean that have the highest risk of erosion. (http://www.preventionweb.net/files/1581_ereurnew2.pdf)

The PESERA approach (Gobin et al) is a process-based and spatially distributed model to quantify soil erosion by water and assess its risk across Europe. The principles and theoretical background are presented for a PESERA that is designed to estimate long term average erosion rates at 1 km resolution for most of Europe. The model is built around a partition of precipitation into components for overland flow (infiltration excess, saturation excess and snowmelt), evapotranspiration and changes in soil moisture storage. Transpiration is used to drive a generic plant growth model for biomass, constrained as necessary by land use decisions, primarily on a monthly time step. Leaf fall, with corrections for cropping, grazing etc, also drives a simple model for soil organic matter. The runoff threshold for infiltration excess overland flow depends on vegetation cover, organic matter and soil properties, varying dynamically over the year, and drives overland flow using the distribution of daily rain amounts. Total erosion is driven by

erodibility, derived from soil properties, powered overland flow discharge and gradient; and is assessed at the slope base to estimate total loss from the land. The model is run, using monthly averages and distributions of daily precipitation, to equilibrium in order to estimate long term averages, and is being validated against the limited erosion data available. Data sources, uniformly available across Europe, include the European Soils Data base, CORINE land use, MARS 50 km interpolated climate data and 90m DEM (SRTM).
(http://www.geog.leeds.ac.uk/fileadmin/downloads/school/groups/pesera/Kirkby_Pesera_submitted.pdf)

As part of a major report on strategies for the European Environment (RIVM, 1992), a baseline assessment of water erosion was prepared for 1990. This assessment of current risk (was combined with climate and economic projections within the framework of the IMAGE 2 model to generate scenario projections for 2010 and 2050. This approach, also expert-based, has the advantage of making explicit scenario projections, a feature lacking in other approaches, but is currently only available at 50km resolution, so that it cannot readily be interpreted at sub-national scales. It may be seen that the soil erodibility takes a similar form to CORINE or USLE, with components for soil type, and a simplified gradient and index. The rainfall erosivity component is seen as an inadequate representation, which contains neither the theoretical basis underlying USLE nor the fair empirical alternatives provided in CORINE. The RIVM method exploits the potential, inherent in any physically based or factor based assessment, of providing scenario analysis, through the inclusion of two dynamic components, the monthly rainfall totals (affecting erosivity) and land cover (affecting the assessed actual erosion). However, neither the 50km resolution nor the implementation of the factors contributing to erosion is seen as providing a state-ofthe-art assessment. (http://www.preventionweb.net/files/1581_ereurnew2.pdf)

The main objective of the GLASOD – Global Assessment of Soil Degradation - was to bring to the attention of decision makers the risks resulting from inappropriate land and soil management to the global well-being. International Soil Reference and Information Centre (ISRIC), in 1988 produced a scientifically credible global assessment of the status of human-induced soil degradation within a very short timescale. The task was subcontracted to correlators in 21 regions to prepare, in close cooperation with national soil scientists, regional soil degradation-status maps, that could subsequently be combined and correlated to produce the GLASOD world map of soil degradation. he information and data on soil erosion and physical degradation in the Dobris assessment (EEA, 1995) are based on an updated version of the European part of the GLASOD map. For this update (van Lynden, 1994), questionnaires were sent to scientific teams in each European country for comments and additions on the original GLASOD assessment. Not all countries completed and returned the questionnaires and the degree of detail of the information received varies greatly. It must also be noted that the scale of the maps (1:10,000,000) limits the detail that can be shown, providing a minimum resolution of approximately 10 km.
(http://www.preventionweb.net/files/1581_ereurnew2.pdf)

An analysis and mapping of soil problem areas (Hot Spots) in Europe was published in the EEA-UNEP joint message on soil (EEA, 2000). This addresses a number of soil problems. The purpose of the study was to support the joint message on the need for a pan-European policy on soil, identifying 'hot spots' of degradation in Europe and examining environmental impacts leading to change and particularly degradation of soil function. The work involved compilation and analysis of data available at the EEA, together with additional data from the scientific literature. These data were incorporated into a GIS for manipulation and display. The map produced has been developed from earlier maps (Favis-Mortlock and Boardman, 1999; de Ploey, 1989), based on local empirical data, as opposed to CORINE or other estimates based on erosion models, that are considered unsuitable for application at coarse scales (Turner et al, 2001). In the Hot Spots approach, expert knowledge is used to identify broad zones for which the erosion processes are broadly similar. Hot Spots are then highlighted within each zone, and associated with the best estimates, from the literature, for rates of erosion in these hotspot areas. The intention is to identify areas of current erosion risk, under present land use and climate, as opposed to either evidence of past erosion, or of the potential for erosion under some hypothetical conditions. The data provides general or particular information about water erosion for approximately 60 sites or small regions across Europe, with measured erosion rates, which could be placed on the map at 35 sites. Measurements are taken from erosion plots, fields and small catchments. (http://www.preventionweb.net/files/1581_ereurnew2.pdf).

The approach elaborated by INRA (Institut National de la Recherche Agronomique, France) should be considered as an intermediate step towards a "state-of-the-art erosion modeling at the European scale", subsequent to the USLE approach (Van der Knijff et al., 2000) and prior to the initiation of the PESERA project. The model uses empirical rules to combine data on land use (250 m resolution raster version of the CORINE Land Cover database at scale 1:100,000), soil crusting susceptibility, soil erodibility (determined by pedotransfer rules from the Soil Geographical Data Base of Europe at scale 1:1 Million), relief (1 x 1 km resolution raster digital elevation model) and meteorological data (25 years of daily meteorological data at 50 km resolution). Factors influencing erosion have been graded for the diverse geographical situations existing in Europe and erosion mechanisms have been expressed with the help of experimental and expert-defined empirical rules. Land cover and crust formation on cultivated soils were considered as key factors influencing runoff and erosion risk .It bases on a modeling approach using a hierarchical multifactorial classification. It is designed to assess average seasonal erosion risk at a regional scale. The model is based on the premise that soil erosion occurs when water that cannot infiltrate into the soil becomes surface runoff and moves soil downslope. A soil becomes unable to absorb water either when the rainfall intensity exceeds surface infiltration capacity (Hortonian runoff), or when the rain falls onto a saturated surface because of antecedent wet conditions or an underlying water table (saturation runoff). (http://www.preventionweb.net/files/1581_ereurnew2.pdf).

Erosion Potential Model (EPM) developed by Gavrilovic S. was based on field researches carried out in South Serbia closely to the Macedonian border. This model is accepted in Macedonia too and comparison with direct measuring proofed it's validity. There are two EPM approaches: expert-based method (used for develop of the Erosion Map of Serbia, 1975 and Erosion map of RMacedonia 1993) and empirical based model. The characteristics of these models are different. Also, EPM was is used for Erosion Map of Bosnia and Herzegovina, 1985, and for some case studies in Croatia , Slovenia, Czech Republic and etc. Erosion Potential Method is based on producing of erosion map for the watershed or erosive region. The coefficient of erosion Z is a numerical expression of the intensity of soil erosion in the watershed . Coefficient of erosion is calculated based on erosion map of the watershed and the formula given by Gavrilovic. (Kostadinov,S., 2000). Erosion Potential Method is based on producing of erosion map for the watershed or erosive region. Erosion map produced by S. Gavrilović's method has been used for watershed management plans for the whole territory of Serbia in 1988. Also the space plan for Serbia is now being produced for, which erosion map is an unavoidable basis. Erosion map is also necessary in land use plans.Finally it should be stated that, in addition to Serbia, erosion maps of Bosnia and Herzegovina and Macedonia have been produced according to this method. (Kostadinov,S., 1987). The erosion map of the watershed or, of the erosive region can be used as the basis for:calculation of production (gross erosion) and transport of sediment for the watershed by EPM (S. Gavrilović's) method or any other method. This is significant especially for the non gauged watersheds (which have not been hydrologically researched), i.e. without measured data on water discharge and sediment transport. These data are necessary for the designs of all types of construction dealing with water; design of all kinds of erosion control and torrent management works. Based on erosion map, erosion control works can be planned at the localities in the watershed. In addition to the above, erosion map is necessary as one of the bases for watershed management plans for different sizes of watersheds. Erosion map produced by S. Gavrilović's method has been used for watershed management plans for the whole territory of Serbia in 1988. Also the Spatial plan for Serbia is now being produced for, which erosion map is an unavoidable basis. Erosion map is also necessary in land use plans.

Former researches related to the study topics

All these methods vary in their characteristics and applicability. All already developed methods and approaches are improved in the recent period through use of geospatial databases developed using GIS technology. Some critics of these method were carried out by Morgan R., Quinton j.r, Smith R., Govers G., , Poesen J., Auerswald K., Chisci D., Torri etc. The most comprehensive cross analyze of various method for erosion risk assessment was carried out within the RAM-SOIL project (2006). Within this project were evaluate 5 characteristics of the methods: scale, transparency, complexity, cost efficiency and ambiguousness. Evaluation was made using expert judgment approach.

Results and discussion

Results of all erosion risk methods could be: numerical (expressed in t/h or $m^3.km^2$ etc), graphical (analog map) or numerical-graphical (digital map prepared using GIS techniques).

Erosion risk assessment methods could be used for various tasks as follow: assessment of average pattern of erosion risk, identification of high risk areas, identification of hot spots, location of depositional and major concentrated flow areas, detailed erosion and deposition pattern and effects of conservation measures, detailed impact of erosion on roads

Evaluation of selected methods

Evaluation of various methods is presented in the above table.
Erosion risk assessment methods (ERAM) could be used for various tasks as follow: assessment of average pattern of erosion risk, identification of high risk areas, identification of hot spots, location of depositional and major concentrated flow areas, detailed erosion and deposition pattern and effects of conservation measures, detailed impact of erosion on roads

Table 1 Evaluation of various ERAM depend on fulfilling various tasks

	assessment of average pattern of erosion risk	**identification of high risk areas**	**identification of hot spots**	**location of depositional and major concentrated flow**	**detailed erosion and deposition pattern**	effects of conservation measures	**detailed impact of erosion on roads (on-site)**	**Estimation of total transported material**	**NOTICE**
USLE	+	+	+	-	-	+	-	-	
PESERA	+	-	-	-	-	-	-	-	
KINEROS	+	+	-	-	-	+	+	-	
EUROSEM	+	+	-	+	+	+	+	-	
WEPP	+	+	+	+	+	+	+	-	
EPM	+	+	+	+	+	+	-	+	

For fulfilling various tasks, the most comprehensive methods are; EPM, EUROSEM and WEPP.

Scale of the result of the erosion risk assessment methods could be on: field (hill slope, parcel), small watershed, large watershed.

Table 2 Evaluation of various ERAM depend on the scale

Method (Model)	On field (parcel)	Small watershed	Large watershed	notice
USLE (MUSLE,RUSLE)	+	+	-	On - site damages - yes; Off - site damages - no
PESERA	-	-	+	Grid 1km
KINEROS	+	+	-	
EUROSEM	+	+	-	
WEPP	+	+	-	
EPM	-	+	+	

No one of the methods is applicable for all scales. More of the methods are useful for on-field analysis or small watersheds. Otherwise EPM method is applicable only for watersheds.

Erosion risk assessment methods could be used for estimation erosion rates of various processes: overland flow: unit or average sheet and individual rills, concentrated and preferential flow (individual gullies, roads, tracks), stream flow (specific and average bank erosion), concentrated flow (large gullies), flow in rivers and streams, sedimentation into the reservoirs. Later based on the outputs could be: designed measures, plan location of conservation measures, planning large conservation areas.

Table 3 Evaluation of various ERAM depend on solving various erosion types

Method (Model)	Sheet erosion	Rill erosion	Gully erosion	Fluvial erosion	Landslides, rock falls,	deposition	notice
USLE	+	+	-	-	-	-	
PESERA	+	-	-	-	-	-	Developed for large area
KINEROS	+	+	-	+	-	?	
EUROSEM	+	+	+	+	-	+	
WEPP	+	+	-	-	-	+	
EPM	+	+	+	+	+	+	

The USLE is not able to predict deposition or the pathways taken by eroded material as it moves from hillslope sites to water bodies. Beside it, the USLE and WEPP can't define gully erosion or quantity of material origin from extreme events as landslides or rock falls. But in a case of dominant erosion types on agriculture areas where on-site effects are dominant i.e. sheet and rill erosion, these methods are the most comprehensive. Otherwise, the EPM method and EUROSEM can estimate erosion intensity never mind the erosion type.

In the chapter theoretical background were presented the main interest of various sectors

Table 4 Evaluation of various ERAM depend on the sector

Method (Model)	Agriculture	Forestry	Water management	Watershed management	Notice
USLE	+++	+	-	-	
PESERA	> + <	-	-	-	
KINEROS	> + <	+	+	-	
EUROSEM	+	+	+	+	
WEPP	++	+	-	-	
EPM	-	+	+	+	

> + < - partially

For solving erosion related problems in **agriculture**, where on-field soil loss and soil erodibility are the dominant interest, the following methods are recommended: USLE, WEPP, EUROSEM.

Regarding the **forestry engineering** purposes, depend on the activity various methods are more or less relevant. For silviculture engineering (planting, thinning etc), dominant interest are on-site damages on small area, so the most appropriate methods are the same as for agricultural engineering. For harvesting especially forest road construction the most appropriate are methods that result in on-site damages but various erosion types. For this purpose, EUROSEM fulfill all needs.

Water management interest mainly for off-site damages as deposition by flash flooding and on-site damages (fluvial erosion). For on-site damages KINEROS and EUROSEM are the most appropriate, but for off-site damages solving the EPM.

Watershed management is the most comprehensive area that perhaps unify all above mentioned, This sector interest for all erosion types, all tasks related to erosion problems are relevant. Scale of work is from small to large watershed. Because of that for this type of work the EPM is perhaps the most relevant because gave answer on all tasks.

Fact that should be appointed is that empirically-based methods need calibration and validation for any region. Beside it some methods (USLE, MUSLE, RUSLE) need a lot of data related to the rainfall intensity i.e. to be defined parameter R and soil characteristics to be defined parameter K. It is limited factor for use of these methods somewhere.

Comments on other methods

More of the other mentioned above methods are in fact approaches used for development of erosion map of Europe (CORINE, GLASOD, INRA, HOT-SPOT). These maps are prepared using GIS technology and mathematical method with square GRID. The size of grid was 1km x 1km. Value in the pixel could be estimated using one of various models, to be defined through direct measuring on plots or to be define using exert-judgment. Next step is interpolation of the results using GIS software tools and categorization of the results. The final result is a map in a large scale. This map is useful for general view of erosion as a problem. For engineering purposes, this type of approach is not useful.

Conclusion

For agricultural engineering needs, the most appropriate method is USLE. But limiting factor is abscenc of dfata and calibration of some parameters. WEPP and EUROSEM are useful for this sector too.

For forestry engineering , in acase os silvicultural engineerin the most relevant are USLE< EUROSEM and WEPP. Related to forest road construction and maintenance, the most relevant metrhod is EUROSEM although the WEPP gave limited results.

KINEROS and EUROSEM are the most appropriate methods fro estimation on-site damages related to water management, but EPM for estimation off-site damages (especially total annual transported material to any reservoir).

Related to the watershed management need, the EPM is the most comprehensive method because it gave solution to almost all tasks.

For the Balkan territory, the EPM method is the most appropriate for hilly-mountain and mountain region, but use of USLE for agricultural area (hilly and valley) is limited because of absence of data (Macedonia, Serbia, Bosnia, Montenegro..). This method although analytical, very easy could be used in GIS environment.

References

Blinkov I., Mincev I., Jagev V., 2007: *GIS aided erosion risk analysis, I III Congress of ecologists of Macedonia with international participation 6-9 October 2007, Struga / Macedonia*

Blinkov I., Mincev I., Trendafilov B, 2008: *Erosion risk analyses on the Vodno mountain and impact to the surrounding areas, BALWOIS conference, Ohrid 25-28.05.2008, proceeding*

***Blinkov I., Mincev I., Trendafilov A., Nikolov N. 2008**: Develop of risk maps - An EU-funded RIMADIMA project 5D102, report related to the w.p4.*

***Blinkov I., Mincev I. 2009:** Multyhazard mapping as a tool for effective risk management, International Conference "Land Conservation" - LANDCON 0905 - 26-30.05.2009, Tara, Serbia*

***Blinkov I., Trendafilov A., Milevski I., 2009:** GIS-based model for assessment of erosion factors, International scientific symposium "Geography and sustainable development"22- 25.10. 2009 Ohrid , Macedonia*

***Bobrovitskaya N.N. (2002):** Erosion and sediment yield modelling in the former USSR, Modelling erosion, sediment transport and sediment yield, Edited by Wolfgang Summer and Desmond E. Walling, IHP-VI Technical Documents in Hydrology No. 60, UNESCO, Paris, 2002 pg 31-46*

***Boardman and Poesen, 2007** - Soil erosion in Europe*, monograph, Willy and sons 2007

***Douglas I.**, 2003 Predicting road erosion rates in selectively logged tropical rain forests, Erosion Prediction in Ungauged Basins: Integrating Methods and Techniques (Proceedings of symposium I-IS01 held during IUGG2003 at Sapporo. July 2003). IAHS Ptibl. no. 279. 2003.*

***Đorđević, M., Jovanovski, S., Lazarević, R. (1987)**: Soil Erosion in SFR Yugoslavia. (in Serbian) First Yugoslav Symposium of Soil Ersion and Torrent Control, Lepenski Vir, Serbia, May 20-21, 1987.*

***Gay, D., Rouet I., Mangeas M., Dumas P., Selmaoui N.** Assessment of classification methods for soil erosion risks pg. 2659-2665*

***Gavrilović, S., 1972**: Torrents and Erosion Engineering; Periodical "Izgradnja" - Special Edition, Belgrade(in Serbian)*

***Graedts, L., Rectala-Boix. L., Ano-Vidal. C., Ritsema J. 2006,** Risk Assessment methods of Soil Erosin by water, RAMSOIL FP6 project, EC, report, 2006*

***Grimm. M., R.J.A.Jones, Montanarella L., 2002** Soil erosion risk assessment in Europey, EC, ESB, JRC, 2002 (revised)*

***Hutzenlaub N., Brajkovic M., 2009** , Soil Erosion Risk Assessment, University of natural and applied sciences BOKU, Viena, 2009*

***Kostadinov, S.(1987):** Some results of the investigation on sediment regime in torrents of experimental watersheds. Geochemistry and monitoring in representative basin. International worksop ″Geomcn″, Prague, Czechoslovakia. April 27-May 1., 1987. p.p45-47.*

***Kostadinov,S., (2000)** Soil Erosion and Sediment Transport in the Torrents of Serbia. XX Conference of the Danubian Countries on " Hydrological Forecasting and Hydrological Bases of Water Management"; Bratislava, Slovakia, 4-8 September 2000. Papers on CD. Abstract Book p.p. 76.*

***Kostadinov,S., (2002)**- Erosion and Torrent Control in Mountainous Regions of Serbia; Proceedings,Keynote paper; International Year of Mountainous Conference:" Natural and Socio-Economic Effects of Erosion Control in Mountainous Regions; Edited by: M.Zlatić, S.Kostadinov, N.Dragović; Belgrade/ Vrujci Spa; Dec.10-13,2002; p.p.33-56 .*

***Kostadinov, S., Zlatić M., Dragović N.,, Todosijević M., and Popović I., (2004) :** Factors of Soil Erosion Risk on the Slopes of Mt. Avala, "Chemistry and Industry" ,Scientific Information Journal. Union of Chemists in Bulgaria.Sofia.*

Knijff van der J.M., R.J.A.Jones, Montanarella L.,2000: *Soil erosion risk assesment in Italy, EC, ESB, JRC, 1999*

Knijff van der J.M., R.J.A.Jones, Montanarella L., 2000*:Soil erosion risk assesment in Europey, EC, ESB, JRC, 2000*

Lambrechtsen N., Hicks D., 2001*Soil Intacteness/Erosion Monitoring Technicues, North Oukland , 2001*

Larkin L.,Titmarsh. G.,2007 *Condamine Catchmemnt Water Erosion monitoring, Quinsland National Land&Water Resources Audit, 2007*

Milevski I., Blinkov. I., Trendafilov A., 2008: *Soil erosion processes and modeling in the upper Bregalnica catchment, **XXIVth Conferen**ce of the Danubian countries on the hydrological forecasting and hydrological bases of water management, 2-4.06.2008, Bled Slovenia, proceeding*

Mincev I., Blinkov I., 2007: *GIS model for assessing water and sediment discharge based on the Gavrilovic methodology**,** International Conference **«**Erosion and torrent control as a factor in sustainable river basin management**»** 25-28 September 2007, Belgrade/Serbia*

Morgan R. P. C. et al 1998: *The European Soil Erosion Model (Eurosem): A Dynamic, Approach For Predicting Sediment Transport From Fields And Small Catchments*: *Earth Surf. Process. Landforms* **23**, 527–544 (1998)

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., Folly, A.J.V. 1998 *EUROSEM (European Soil erosion model) - guide, Cranfield university, 1998*

Web-sites:

http://www.ars.usda.gov/Research/docs.htm?docid=10621

http://ecobas.org/www-server/rem/mdb/creams.html

http://www.es.lancs.ac.uk/people/johnq/EUROSEM%20ESPL.pdf

(http://www.tucson.ars.ag.gov/kineros/)

http://www.omafra.gov.on.ca/english/engineer/facts/00-001.htm

http://www.preventionweb.net/files/1581_ereurnew2.pdf

(http://www.geog.leeds.ac.uk/fileadmin/downloads/school/groups/pesera/Kirkby_Pesera_submitted.pdf)

(http://www.preventionweb.net/files/1581_ereurnew2.pdf)

http://www.ramsoil.eu/NR/rdonlyres/9179FD01-072A-449C-8EE4-CE1DC33DFF76/56313/PR21Erosionreport.pdf