Soil Erosion Workshop 2022

Abstracts

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Session 1

Sediments

EuSEDcollab: A collaborative European database from monitored watershed outlets

Francis Matthews

Sediment yield and water discharge measurements from monitored catchments provide valuable insights into the processes governing soil erosion and sediment delivery across a spectrum of spatial and temporal scales. This data provides an essential baseline for further model application and development, allowing their confrontation with physical measurements of process rates. As a user-orientated EUSO initiative, we present a collaborative European database of measurements from monitored watersheds in Europe based on inputs from the research community. We propose a data harmonisation procedure with accompanying meta-data that can facilitate analysis across spatial domains in Europe. This database seeks to provide the research community with a starting point for new research opportunities in a range of sediment-related research avenues, as well as the opportunity to iteratively improve its design and content through user-based feedback.

Towards a global, georeferenced database of contemporary sediment yield observations

Florence Tan[1], Pasquale Borrelli[2], Gert Verstraeten[1], Anatoly Tsyplenkov[3], Benjamin Campforts[4],Valentin Golosov3, Bernhard Lehner5, Jean Poesen1,6, Matthias Vanmaercke1

[1] Department of Earth and Environmental Sciences, KU Leuven, Leuven, Belgium
[2] Department of Earth and Environmental Sciences, University of Pavia, Pavia, Italy
[3] Faculty of Geography, Lomonosov Moscow State University, Moscow, Russia
[4] Institute for Arctic and Alpine Research, University of Colorado, Boulder, USA
[5] Department of Geography, McGill University, Montreal, Canada
[6] Institute of Earth and Environmental Sciences, UMCS, Lublin, Poland

Sediment yield (SY) observations exist worldwide but remain poorly accessible, especially for large-scale studies. This is in part because many of these measurements are collected on an isolated basis, leading to inconsistencies across data sets. To address these shortcomings and provide a standardized global reference for SY data, we are developing an extensive, coherent and georeferenced global database of contemporary annual SY observations. Through a comprehensive review of (grey) literature and contacts with numerous research groups, we already compiled SY observations for >10,000 catchments worldwide (including >5,000 European catchments). Here we present a first overview of the data collected so far, its spatial patterns and its research potential.

Rainfall thresholds for soil erosion processes in an agricultural catchment in Poland

Jolanta Święchowicz <https://orcid.org/0000-0002-0040-8378>

Institute of Geography and Spatial Management, Jagiellonian University in Kraków, 7 Gronostajowa Str., 30-387 Kraków, Poland; jolanta.swiechowicz@uj.edu.pl

Rainfall thresholds for soil erosion by water were determined based on rainfall data for a 23-year period (1987−2009) and field data (2007−2009) on raindrop erosion, slope wash and linear erosion in an agricultural foothill catchment in southern Poland. As transport of eroded soil downslope and its supply to stream channels result from different processes, there are several thresholds involved in soil erosion. This research describes the frequency and probability of crossing thresholds for splash, slope wash and linear erosion and the movement of sediment directly into river channels (transfer thresholds). On the basis of the field research, rainfall thresholds for splash erosion were EI30 = 2.3 MJ mm ha-1 h-1 or I30 = 1.6 mm h-1. Rainfall thresholds for slope wash were EI30 = 100.0 MJ mm ha-1 h-1 or I30 = 20.0 mm h-1, and those for linear erosion were EI30 = 106.0 MJ mm ha-1 h-1 or I30 = 30.0 mm h-1. The movement of soil from slopes to river channels occurred at EI30 = 40.5 MJ mm ha -1 h-1 or I30 = mm h-1, when part of soil material was transported and locally deposited on slopes, not transforming the slope morphology in any visible way (first transfer threshold). The values were EI 30 = 106.0 MJ mm ha-1 h-1 or I30 = 30.0 mm h-1, when the material was only transported from the water divide to the foot of the slope and deposited there (second transfer threshold) and EI30 = 226.8 MJ mm ha-1 h-1 or I30 = 35.0 mm h-1, when the soil was supplied directly to the stream channel (third transfer threshold).

Exploring the relationship between water turbidity and sediment concentration in agricultural experimental watersheds in Navarre (Spain)

Eduardo Luquin[1], Miguel Ánge[l] Campo-Bescós[1], Iñigo Barberena[1], Javier Eslava[2], Javier Casalí[1], Rafael Giménez[1]

[1]Dep. of Engineering; IS-FOOD Institute (Innovation & Sustainable Development in Food Chain) – Public University of Navarre, Pamplona, Spain.
[2]Division of Soils and Climatology, Department of Rural Development and Environment, Government of Navarre, Pamplona, Spain.

In site-specific and small watersheds, the variability in the nature and composition of suspended particles often leads to a weak association between suspended sediments and turbidity. The objective of this study is to establish a calibrated model to predict the sediment concentration (SC) in four agricultural watersheds from high-resolution turbidity data and other simple variables that help to explain the watershed's hydrology. In the experimental watersheds of Navarre (northeast Spain), between 512 to 765 samples per watershed were taken during high runoff-erosive events. Results showed that SC was moderately correlated to turbidity. A single regression model could not be fitted for all data. However, good correlations were found during shorter time periods when conditions are more uniform and stable. Other important findings and implications will be presented.

Post-fire impact of sediments on water quality and their drivers in Portuguese reservoirs

Niels Nitzsche1, niels.nitzsche@gmx.de; João Pedro Nunes[1,2], joao.carvalhonunes@wur.nl; Joana Parente[1], joaparente@gmail.com

[1]Centre for Ecology, Evolution and Environmental Changes (cE3c), Faculty of Sciences, University of Lisbon, Portugal
[2]Soil Physics and Land Management Group, Wageningen University & Research, the Netherlands

Wildfires, through elevated soil erosion and ash deposits, can create impacts on aquatic ecosystems and ultimately water supply. After a wildfire, surface waters experience increased imports of fine sediments, nutrients, and other water quality related constituents.For our study we searched for post-fire changes in long term time series of TSS (and other water quality parameters in Portuguese reservoirs. The time series were spanning mainly from 2000–2018 and contamination events were spotted via changepoint analysis.Post-fire sediment impacts were seen after some fires, with the strongest impacts being after the 2003-2005 fire seasons in the Algarve region. Fire size (as % of the watershed area burnt) and the post-fire reservoir water levels were identified as the main drivers for a change.

From code to sediments, an example of two tools for soil erosion monitoring

Ivan Lizaga[a], Borja Latorre[b], Leticia Gaspar[b], Ana Navas[b]

[a] Isotope Bioscience Laboratory - ISOFYS, Department of Green Chemistry and Technology, Ghent University, Coupure Links 653, 9000, Gent, Belgium
[b] Estación Experimental de Aula-Dei (EEAD-CSIC), Spanish National Research Council, Zaragoza, Spain. Avenida Montañana, 1005, 50059 Zaragoza, Spain

Soil erosion and sediment delivery to rivers are important drivers of land degradation and environmental change worldwide, and their understanding is key to guaranteeing food security and water quality. To this end, and thanks to the computational improvements, several tools have been developed to either facilitate the use of existing models or create new tools to understand sediment transport and soil erosion better. In this research, two recently developed tools are explained, one to automate the use of the widely used WaTEM/SEDEM model and the FingerPro package to analyse the sediment provenance.

Assessment of soil losses on agricultural slopes in Poland

Ewa Smolska[1], Jerzy Rejman[2], Jan Rodzik[3], Krzysztof Stępniewski[3], Józef Szpikowski[4], Jolanta Święchowicz[5]

[1] University of Warsaw, Poland
[2] Institute of Agrophysics PAS, Lublin, Poland
[3] Maria Curie-Skłodowska University, Lublin, Poland
[4] Adam Mickiewicz University, Poznań, Poland
[5] Jagiellonian University, Kraków, Poland

Soil losses were assessed on runoff plots that were located in 5 sites of Poland in 2007-2009. Experimental sites varied by soil texture from sand and loamy sand to silt loam. Plots were located on slopes with inclination of 2-8^0. Plots 22.1 m long with bare soil, crops (potatoes, sugar beets, cereals) and grassed. Additionally, plots of other lengths (11.1, 5.5 and 2.8 m) were located on 4 sites. After each period of rainfall, runoff and soil loss was measured. Annual precipitation was varied from 453 to 814 mm, R-factor from 567 to 1828 $MJ \cdot mm \cdot ha^{-1} \cdot h^{-1} yr^{-1}$. Studies showed that largest soil losses were found on silt and loamy silt (20-30 t/ha), smaller on loamy sand and sand (2,4-3 t/ha). Overall the results are in line with the study for Europe (Panagos et al. 2015). Analyzing soil loss data from plots of different length, total soil loss for sugar beet increased with plot length, for potatoes was similar on plots 22.1 and 11.1 m, and for cereals - on plots of 22.1, 11.1 and 5.5 m long. The results showed that sediment transport is prevailing on short distances with its deposition inside longer plots.

Wildfire ash: the illusive component of post-fire erosion

R. Martins[1], L. Godoy[1], L. Simões[1], I. Gama[2], I.P. de Lima[2], J.P. de Lima[2], J. Keizer[1]

[1] University of Aveiro, Portugal
[2] University of Coimbra, Portugal

Rural fires can lead to major increased in the risks of on-site soil losses and of associated off-site impacts such as flooding, silting-up of reservoirs and surface water contamination during the so-called window-of-disturbance. This window-of-disturbance often lasts just a single hydrological year but can last several, depending especially on the development of an effective protective soil cover through spontaneous mulching, post-fire vegetation recovery or development of a stone lag. Post-fire erosion rates have been quantified for fire-prone areas across the world, especially at the plot to slope scale (as opposed to the catchment scale). However, the contribution of wildfire ash to the reported erosion rates has not been quantified in any study hitherto, even if the importance of wildfire ash in terms of nutrient losses and contaminant experts is widely recognized. Arguably, the main reason for this knowledge gap is the lack of a reliable methodology to separate the ash component from the other eroded sediments collected in field studies. Therefore, the ASHMOB and ASHES projects have carried our several laboratory and lysimeter experiments to improve the insights in wildfire mobilization by overland flow. The envisaged presentation will give a overview of these experiments and present some of their most relevant findings.

Sediment export in agricultural lands: highlights from the Experimental Agricultural Watershed Network of the Government of Navarre (Spain)

Javier Casalí1, Eduardo Luquin[1], Miguel Ángel Campo-Bescós[1], Javier Eslava[2,] Iñigo Barberena[1], Rafael Giménez[1]

[1] Dep. of Engineering; IS-FOOD Institute (Innovation & Sustainable Development in Food Chain) – Public University of Navarre, Pamplona, Spain.
[2] Division of Soils and Climatology, Department of Rural Development and Environment, Government of Navarre, Pamplona, Spain.

This study describes the data acquired in a long-term monitoring program in the Experimental Agricultural Watersheds Network developed by the Government of Navarre (http://cuencasagrarias.navarra.es/), consisting of five watersheds. Along with other variables, discharge and suspended sediment concentration data were collected at each watershed outlet for fifteen hydrological years (2007-2021) on 10 minutes and daily, respectively, and loads were computed from discharge and concentration values. Results showed a significant interannual and seasonal runoff and sediment export variability. In general, the two Mediterranean rainfed cereal watersheds (3.04 ± 3.48 Mg ha^{-1} in La Tejería and 1.14 ± 1.44 Mg ha^{-1} in Latxaga) showed higher erosion rates than the sub-Atlantic watersheds with pasture and forest (1.28 ± 0.84 Mg ha^{-1} in Oskotz Principal and 0.98 ± 0.72 Mg ha^{-1} Oskotz Forested). The updated data and the main peculiarities of these relevant experimental watersheds will be presented in the workshop.

Sediment yields from mildly sloping cultivated fields – case study of Nucice catchment, Czech Republic

David Zumr, Jakub Jeřábek, Tailin Li, Tomáš Dostál

Faculty of Civil Engineering, Czech Technical University in Prague, 16629, Prague 6, Czech Republic
david.zumr@cvut.cz

Nucice catchment is a small experimental site (51 ha) established for monitoring of water balance, runoff and soil erosion processes in an intensively cultivated landscape. The area is from 95% composed of arable soils with three fields tilled to the edges of the drainage channel, part of the catchment is tile drained. Based on the long term monitoring of runoff and sediment yields at the catchment's outlet we show that even a landscape with low slopes, but inadequate soil management, releases a considerable amount of sediment downstream. The effects of soil erosion are not usually apparent in the field as the visible preferential sediment pathways or rills develop only rarely. But still increased turbidity is detected at the catchment's outlet during the rainfall events. We explain the rapid movement of the eroded soil particles mainly by preferential sediment routing via slope-wise oriented wheel tracks. A plot scale study with a rainfall simulator was done to quantify the wheel tracks effect on sediment transport. The results show that during a rainfall event the wheel tracks and adjacent soil surface get quickly connected, eroded soil particles are transported towards the wheel tracks and routed into the bottom parts of the catchment. Therefore contour tillage, as has been demonstrated already by several teams in various conditions, is a feasible and very efficient measure to reduce the soil erosion.

Water erosion monitoring in a small loess agricultural micro-catchment

Jan Jadczyszyn[1], Jerzy Rejman[2]

[1]Department of Soil Science and Land Conservation, Institute of Soil Science and Plant Cultivation - State Research Institute, Poland,
[2]Department of Plant and Soil Relations, Institute of Agrophysics – PAS, Poland

Monitoring of water erosion is carried on in the loess catchment of the area of 0.95 ha in Rogalów, Nałęczów Plateau, Lublin Upland, Poland (51˚19'06" N latitude, 22˚08'30" E longitude). The catchment is very prone to water erosion. The difference in altitude is 19 m and the average slope is 7.6°. The catchment is a part of larger arable field. Monitoring of water erosion in the catchment has been continued from 2003.
The catchment is equipped with a sluice-gate for measurements of water erosion. The installed flow probe (SIEMENS) measures the intensity and cumulative flow of water, and results are registered by data logger. The surface runoff is measured for each individual erosive rainfall and snowmelt event. The installation enabled to register flows up to 2.36 $m^3 \cdot s^{-1}$. Samples of runoff are taken manually in intervals of 5-10 minutes during the runoff events. Concentration of sediment, organic matter and nutrients is determined in the samples. Automatic weather station with precipitation, air and soil temperature sensors is installed at the distance of 50 m to the catchment outlet.
The studies enabled to collect data that could be useful to determine relations between water erosion and precipitation during singular erosion events and at the annual scale, and factors that affect delivery of organic matter and nutrients to streams. The studies enabled also to analyze the effect of crops on water erosion at the catchment scale as the experimental site is used as a single field with a one crop during a year.
The presentation includes a description of the research scheme and examples of water erosion monitoring.

Dynamic Erosion Model and Monitoring System (DEMIS)

Kenan Ince[1], Ayten Demirhan[1], M. Ali Akdag[1*], Iskender Demirtas[1*], Gunay Erpul[2]

[1]Ministry of Environment, Urbanization and Climate Change, General Directorate of Combating Desertification and Erosion, Ankara, TURKEY

[2] Department of Soil Science and Plant Nutrition, Faculty of Agriculture, University of Ankara, TURKEY

*Corresponding Authors: iskender.demirtas@csb.gov.tr, mehmetali.akdag@csb.gov.tr

Soil erosion is a considerably increasing problem from land degradation, agricultural intensification, and anthropogenic degradation of the environment. Estimation of soil erosion and evaluation has become an important and immediate mission by many countries before implementing soil preservation applications. There is much recent published literature on the application of the Revised Universal Soil Loss Equation (RUSLE) model with combined GIS technology for predicting soil erosion amount. Turkey also has a rapid assessment of the combined application of RUSLE and GIS, a Dynamic Erosion Model and Monitoring System (DEMMS) is accordingly established to monitor soil erosion in micro-basin to 25 river-basins based on the five RUSLE components and technically reinforced by Remote Sensing and GIS. The DEMMS successfully generated all erosion statistical results for three essential land use types including agricultural, forest, and basin lands. Besides, all statistical results obtained by the DEMMS and it provides erosion severity distribution maps on which detailed action plans on a province scale for preventing soil erosion would be ably implemented.

Suspended sediment transport in a lowland small catchment on example of the upper Szeszupa river (NE Poland)

Ewa Smolska

University of Warsaw, Poland

The studied catchment area of 14.2 km^2 is characterized by a typical postglacial relief in NE Poland. The river is 4.6 km long. It is an agricultural catchment with a predominance of pastures. The monitoring carried out in 1988-1989, 1998-1999 and 2007-2010 covered various hydrometeorological conditions. Extreme discharges amounted to 0.08 and 0.73 m^3s^{-1}. The highest concentrations of suspended material were recorded during heavy rainfall (25-46 mm) with erosivity EI_{30}> 200. The river's reaction to rainfalls was short (from one to several hours), the SSC was usually 150-300 gm^{-3} and the SSL was in the range of 2-5 t. Extreme rainfall which occurred on 17.05.2010 (P = 46 mm; EI30 = 608 MJ mm ha^{-1} h^{-1} yr^{-1} resulted in the highest SSC = 560 gm^{-3}, and the SSL reached 17.8 t. On the other hand, during the thaw, the measured concentration was small (below 150 gm^{-3}), but due to high discharge for 5-7 days, the SSL was significant (7-11 t). The catchment response to rainfall was clear in May and June. Later, the vegetation limited the sediment supply to the river bed.

Identifying a reliable method for estimating suspended sediment load in a temporary river

De Girolamo Anna Maria*[1], Di Pillo Raffaele[2], Lo Porto Antonio[1], Todisco Maria Teresa[2], Barca Emanuele[1]

[1] Water Research Institute, National Research Council, Bari, Italy
[2] DICEAA, Department of Civil, Environmental and Architecture Engineering, University of L'Aquila, Italy

Sampling strategies and methods used for estimating load can lead to large uncertainties in suspended sediment transport quantification when suspended sediment concentrations are discrete measurements. The aim of this work is to evaluate suspended sediment load, using a number of direct estimation techniques, in order to find a suitable method for temporary river systems, and to assess the uncertainty associated with load estimation, due to the specific method applied. One year of continuous measurement of flow, and discrete sampling (n = 216) of SSC, taken in the Celone River (SE, Italy), were used to estimate annual load. Averaging, ratio, and regression estimator methods were applied to the entire dataset, and to subsets of data, to calculate load. The results show a wide range of values, from 220 to 1123 t km−2 yr−1, with respect to the applied suspended sediment load estimation techniques. Averaging methods resulted biased. Sediment rating curves underestimated load, while, if the back-transformation bias correction was used, load was overestimated. The ratio methods generally overestimate load. Increased precision and accuracy were achieved through applying data stratification, based on flow regime and seasonality.

Session 2

Farm/Field scale modelling

Erosion risk assessment in olive orchards through a combined approach based in stakeholders, GIS and RUSLE

Gómez, José A.[1], Sánchez, A.[1], Soriano, M.A.[2], Guzmán, G.[1]

[1] Institute for Sustainable Agriculture. CSIC. 14004. Cordoba Spain.

[2] Department of Agronomy, University of Cordoba, Campus of Rabanales, Madrid-Cádiz Road Km. 396, 14014 Córdoba, Spain.

This ongoing cooperative project aims to evaluate the hillslope water erosion risk of the Protected Appellation of Origin Estepa, in Southern Spain, encompassing approximately 40,000 ha of olives under different soil management systems, from bare soil using tillage or herbicide to temporary cover crops. Its final goals are to establish a monitoring system to detect areas with higher risk of soil erosion, raise farmers' awareness on the need to improve soil care and, overall, to contribute to the improvement of soil conservation in the region.

Runoff mitigation via micro-dams and conservation tillage—Numerical modeling of runoff and erosion from maize field trials

Sittig Stephan

We have evaluated maize field trials conducted over complete seasons with the application of mitigation measures, i.e. micro-dams (small earthen dams between the rows) and/or conservation tillage (in the form of subsoiling). Besides reporting the effects on water runoff and soil erosion quantitatively, the goal was to derive input parameters for regulatory models, i.e. the runoff curve number (CN) and the C—parameter for the MUSS equation. To this end, we have simulated the trials over the complete seasons with the model PRZM and inversely estimated values for these parameters. Mean resulting CN reductions by micro-dams or conservation tillage were ascertained to be 6% (±2.5%) or 12% (±3.0%), the C-factor was reduced by a factor of 0.1 (±0.15) or 0.48 (±0.19). Example calculations show reductions in the ranges of 11%–100% for PECs (EU risk assessment) and 30%–98% for EECs (US risk assessment).

Making vineyards more sustainable and resilient to soil erosion: experiences from the SOiLUTION SYSTEM project

Eugenio Straffelini[1], Paolo Tarolli[1]

[1] Department of Land, Environment, Agriculture and Forestry, University of Padova, 35020 Legnaro (PD), Italy. eugenio.straffelini@unipd.it; paolo.tarolli@unipd.it

Steep slope viticulture is a common practice in Europe. Under particular conditions, vine cultivation has led to the creation of cultural landscapes of immense historical, social, and economic value. One example is the Soave wine production area (Veneto region, Italy), an FAO-GHIAS site where heroic viticulture has been practised for centuries. These territories are characterised by complex landforms that are inherently susceptible to extreme rainfall events that are occurring more frequently due to climate change. Related problems are surface overflow and soil erosion, which cause landslides, terrace wall collapses and widespread land degradation. In order to make steep slope viticulture more resilient, it is essential to increase vineyard sustainability. That is the reason behind the SOiLUTION SYSTEM project (*www.soilutionsystem.com; Programma di Sviluppo Rurale per il Veneto 2014–2020*), developed as part of a multidisciplinary collaboration between the University of Padova, the Soave Wine Consortium and other local entities (such as farms, research centres and a land reclamation consortium). The aim is to identify an integrated system of environmentally and economically sustainable interventions able to reduce erosion risk and improve soil management in hill and mountain viticulture. Specifically, we emphasized the crucial role of high-resolution spatial data derived from remote sensing technology for monitoring surface processes at different spatial scales. Within the project, a modelling approach was applied to assess the runoff and erosion occurring after intense rainfall for 5 different vineyard configurations in an extensive comparison of 50 study areas (Pijl et al., 2022). Furthermore, we investigated the hydrogeological risk mitigation capacity of 4 different inter-row soil management, also testing a grass cover able to increase vineyard biodiversity (Straffelini et al., 2022). The methodology is based on simulations using a physically-based model (SIMWE) on high-resolution UAV-SfM data and a cost-effective field measurement procedure. Project findings could become guidelines for better steep-slope vineyard management under climate change conditions, supporting stakeholders in selecting more sustainable farm governance (Tarolli and Straffelini, 2020).

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Assessing soil erosion rates at vineyard scale: a study case in North-West Italy using different DEM resolutions for the LS factor computation

F. Palazzi[1,2], M. Biddoccu[1], E. Borgogno Mondino[2], E. Cavallo[1]

[1] Institute of Sciences and Technologies for Sustainable Energy and Mobility (STEMS) – National Research Council of Italy (CNR), Turin, Italy

[2] Department of Agricultural, Forest and Food Sciences (DISAFA) – Turin, Italy

francesco.palazzi@stems.cnr.it, marcella.biddoccu@stems.cnr.it, enrico.borgogno@unito.it, eugenio.cavallo@stems.cnr.it

Soil erosion is an important issue in sloping areas where vineyards are typically grown. In vineyards, differentsoil management can be applied to reduce soil losses, although multiple factors affect this soil degradation process. The Revised Universal Soil Loss Equation (RUSLE) is one of the most widely used models to assess soil management role in reducing soil erosion at field scale. The RUSLE topographical LS factor can nowadays be derived from a Digital Elevation Model (DEM) in a GIS environment. Different algorithms have been developed to obtain LS automatically. Differences in the results between operator-measured and algorithm-derived values available in SAGA GIS were tested for different DEM geometrical resolutions (5, 10 and 25 m). Linear regression helped identifying the best combination of both parameters. Additionally, SAGA algorithms provided information on the spatial variability of this factor within the field as well. The resulting soil losses were then computed with the ORUSCAL model (a simplified version of RUSLE2) for different fields within a hilly study area in the Alto Monferrato (NW Italy), considering different inter-row soil managements. As expected, DEMs with a higher resolution gave the best results ($R2 \geq 0.8$) for all algorithms in both LS and soil loss estimates. In any case, results for soil loss estimates showed that an inter-row management having a consolidated grass-cover can significantly reduce soil erosion within the vineyard. Soil losses estimates equally displayed a certain degree of variability (average coefficient of variation: 30%), highlighting the importance of correctly assessing this factor using data characterised by a good geometric resolution.

Simulation of ephemeral gully erosion in the agricultural fields of Navarre (Spain)

Eduardo Luquin[1], Youssef Chahor[1], Miguel Ángel Campo-Bescós[1], Iñigo Barberena[1], Rafael Giménez[1], Javier Casalí[1]

[1] Dep. of Engineering; IS-FOOD Institute (Innovation & Sustainable Development in Food Chain) – Public University of Navarre, Pamplona, Spain.

Ephemeral gully (EG) erosion is an important soil erosin class, and produces substantial soil losses. However, watershed models including an EG component are scarce and not properly evaluated. Our study analyses the Annualized AGriculture Non-Point Source Pollution Model (AnnAGNPS) capabilities to simulate the EG erosion in Navarre (Spain). The EG dataset includes four EGs, of which their dimensions, date of appearance, and land use and management of the fields are known for five years. Once properly validated, the model has been used to simulate scenarios such as annual tillage vs. no-tillage. Preliminary results indicate that the model correctly simulates 80% of the gully formation events. In addition, in the study fields, the magnitude of soil erosion decreases considerably under no-till vs annual tillage (-43%). A more in-depth explanation of how the model simulates EG and results will present during the Workshop.

Modelling post-fire erosion at event scale

Marta Basso[1] , Jantiene Baartman[2], Martinho Martins[1], Jacob Keizer[1], Diana Vieira[3]

[1] CESAM - Centre for Environmental and Marine Studies, Department of Environment and Planning, University of Aveiro, Aveiro, Portugal
[2] Soil Physics and Land Management group, Wageningen University, Wageningen, The Netherlands
[3] Joint Research Centre (JRC), European Commission, Ispra, Italy

Wildfires are a recurrent threat to Mediterranean basins, endangering the water quantity and quality in downstream waterbodies. The increase in overland flow and erosion yield that is generally observed in recently burned areas is closely linked to rainfall events with substantial volumes and/or elevated intensities. Simulation at hourly, daily, and coarser time scales are less adequate to predict the risks of post-fire flood events and peaks in sediment concentrations and yields due to the smoothing effects on the results. However, few studies have modeled post-fire runoff-erosion events at sub-hourly resolutions. To this end, the present study aims to compare the capability of two hydrological models to simulate quickflow and sediment transport during the first year after a fire to ultimately understand which one would best serve as a post-fire hydrological assessment at event scale.

Transforming Unsustainable management of soils in key Agricultural Systems in EU and China – a Decision Support Tool for soil erosion

Raquel Falcão[1], Josef Krasa[1], Michal Vrana[1], Tomas Dostal[1], José Gomez[2], Mllanos Lopez[3], Gema Guzmán[2]

[1] Czech Technical University, Czech Republic[2]

[2] CSIC, Spain

[3] AgriSat Iberia, Spain

Within the scope of the TUdi project, EU Horizon 2020 Grant Agreement No 101000224, meetings involving different stakeholders were held, along with a questionnaire that was responded by almost 400 farmers from seven different countries in Europe and China. This aimed to assess the major concerns of farmers, and to develop Decision Support Tools targeted at these issues. The questionnaires also revealed that a considerable number of farmers do not use official data, nor digital maps to help make decisions. The first tool currently being developed targets soil erosion and aims to provide farmers with publicly available historical satellite imagery in a user-friendly platform, as well as guidelines on easy-to-use methodology to assess the degree of soil erosion on the field. With this, the project hopes to contribute to democratising the access to science, helping farmers – ultimately, the ones who implement soil conservation practices, to make data driven decision on soil management exploring different alternatives. The preliminary version of this tool will be presented at the workshop.

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Estimating Soil Surface Roughness by proximal sensing for soil erosion modelling implementation at field scale

G. Matranga[1], A. Leanza[2], F. Palazzi[1], A. Milella[3], E. Cavallo[1], G. Reina[2], M. Biddoccu[1]

[1] Institute of Sciences and Technologies for Sustainable Energy and Mobility (STEMS), National Research Council of Italy (CNR)
[2] Department of Mechanics, Mathematics, and Management, Politecnico di Bari
[3] Institute of Intelligent Industrial Technologies and Systems for Advanced Manufacturing (STIIMA), National Research Council of Italy (CNR)

Soil Surface Roughness (SSR) is a physical feature of soil microtopography, which is strongly influenced by tillage practices and plays a key role in hydrological and soil erosion processes. Therefore, surface roughness indices are required when using models to estimate soil erosion rates, where tabular values or direct measurements are typically used. Field measurements often imply out-of-date and time-consuming methods, such as the pin meter and the roller chain, providing inaccurate indices. A novel technique for SSR measurement has been adopted, employing an RGB-Depth camera to produce a small-scale Digital Elevation Model of the soil surface, in order to extrapolate roughness indices. The values obtained for SSR indices were implemented in the MMF (Morgan-Morgan-Finney) and ORUSCAL (Orchard RUSLE CALibration) models, to validate the reliability of the proposed methodology by comparing the models' results for sediment yields with long term soil erosion measurements in sloping vineyards in NW Italy.

Application of laboratory-scale pressurized nozzle type rainfall simulator in study of sediment yield

V. G. Jadhao[1], Ashish Pandey[2], and S. K. Mishra[3]

[1]Research Scholar, Department of Water Resources Development & Management. Institute of Technology Roorkee-247667, INDIA Email: jgunvantrao@wr.iitr.ac.in (corresponding author)

[2] Professor, Department of Water Resources Development & Management, Indian Institute of Technology Roorkee-247667, INDIA Email: ashish.pandey@wr.iitr.ac.in

[3] Professor, Department of Water Resources Development & Management, Indian Institute of Technology Roorkee-247667, INDIA Email: s.mishra@wr.iitr.ac.in

In the absence of natural rain, a rainfall simulator is an advanced tool for characterizing raindrop sizes and conducting field studies on soil erosion and infiltration. It is essential to develop various empirical models to correlate various rain and soil erosion parameters for different localities due to timely non-availability and changes in the microphysics of rainfall. A rainfall simulator with six pressurized nozzles (Spraying System Co.) of different capacities and a Laser Precipitation Monitor (LPM) was engaged to generate various intensities (21.14 to 78.93mm/hr) and register rain granulometry, respectively. A soil erosion flume of size 2.50×1.25×0.56m with an adjustable longitudinal slope was used to investigate the sediment transportation induced by rainfall and runoff. Various rain characteristics, including drop size, spatial uniformity, raindrop velocity, drop size distribution, and kinetic energy, were estimated through conducting 32 experiments per slope. The Simulator produces the median drop sizes of 0.38 to 2.11mm at generated rain intensity coincides with natural rain. Experiments were performed at flat, 5, 10, and15% slope of the erosion flume to record the runoff and sediment yield. Various linear and non-linear empirical models were developed through multiple regressions to correlate sediment yield and rain intensity with optimization of the parameters from obtained results. The developed models yielded the best fit ($R2= 0.75$ to 0.93; $P<0.001$). The residual analysis of the developed models performed for accuracy testing showed a lower estimate of MAE, MSE, and RMSE errors. The slope is revealed as a main contributing factor to sediment transport. The results indicated that the natural rain conditions could be simulated in the laboratory with sufficient accuracy for measuring sediment transport.

Spatio-temporal variability in surface soil moisture under different landuses in southwestern Nigeria

Adewole, A.O. and Eludoyin, A.O.

Department of Geography, Obafemi Awolowo University, Nigeria

This study investigates the spatial dynamics of soil moisture in different landuses/cover using SM150 Delta-T Soil moisture kit at 20 randomly selected points within 25m by 25m quadrat in each landuse/cover. Records of rainfall and ground temperature were also examined due to their dominant influence on soil moisture content. Preliminary results showed different level of wetness in different landuses under same weather conditions and that soil properties differ across the landcover/use types.

Session 3

Erosion mitigation & management practices

From assessing soil erosion to estimating its costs for Luxembourg society

Christian Braun[1], Claudia Hitaj1, Núria Martínez-Carreras[1], Gaëtan Fourvel[2]

[1] Luxembourg Institute of Science and Technology (LIST), Environmental Research and Innovation (ERIN) Department, 41 rue du Brill, L-4422 Belvaux, Luxembourg
[2] Luxembourg Environnent Agency, Strategy and Concept Unit, 1 avenue du Rock'n'Roll, L-4361 Esch-sur-Alzette, Luxembourg

Soil erosion may have negative outcomes on the plot where it occurs but also much further in the catchment through the sediment movements. In order to make stakeholders fully aware of these multiple consequences, we undertook to estimate the economic costs induced by soil erosion directly on the eroded agricultural plots (on-site costs) and indirectly out of these plots (off-sites costs). To quantify soil erosion, we used the WaTEM/SEDEM model (Van Oost et al., 2000) which was calibrated using data from four reference catchments. Then the findings calculated from these catchments were extrapolated at national level and were used in order to estimate the on-site costs (i.e. costs of agricultural productivity loss and nutrient loss) and the off-site costs (i.e. costs of the soil C loss leading to GHG emissions, nitrates removal in drinking water, nutrients impacts in rivers, sediments management in rivers and reservoirs) of the soil erosion in Luxembourg. Despite the relative lack of data which constrained us to make several unverifiable assumptions to be able to convert soil erosion estimates into economic costs, we believe that the estimates of the soil erosion costs are a precious tool to convince stakeholders to strive to limit soil erosion and its induced social and environmental damage.

Challenges and shortcomings of current vegetative filter strip research, design, and implementation

David Ramler, Elmar Schmaltz & Peter Strauss

Institute for Land and Water Management Research (BAW-IKT), Austrian Federal Agency for Water Management

Vegetative filter strips (VFS) are considered best management practices with the primary aim of protecting surface waters from eutrophication resulting from excess sediment and nutrient inputs from agricultural sources. However, there is a substantial time and knowledge lag from the science underpinning VFS to policy and implementation. In this presentation, we introduce overdue conceptual changes in VFS research and management, based on an updated, more holistic approach. Examples from the literature and ongoing experiments at the BAW-IKT illustrate shortcomings and challenges encountered in current VFS practice and shall initiate a discussion. The focus is on phosphorus; however, the suggested ideas and measures are to a large extent also transferable to other nutrients and issues related to erosion and runoff.

Comparing tree mastication and helimulching effectiveness for soil losses mitigation after wildfire in NW Spain

Cristina Fernández

Centro de Investigación Forestal de Lourizán-Xunta de Galicia (Spain)

Mulching application after severe fire is a common practice to reduce erosion risk after fire in NW Spain. Usually, agricultural straw is applied aerially from helicopters to protect large areas of burned land in a relatively short time. In recent years, mastication of non-commercial burned trees has become a common practice as a way of providing cover on the burned soil and preventing erosion. However, little is known about its possible effects. A field experiment was carried out in two forest areas affected by wildfire to determine whether helimulching treatment has a similar effect than mastication of non-commercial trees in reducing post-fire soil loss during the first two years after fire in NW Spain. The obtained results showed a better performance of helimulching when the masticated material is not efficient covering the burned soil.

Soil moisture data from cosmic-ray neutron sensors for addressing soil degradation

Gaspar et al.

According to the UNCCD, more than 40% of all land on earth is now “degraded” due to unsustainable land and water use and harmful agricultural practices. To ensure sustainable agricultural management, there is a need not only to quantify soil erosion rates but also to obtain information on the impacts of soil loss and water hold capacity under different land uses. A clear understanding of the temporal dynamics and spatial variability of soil moisture will help to control soil degradation by hydrological processes. In this study, we are investigating the sensitivity of using cosmic-ray neutron sensor (CRNS) for quantifying different dynamics of soil moisture along a toposequence with underlying contrasting parent materials. Our preliminary results indicate that CRNS captured soil moisture dynamics along the toposequence and demonstrated the sensitivity of neutron sensors to investigate the effect of parent material on soil water. Together with soil erosion rates estimated by 137Cs fallout, the combination of these nuclear techniques may result in a better understanding of how water content affects the process of soil degradation.

Statistical evaluation of Agricultural terraces control on soil erosion

Pascal Breil[c]; Arnaud Cerbelaud [abc] ; Laure Roupioz[a] ; Gwendoline Blanchet[b]; Xavier Briottet[a]

[a] ONERA, DOTA, Université de Toulouse, F-31055 Toulouse, France
[b] Centre National d'Etudes Spatiales (CNES), EO Lab, 31400 Toulouse, France
[c] Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnement (INRAE), UR RiverLy, 69100 Villeurbanne, France

Agricultural terraces, built on slopes, are known to limit soil erosion, promote water retention and increase yield. This information is mainly feedback from experimental plots (Deng et al., 2021). Agricultural terraces are now seen as a method of adaptation to climate change, which in some regions will result in prolonged droughts interspersed with intense rainfall events (e.g. Kosmowski, 2016). The question of their resistance to extreme rainfall remains. The research work presented here exploits the comparison of Sentinel2 satellite data acquired before and after the storm Alex that hit the south of France in October 2020. A change detection model (Cerbelaud et al., 2021) is used to assign a probability of damage to agricultural plots. Outside the major river beds, this damage is the consequence of intense runoff with erosion and deposition processes. The territory studied is that of the Alpes Maritimes, located on the Mediterranean coast. It still has many terraces maintained or used for the cultivation of olive trees. The approach consists in evaluating whether the probability of damage is statistically lower in plots with terraces than in plots without terraces. The results indicate a significant effect of terraces on damage limitation in agricultural plots.

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Connectivity elements and mitigation measures in policy-relevant soil erosion models: A survey across Europe

Elmar M. Schmaltz

This study is was conducted within EJP-SOIL's SCALE-Project and provides an overview of the current soil erosion and sediment transport model applications in European countries with policy relevance at various spatiotemporal scales. The analysis was performed on the basis of survey responses from 46 soil erosion model users across 18 European countries. The most widely used model type among the respondents was the Universal Soil Loss Equation and its other versions. About two-thirds of the model applications were used by an authority for soil erosion risk assessment or implementation of mitigation measures. The analysis highlighted the use of different parameters, also between models of the same type, and the prevalence towards use of national or regional datasets. Although the majority of modellers stated to include one or more of the proposed connectivity elements in their modelling procedure, detailed modelling of sediment connectivity was only focused on in a few model applications.

The not so micro effects of micro-dams on surface runoff and soil erosion in potato farming

Matthias Konzett*, Peter Strauß, Elmar Schmaltz

Potatoes are particularly vulnerable to erosion because of their late seed development and the unique seedbed structure; thus, there is a need to mitigate further adverse effects of erosion. This study determined the effects of micro-dams and cover crops in the furrows on surface runoff, soil erosion, soil water content, and potato yield over three years. The results show a reduction of surface runoff on the greened variants between 40 – 68% and 50 – 95% on the micro-dam variants compared to the control variant. Similar ranges have been measured in terms of soil erosion reduction: the sediment yields observed on the greened variants were 48 – 83% lower, and the ones on the micro-dam variants were 79 – 98% lower than those of the control variant. While the soil water content was significantly higher on the micro-dam variants compared to the control or greened variant, no significant difference was observed regarding the potato yield.

Erosion and sediment transport using UAV derived data: a field study in fruit orchards in Spain

Saskia Keesstra, Henk Kramer, Artemi Cerdà

In the framework of the SENRES project funded under the European Joint Programme on Soil a almond orchard in Eastern Spain has been evaluated on erosion features and sediment relocation within the field. The study revealed recurrent rill formation and a very high relocation of sediment redistribution within the field. In another field UAV data was collected in two adjacent fields with a new orange plantation where the terraces were removed; and a terraced orange plantation. The new orange plantation includes drip irrigated systems. The plant rows are far apart to allow tractors to drive between the trees to spray chemicals on the trees and soil and for harvesting. To allow this industrialized farming system the traditional terraces have been removed and new soil has been transported to the field. We found that the number of rills and other erosion features in the new plantation compared to the old one were more than a number of magnitude larger in the new field after a mid-sized summer rainstorm event. This shows that the sustainability of the new, CAP subsidized fruit plantations is very low and policy should reconsider to subsidize such unsustainable systems.

Automated planning tool for potential windbreak plantings to reduce wind erosion

Simon Scheper[1,2,3], Barbara Kitzler[2] and Kerstin Michel[2]

[1]Dr. Simon Scheper – Research | Consulting | Teaching, DE-29413 Dähre, Germany
[2]Federal Research and Training Centre for Forests, Natural Hazards and Landscape, AT-1131 Vienna, Austria
[3]Environmental Geosciences, University of Basel, CH-4056 Basel, Switzerland

One of the most effective measures to prevent or at least reduce wind erosion is the planting of natural windbreaks like hedges, tree rows, or shrubs. However, when deciding where to plant a windbreak, many variables and criteria must be considered to help select the most appropriate locations. We have developed an automated routine that suggests the best locations for potential windbreaks based on a wind erosion risk assessment, consideration of existing windbreaks, land use classes, and the vicinity to roads for a study region in Eastern Austria. The routine is highly transparent, can be transferred to other regions and can be adapted to the user's needs. Our goal with this first step in the planning chain is to support policymakers to deal with the construction of windbreaks.

Can a multi-modelling approach provide more detail about runoff and soil erosion under different management techniques and reduce model uncertainty?

Ana Rita Lopes

Department of Environment and Planning, Centre for Environmental and Marine Studies, University of Aveiro,Portugal.

Modelling can be a powerful tool for forest management decision, especially considering the actual and potential extreme climate demands. Among the several approaches for modelling the hydrological anderosive response in forest lands, one can apply an empirical or physically based model developed for the process, or apply a statistical model to the same dataset. In general, the adaptation and calibration of pre-developed model are often data-demanding, whereas the statistical approach is often site-specific. Plowing is one of the most common management techniques applied before and after a wildfire toprepare the forest soil for new use. These techniques can further change the hydrological connectivity of burned areas and add heterogeneity to the soil properties and hydrological response. However, such management operations are often not included in the model structure, although various researchers already developed several ways to tackle their impacts for agricultural lands, but not for burned forest areas. Through the application of a semi-empirical soil erosion model (revised MMF), and a statistical based model (MRM), was possible to calibrate 12 soil erosion plots over 3 years period assessing their different pre-fire soil management practices, such as doing nothing (unplowed) and two distinct plowing configurations (downslope plow, contour plow). Our preliminary results show that both model performances are better for individual management practices, such as unplowed and contour plowing, while modelling results revealed inefficient predictions for predict downslope plowing soil erosion after wildfire. These results indicate a potential base for multi-modelling application towards better soil erosion predictions and their management in an efficient soil erosion prevention, but also by considering not only the wildfire and local characteristics but also the previous forest soil management as an important factor for emergency mitigation acting.

Assessing and Mapping Water Erosion in Korifla Watershed in Central Morocco, Using RUSLE Equation, GIS, and Remote Sensing

Houda Lamane[1, 2, *], Latifa Mouhir[1], Rachid Moussadek[2, 3], Bouamar Baghdad[4], Abdelmjid Zouahri[2]

[1] Laboratory of Process Engineering and Environment, University of Hassan II, Mohammedia, Morocco
[2] Research Unit on Environment and Conservation of Natural Resources, National Institute for Agricultural Research, Rabat, Morocco
[3] International Center for Agricultural Research in the Dry Areas (ICARDA)
[4] Georesources and Environment Laboratory, Department of Natural Resources and Environment, Hassan II Agronomy and Veterinary Institute, Rabat, Morocco.

Soil erosion by water is one of the major threats to our planet's soils. Data on soil loss are essential to support agricultural productivity and natural resource management. In this context, modeling can provide a quantified and consistent approach to assessing soil erosion and sediment yield under a wide variety of conditions in order to find appropriate solutions to this problem. The application of Geographic Information Systems (GIS) and Remote Sensing (RS) techniques allows the identification of potential risk areas and the quantification of displaced material rates, thanks to an overlay of thematic maps of the different factors involved in this phenomenon.

In this study, modeling of water erosion is conducted in the Korifla watershed, classified as a site of biological and ecological interest (SBEI) by the Moroccan Ministry of the Environment, in addition to its location near the SMBA dam that irrigates the largest cities in Morocco. The Revised Universal Soil Loss Equation (RUSLE) model integrated with geographic information system (GIS) and remote sensing (RS) data was applied in modeling the combination of input factors (Rainfall erosivity, Soil erodibility, Cover-Management, Topography, Support practices) in erosion phenomena with the most recent available datasets, in order to estimate the potential annual and spatial variation of soil erosion and to propose appropriate erosion control management measures independently of the erosion rate and the characteristics of the study area. The parameters used for this model were prepared from climate data, field data and satellite images (sentinel-2).

The output is a quantitative map, indicating soil erosion rates from 0 to 5.52 (t/ha/yr), reveals that the region under study is characterized by low soil loss rates (84.60%). The zones with a value of slightly high factor (LS) are marked by a moderate vulnerability to erosion. Based on these results, specific proposal management were developed, such as slope farming, land use planning, hydro-agricultural development, trail improvement, forestry management, water system development, and trail opening and maintenance .

Implementation of an indoor/outdoor laboratory in the teaching of applied geography: usefulness and applicability in the teaching-learning processes of soil erosion studies

Jesús Rodrigo-Comino[1], Jonatan Arias-García[1], Jesús Fernández Gálvez[1]; Andrés Caballero-Calvo[1]; Víctor Hugo Durán Zuazo[2]; Artemi Cerdà[3].

[1] Departamento de Análisis Geográfico Regional y Geografía Física, Facultad de Filosofía y Letras, Campus Universitario de Cartuja, Universidad de Granada, 18071 Granada, España; jesusrc@ugr.es; jariasgarcia@ugr.es; jesusfg@ugr.es; andrescaballero@ugr.es
[2] IFAPA Centro "Camino de Purchil", Camino de Purchil s/n, 18004, Granada, Spain
[3] Soil Erosion and Degradation Research Group, Department of Geography, Valencia University, Blasco Ibàñez, 28, 46010 Valencia, Spain

Environmental degradation and especially, soil erosion is a pressing problem for humans and natural ecosystems. In accordance with the Sustainable Development Goals (SDGs) formulated by the United Nations, governments and institutions must be active in proposing solutions to issues related to environmental degradation. Higher Education, and disciplines such as Geography, must play a key role in the training of specialists. This didactic methodology consists of the implementation of an indoor/outdoor laboratory that allows progress in the teaching-learning processes related to awareness and the articulation of possible solutions for environmental degradation. As a pilot experience, its implementation is carried out in the Degree in Geography and Land Management of the University of Granada. The main objectives of the didactic proposal are: 1. Creation and start-up of an indoor (Terra Lab UGR) and outdoor laboratory (Baetic Experimental Plot) that allows promoting practical teaching in content related to environmental degradation and its adaptation to the SDGs. 2. Promote collaborative learning (CL) as a teaching technique that promotes learning in groups, as well as working on soil erosion content treated from a multidisciplinary approach.

Detecting potential areas for locating grassed water ways as a soil erosion mitigation measure

Dr. Elmar M. Schmaltz

Grassed water ways are useful measures to hamper overland flow, to lower the sediment transport capacity of runoff and thus to reduce sediment outputs from agricultural fields. In 2023, grassed water ways will be implemented as a fundable measure in the Austrian agri-environmental program ÖPUL. In this regard, we present a statistical approach using a Generalised Additive Model in combination with topographic indices as predictor variables to locate depression lines and thalwegs for the entire territory of Austria that could be potentially used as grassed water ways.

Session 4

Soil organic carbon

Matrix representation of lateral soil movements: scaling and calibrating CE-DYNAM at a continental level

Arthur Nicolaus Fendrich[1,2]

[1] European Commission, Joint Research Centre, Sustainable Resources Directorate, Via E. Fermi 2749, I-21027 Ispra, Italy
[2] Laboratoire des Sciences du Climat et de l'Environnement, CEA-CNRS-UVSQ-UPSACLAY, Gif sur Yvette, France

Potential areas: "Large scale modelling" or "Soil organic carbon and erosion"

The use of spatially explicit models to anticipate the effect of possible actions on soils at a regional scale is widespread. However, the implementation state of most models currently does not cover relevant processes such as lateral displacement of nutrients in the soil due to erosion, transport, and deposition (ETD) processes. ETD is argued to affect the carbon cycle dynamically during its occurrence by inducing lateral fluxes of C in the landscape and vertical fluxes between soil layers, and their absence in models leads to an oversimplified representation of the reality. The modeling complexity and the scarcity of empirical data for the phenomenon hinder, for example, a further understanding of how erosion has been affecting the soil C pools through time. In this work, we explored the problem of applying CE-DYNAM, a hybrid empirical-mechanistic ETD model at a European scale.

Dynamics of nitrates, salts and sediments in a Mediterranean agro-forestry basin

António Canatário Duarte[1,2,3] , Carla S.S. Ferreira[4,5,6], Giuliano Vitali[7], Zahra Kalantari[4,5,8]

[1] School of Agriculture/Polytechnic Institute of Castelo Branco, Portugal
[2] Research Centre GEOBIOTEC/University of Beira Interior, Covilhã, Portugal
[3] Research Centre IPCB/CERNAS, Polytechnic Institute of Castelo Branco, Portugal
[4] Department of Physical Geography, Stockholm University, and Bolin Centre for Climate Research, SE-10691 Stockholm, Sweden
[5] Navarino Environmental Observatory, Costa Navarino, Navarino Dunes Messinia, 24001, Greece
[6] Research Centre of Natural Resources, Environment and Society (CERNAS), Polytechnic Institute of Coimbra, Coimbra Agriculture School, Bencanta, 3045-601 Coimbra, Portugal
7 School of Agriculture/University of Bologna, Italy
8 Department of Sustainable Development, Environmental Science and Engineering, KTH Royal Institute of Technology, SE-100 44 Stockholm, Sweden

Agro-forestry activities impact soil and water quality, but the magnitude of the impacts at the basin scale is not well understood. This study investigates the temporal dynamics of nitrates, total dissolved solids (salts) and suspended sediment in the study basin, in surface water from 2004 to 2017. The experimental basin is located at center-east of Portugal and covers an area of 189 ha. It has a Mediterranean continental climate, predominant soil groups are Luvisols and Cambisols, the slopes range from 0% to 4%, and it is drained 3rd order stream. Daily loads of nitrated depend on runoff volume and the availability of nitrogen in the soil; the high solubility and mobility of nitrogen determine its concentration in both surface runoff and baseflow. Daily salt loads show a dependence of runoff volume at the basin outlet, including both the dry season subject to irrigation and the rainfall season. Daily suspended sediment loads seem dependent on the runoff volume only when it has enough energy to detach and transport sediments out of the basin. Understanding nutrient and sediment dynamics in agro-forestry basins is important to improve management practices and prevent land degradation.

Session 5

Food security, nutrient losses

Using OC fingerprinting to evaluate the performance of erosion risk models in a Scottish catchment

C. Wiltshire [1,*], T. W. Waine[1], R. C. Grabowski[1], J. Meersmans[3], B. Thornton[2], S. Addy[2], M. Glendell[2]

[1] School of Water, Energy and Environment, Cranfield University, Bedford, MK43 0AL, United Kingdom
[2] The James Hutton Institute, Craigiebuckler, AB15 8QH, Aberdeen, Scotland, United Kingdom
[3] TERRA Teaching and Research Centre, Gembloux Agro-Bio Tech, University of Liège, Gembloux, 5030, Belgium

Tackling rural diffuse pollution, including surface runoff and soil erosion, is a key factor in river basin management to improve the status of waterbodies. Identification of hotspots, where a high risk of soil degradation could increase the risk of diffuse water pollution, are a key step in the implementation of Good Management Practices (GMP) so that land can be cultivated to maintain a healthy soil and environment and minimize the risk to watercourses. Hotspots can be identified by modelling erosion using readily available empirical models such as the Revised Universal Soil Loss Equation (RUSLE) whose extensive application based on accessible data means that it can be easily applied in a wide variety of catchments. In addition, in Scotland, soil risk maps have been developed to help stakeholders plan agricultural activities to minimize the risk of erosion and manage their soils sustainably. The utility of these erosion risk models in identifying hotspots, and guiding GMP, depends upon their accuracy and there is a need to assess model usefulness.

This study was carried out in the catchment of Loch Davan, Aberdeenshire, Scotland. We constructed OC loss models to compare land use specific OC yields based on RUSLE and the Scottish erosion risk map (ERM) of Lilly and Baggaley, (2018). Existing OC fingerprinting was used as a benchmark to determine which erosion model best identified the relative land use OC yields in streambed sediment.

Although, the ERM best identified relative land use OC yields in streambed sediment, the results of RUSLE were very similar suggesting that, in this catchment, RUSLE erosion rate estimates could be used to quantify the amount of soil eroded from the high-risk areas defined by the ERM.

Integration of soil erosion, quality and productivity potential into soil management system

Jung-Hwan Yoon, Hyucksoo Kim, Kyung Jae Lim, Sungchul Kim, Pasquale Borrelli, Panos Panagos, and Jae E. Yang

Land degradation in Korea is closely related to erosion due to topography, rainfall pattern and intensive cultivation. In an attempt to relate soil erosion with food security, three dimensional matrix, which is consisted of soil erosion, soil quality and land productivity potential, was employed to assess the status of soil security. The quantity of soil erosion was determined by the Korean Soil Loss Equation (KORSLE), soil quality was assessed based on soil conditions and productivity potential was based on the crop suitability classes. Based on the level of soil security at each field, a pertinent BMP is recommended. This process was developed as the WEB-GIS-based system, which will be introduced in the presentation.

Risk mapping of water erosion in the Srou watershed (Middle Atlas, Morocco) using the Gavrilovic "EPM" model, GIS and magnetic susceptibility

Hassan MOSAID [1]* and Ahmed BARAKAT[1]

[1] Georesources and environment laboratory, Faculty of Sciences and Techniques, Sultan My Slimane University, Béni-Mellal, Morocco * h.mosaid@usms.ma

The Oued Srou watershed is located in the Middle Atlas Mountain of Morocco and has been a subject of serious soil erosion problems due to the combination of natural factors and anthropic activities. The continuous degradation of natural resources in general, and of the soil in particular, is a problem that is still difficult to apprehend. Indeed, water erosion of the soil contributes to land degradation, particularly in mountainous areas, and to the silting up of dam reservoirs. Given the dominance of less erosion-resistant rocks in the area in question, the Oued Srou watershed can be considered a major contributor to the silting of the Ahmed El Hansali dam. For this reason, an in-depth study is necessary to quantify and map the risks of water erosion in this watershed. For this purpose, the Gavrilovic's EPM (Erosion potential Method) model and the magnetic susceptibility method were employed, using the geographic information system (GIS)

Session 6

Large scale modelling

Predicting gully erosion at the Global Scale: a data-driven approach

Matthias Vanmaercke, Yixian Chen, Sofie De Geeter, Jean Poesen, Benjamin Campforts, Pasquale Borrelli, and Panos Panagos

Gully erosion is increasingly recognized as a critical concern for land degradation. Apart from greatly accelerating soil erosion rates, gullies often lead to additional on- and off-site impacts. Nevertheless, our ability to quantify and predict this process remains notoriously difficult, especially at larger scales. Recent machine learning techniques offer promising perspectives here, as they are in principle capable to deal with the many interactions and non-linearities between the factors controlling gully erosion. However, due to the associated large data requirements, current applications generally remain limited to local scales.

Here we present our recent advancements in applying such an approach at the global scale. Using an efficient scoring approach we mapped gully densities for ~20,000 sites worldwide. These data were used to train and test a random forest model that is capable to robustly simulate global patterns of gully density at a 1 km² resolution. Yet, while already relevant as such, patterns of gully density do not necessarily correspond to the patterns of gully erosion. For example, not all gullies are necessarily active. By combining our map with results from other global empirical studies, we therefore also present a first global gully erosion risk map.

Modeling the effect of best management practices on sediment yield in a Mediterranean watershed

Giovanni Francesco Ricci[1], Anna Maria De Girolamo[2*], Francesco Gentile[1]

[1] Dipartimento di Scienze Agro-Ambientali e Territoriali, Università di Bari Aldo Moro, via Amendola 165/A, 70126 Bari
[2] Istituto di Ricerca Sulle Acque, Consiglio Nazionale delle Ricerche (IRSA-CNR), Viale F. De Blasio 5, 70132 Bari

Corresponding author: annamaria.degirolamo@ba.irsa.cnr.it

To counteract the threat of soil erosion, the most widespread form of soil degradation, European policies (PAC, 2014-2020) incentive the implementation of Best Management Practices (BMPs). Therefore, European countries are called to identify the areas at a high risk of soil erosion and to adopt conservation measures. In this study, the Soil and Water Assessment Tool (SWAT) was used to quantify the soil erosion rates for the current management options and to identify the critical source areas in the Carapelle watershed, an agricultural watershed located in the Puglia region (Southern Italy). The model was calibrated and validated for streamflow and sediment load at a daily time scale (2007-2011). The results showed that in the Carapelle basin the average annual sediment load is 5.95 t ha^{-1} yr^{-1}. The areas under severe soil erosion rate (10 t ha^{-1} yr^{-1}) were identified resulting in 59 HRUs located in the mountainous part of the watershed and characterized by agricultural land use. Different BMPs scenarios, based on the regional policies, were modelled in the areas under severe soil erosion: contour farming (BMP1), no-tillage (BMP2), reforestation (BMP3), and the combination of contour farming and reforestation (BMP4). Results showed that BMP4 was the most effective for soil erosion control (38%; 5.95 to 3.70 t ha^{-1} yr^{-1}), followed by BMP2 (29 %; from 5.95 to 4.20 t ha^{-1} yr^{-1}), BMP1 (22 %; from 5.95 to 4.61 t ha^{-1} yr^{-1}) and BMP3 (15 %; from 5.95 to 5.04 t ha^{-1} yr^{-1}). An analysis of the farmer return-production cost ratio (FR/PC) indicated that the baseline (conventional tillage) and BMP1 were both economically sustainable in areas with slope < 20 % (FR/PC = 1.12 and 1.11, respectively). BMP2 received the highest FR/PC rating of 1.67 in areas with slope < 20 %. The baseline scenario had no economic advantage (FR/PC = 0.93) in steep slope areas. BMP3 was ranked at the top (FR/PC = 1.49) followed by BMP2 (FR/PC = 1.41) in areas with slope > 20 %. The results show that a program of measures can be effective for controlling soil erosion but it must be implemented over long time frames and it requires relevant investments from the public and private sectors.

Sediment redistribution impacted by large wildfires over multiple decades – a landscape evolution modelling approach

Follmi D, Nunes JP, Baartman J, Benali A

Wildfires can enhance soil erosion during the post-fire recovery period, and recurrent fires can lead to soil degradation at longer time-scales. The resulting sediments can cause water quality problems downstream for several years after the fire. Yet, post-fire erosion studies usually focus on short time windows and on the burnt plot scale, ignoring catchment sediment dynamics. We address this by applying the landscape evolution model LAPSUS to simulate erosion and sediment movement in the 404 Km2 Águeda catchment in northern Portugal for a 41 year period (1979-2020), during which eight large wildfires burnt over 1000 ha each. The model considered fire severity and vegetation recovery using the difference Normalized Burn Ratio (dNBR) collected from satellite images, and the model predictions were assessed against multiple field studies conducted in the region. The results indicate that fires significantly enhanced long-term net erosion rates in the area (6.0 vs 0.6 ton/ha.yr for a scenario without fire occurrence). Erosion patterns showed a large spatial variability, with large erosion and deposition rates inside streams, indicating a complex relationship between burnt landuse type, topographical features, and fire severity. This work showed the potential of LAPSUS to support the management of fire-prone forests.

The effects of Soil Improving Cropping Systems (SICS) on soil erosion and SOC stocks across Europe: a simulation study

Jantiene Baartman[1], Joao Pedro Nunes[1], Hedwig van Delden[2,] Roel Vanhout[2] and Luuk Fleskens[1]

[1] Soil Physics and Land Management group, Wageningen University, Wageningen, The Netherlands;

[2] RIKS, Maastricht, The Netherlands

The SoilCare project aimed at identifying and evaluating promising Soil Improving Cropping Systems (SICS) that increase sustainability of agriculture in Europe. To do so at EU scale, a modelling approach was taken: we simulated the effects of four common and widely used SICS (cover crops, mulching, minimum tillage and compaction reduction) on soil erosion, as an important form of land degradation, and SOC stocks, as an important indicator of soil health. We used the spatially explicit PESERA model at a 500m resolution and simulated four scenarios from until 2050. Scenarios differed in the assumed level of sustainability: either no SICS (low sustainability), one type of SICS applied by each farmer (medium sustainability), a combination of minimum tillage, compaction reduction and either cover crops or mulching (high sustainability) or a mixed scenario in which 1.3 of the farmers applied no SICS, 1/3 applied one SICS and 1/3 applied all SICS. Results show that while in the scenario without SICS, erosion slightly increases on average across Europe, it significantly decreases in the scenario with the highest level of SICS applied, especially in the cropping areas e.g. in the central European Loess Belt. Regarding SOC stocks, the simulations show a substantial decrease for the scenario without SICS and a slight overall decrease for the medium level scenario and the scenario with a mix of high, medium and no SICS. The scenario with a high level of SICS implementation showed an overall increase in SOC stocks across Europe. Future improvements are to include dynamic land use, climate change and an optimal spatial allocation of SICS.

A 5-dimensional (3D+scale+time) framework for assessment of water-induced soil erosion in Crete, Greece

D.D. Alexakis[1], C. Polykretis[1], M.G. Grillakis[1], S. Manoudakis[1]

[1] Lab of Geophysical – Satellite Remote Sensing and Archaeo-Environment, Institute for Mediterranean Studies, Foundation for Research and Technology – Hellas, 74100, Rethymno, Crete, Greece.

The study focus on assessing the impact of a changing climate, land use and vegetation cover on the erosion process on different scales and time periods in the island of Crete, Greece. The empirical RUSLE modeling was applied and its key factors were generated by using relevant data in GIS and Remote Sensing-based techniques. Rainfall station measurement and satellite imagery data time-series were used, along with future climate (RCP 2.6, 4.5 and 8.5) and land cover projections to estimate the potential future changes of the relevant temporally dynamic (R and C) factors. The final results revealed a higher erosion risk from the more detailed to the more coarse data of the different spatial scales. Temporally, a degradation of the risk was generally projected from the present to future. In addition, despite their different levels of greenhouse gas emissions/concentrations, no significant differences were found between the three climate projections in each of the examined future time periods.

New (R)USLE C-factor maps based on multi-annual data for Germany

BASTIAN STEINHOFF-KNOPP[1,2], PHILIPP SAGGAU[3]

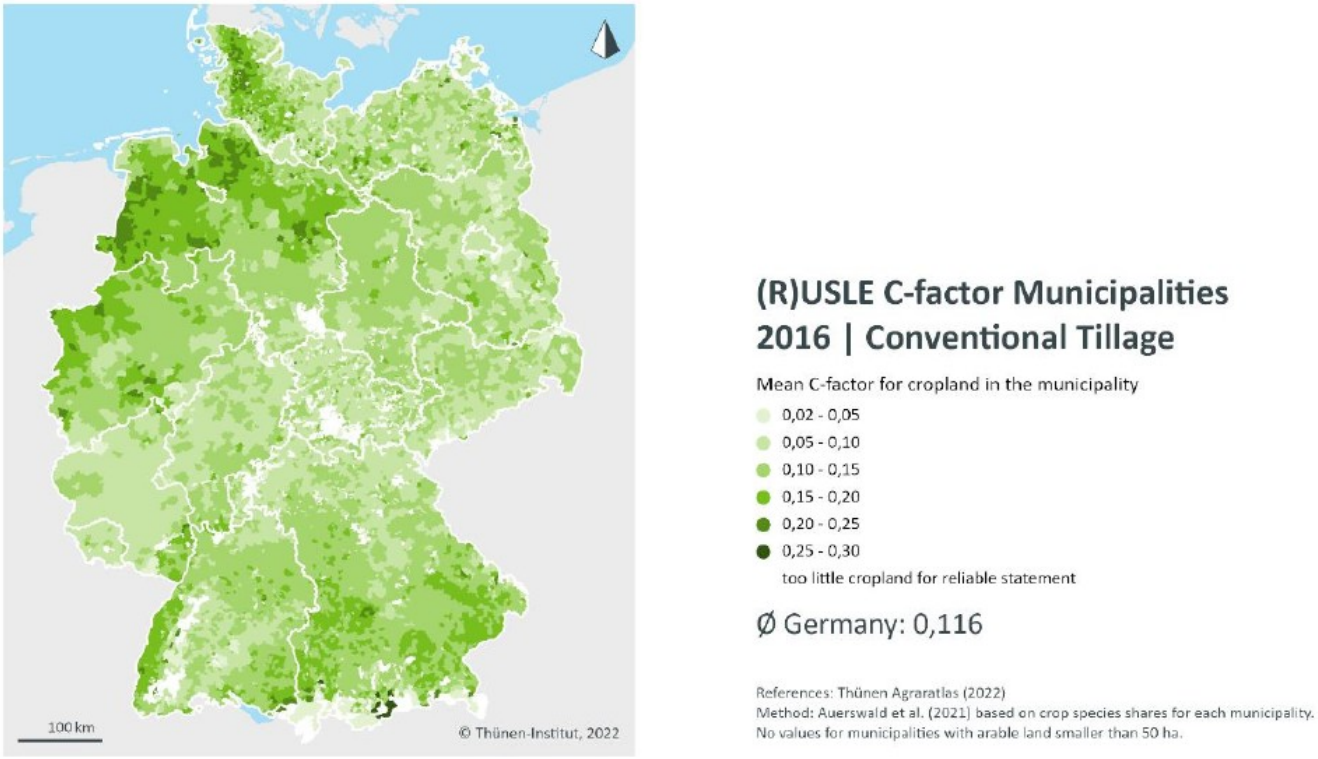
[1] Thünen Institute of Farm Economics, Germany
[2] Leibniz University Hannover (LUH), Germany
[3] Kiel University (CAU), Germany

The C-factor represents the impact of crop and soil management on soil erosion risk in the (R)USLE. Its exact and spatial explicit determination is difficult, especially on regional-scales, as a variety of spatio-temporal data is needed. Based on recent improvements in calculation methods and remote sensing, the C-factor can be estimated using agricultural statistics or parcel-based information on crop rotation. For this reason, we developed two types of spatial explicit and regional C-factor datasets for Germany:

• Harmonized mean C-factors for municipalities and counties for 1999, 2003, 2007, 2010, 2016 and 2020.

• Parcel-based C-factors for the period 2017-2020 based on satellite data derived crop type maps.

The results enhance the spatial C-factor allocation and accuracy on parcel and regional level and allow the evaluation of temporal changes, which is an important improvement for an optimized identification of at-risk areas for the implementation of soil conservation measures.



Assessing the hillslope-channel contributions to the total sediment balance at large spatial scales

Joris Eekhout[1], Carolina Boix-Fayos[1], Pedro Pérez-Cutillas[2], and Joris de Vente[1]

[1] Soil and Water Conservation Research Group, CEBAS-CSIC, Murcia, Spain
[2] Department of Geography, University of Murcia, Murcia, Spain

Previous research suggests that channels have a significant contribution to the total sediment balance in large catchments. Channels are also very sensitive to land use and management changes, with implications for channel morphodynamics and the quantity of sediments and nutrients flowing through the system. Here we present a new channel module for the hydrology-soil erosion model SPHY, with the aim to quantify the contribution of hillslope and channel erosional processes to the total sediment balance in large catchments. The model SPHY simulates all relevant hydrological and soil erosion processes, including infiltration excess surface runoff and soil detachment by raindrop impact and runoff. We developed a novel channel module that simulates river hydraulics and morphodynamics in the channel network. The model was applied to a semi-arid catchment in the southeast of Spain and calibrated using observed sediment yield and channel morphological observations. The model simulates the observed channel morphodynamics as a response to reforestation in the period 1956-2001. Furthermore, the model shows that channels contribute significantly to the total sediment balance, which highlights the importance of accounting for channel morphological processes in large-scale erosion assessments.

Global soil erodibility mapping using legacy soil data

Laura Poggio, Andre Kooiman, Niels H. Batjes, Bas Kempen, Johan G.B. Leenaars, David G. Rossiter

Soils are a key natural resource to realise several UN Sustainable Development Goals. Consistent global soil information is required to underpin a large range of assessments, such as soil and land degradation, climate change mitigation and adaptation, food security, sustainable land management, and environmental conservation. The assessment of soil erodibility is a key parameter. There are numerous equations developed in the past. Some of these equations require information on soil structure and other complex parameters. Maps of primary soil properties are available at global scale (e.g. SoilGrids). However, using legacy soil data to derive complex parameters (such as soil structure) is still a challenge due to the limited amount of information available, variability over time and interaction with land cover and land use. In this paper we will present a global soil erodibility map derived using only primary soil properties and discuss the pros, cons and limitations of such an approach.

A data-driven gully head susceptibility model at 30 m resolution

Sofie De Geeter[1,2,3]*, Gert Verstraeten[1], Jean Poesen[1,4,] Benjamin Campforts[5], Matthias Vanmaercke[1]

[1]KU Leuven, Division of Geography and Tourism, Department of Earth and Environmental Sciences, Celestijnenlaan 200E, 3001 Heverlee, Belgium
[2]University of Liège, Department of Geography, Clos Mercator 3, 4000 Liège, Belgium
[3]Research Foundation Flanders – FWO, Brussels, Belgium
[4]Maria-Curie Sklodowska University, Faculty of Earth Sciences and Spatial Management, Krasnicka 2D, 20-718, Lublin, Poland
[5]University of Colorado, INSTAAR, Community Surface Dynamics Modeling System, Boulder (CO), USA
*Corresponding Author: sofie.degeeter@kuleuven.be

Gully erosion models are essential for the development of appropriate land management strategies, but also to better quantify the role of gully erosion in sediment budgets. One of the main challenges is that patterns of gully erosion depend on regional patterns of controlling factors (e.g., rainfall, lithology, soils), but are also strongly determined by local factors (e.g., topography, vegetation cover, land management). This greatly increases the complexity of potential models and their data requirements. To bridge this gap, we are developing a robust, empirical model at 30m resolution based on a dataset covering the continental scale of Africa. This model gives promising results (see Figure 1) with AUC values of around 0.8. Given the strong data limitations in Africa, this opens up perspectives: the insights learned from this model will also be applicable on a European scale where better GIS data products are available.

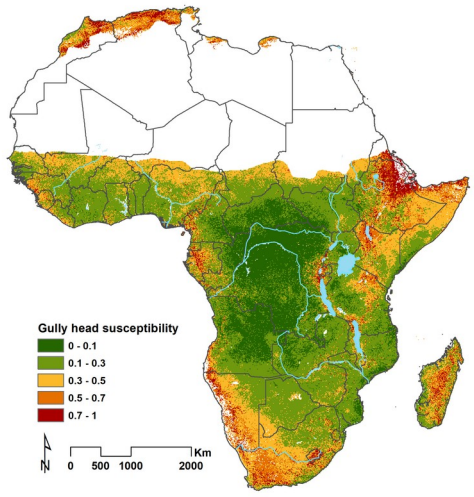


Figure 1: Gully head susceptibility map of Africa.

Connecting the dots in soil erosion knowledge

Professor emeritus Dr. A. Imeson and drs H. Alkemade

Accelerated soil erosion very often is a signal of unsustainable land use.

When advizing policy-makers, landowners or other stakeholders sustainability is key in their advice. This requires scientists to take a broader view when assessing the effects of their advice. Both in time and in space. To include not only the “here and now” , but also the “there and than”.

The authors are convinced the corpus of knowledge on soil erosion already available, expanded with pre-digital era research and other sources, and complemented with modern monitoring methods, is adequate to model effects of measures or developments over a larger area and over a longer period of time.

This enables the scientific community to give sound, science based, assessments and advice on soil erosion, preventive and mitigating long term measures, at least at regional and higher scales.

Evaluation of the applicability of the erosion potential model for the global assessment of soil erosion

Nejc Bezak, Pasquale Borrelli, Mateja Jemec Auflič, Matjaž Mikoš, Panos Panagos

The Erosion potential model (EPM) also known as the Gavrilović method, is one of the most widely used soil erosion methods in the Mediterranean region. The applicability and usefulness of this model for large-scale and global assessments has not yet been evaluated. Therefore, the objective of this contribution is to present the first steps taken to assess global soil erosion by water using the EPM. These steps include the data preparation required to estimate model parameters (e.g., soil cover, erosion and landslides and soil resistance coefficients) and other input data (e.g., total annual precipitation, mean annual air temperature, etc.). Additionally, suspended sediment data for selected large river basins will be used to calibrate sediment delivery ratio and evaluate model performance.

Fallout radionuclides indicate a 10% loss of European topsoil in 50 years

Katrin Meusburger*[1], Olivier Evrard[2], Cristiano Ballabio[3], Pasquale Borrelli[4], Michael Ketterer[5], Panos Panagos[3], Kristof van Oost[6,7], Florian Wilken[8], Christine Alewell[9]

[1] Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), CH-8903 Birmensdorf, Switzerland. *E-Mail: Katrin.Meusburger@wsl.ch
[2] Laboratoire des Sciences du Climat et de l'Environnement (LSCE-IPSL), UMR 8212 (CEA-CNRS-UVSQ), Université Paris-Saclay, CEA Saclay, l'Orme des Merisiers, 91191 Gif-sur-Yvette Cedex, France.
[3] European Commission, Joint Research Centre, Via E. Fermi 2749, I-21027 Ispra (VA), Italy.
[4] Department of Earth and Environmental Sciences, University of Pavia, Via Ferrata, 1, 27100 Pavia, Italy
[5] Chemistry Department, Metropolitan State University of Denver, Colorado, USA.
[6] TECLIM, George Lemaitre Center for Earth and Climate, Earth and Life Institute, Université Catholique de Louvain, Louvain-La-Neuve, Belgium.
[7] Fonds de la Recherche Scientifique (FNRS), Brussels, 1000, Belgium.
[8] Institute for Geography, Universität Augsburg, Augsburg, Germany.
[9] Environmental Geosciences, University of Basel, Bernoullistrasse 30, CH-4056 Basel, Switzerland.

Quantifying soil erosion is a major research challenge due to erosion's episodic character and spatial variation. Fallout radionuclides as $^{239+240}$Pu and ^{137}Cs are powerful tools to assess net soil losses integrated over long periods applicable to most regions of the world. The traditional approach of the FRN method is based on the comparison between an inventory (total radionuclide activity per unit area) at a given sampling site and that of an undisturbed reference site (e.g., located in a flat and well-vegetated area). Compared to reference, a decrease in the FRN inventory indicates erosion and an increase indicating deposition of sediments and associated FRN. So far, FRN based assessment was restricted to a regional/catchment scale as spatially distributed data of reference inventories was missing.

In this study, we aim at upscaling the FRN approach to a central area of Europe covering France, North Italy, South Germany, and Belgium using the Land Use/Cover Area frame Survey – LUCAS soil sample bank. Both fallout sources left a specific radionuclide imprint in European soils. First, plutonium was used to quantify global versus Chernobyl fallout contributions to ^{137}Cs found in European soils. Subsequently, spatial prediction models (general additive models) allowed reconstructing the global versus Chernobyl ^{137}Cs fallout pattern across national boundaries. The definition of these ^{137}Cs and the Pu baseline maps allows assessing soil redistribution rates at n=137 cropland sites with both FRNs across the study area. We selected barley, wheat, maize, and vineyard plots covering different slope angles as cropland sites. For both FRNs, differences between the reference and site-specific FRN inventory show an inventory and associated topsoil (0-20cm) loss of approximately 10% since 1963. Converting these inventory changes with a simple mass balance model to soil redistribution rates results in average soil erosion rates of 8.8 ± 6.3 t/ ha yr, assuming a tillage depth of 20 cm. Although the involved uncertainties are large, these net erosion rates exceed the expected magnitude.

Innovations in Monitoring of Soil Erosion: Combining Systematic Field Assessments with Spectroscopy and Earth Observations

Leigh Ann Winowiecki, Zampela Pittaki-Chrysodonta*, Tor-Gunnar Vågen

World Agroforestry Centre (ICRAF), P.O. Box 30677-00100 Nairobi, Kenya

Soil erosion has long been recognized as a major process of land degradation globally, affecting millions of hectares of land in the global tropics, resulting in losses in productivity and increased food insecurity, decreased resilience of ecosystems, and increased vulnerability to climate change. Combining systematic field surveys using the Land Degradation Surveillance Framework (LDSF) methodology, soil spectroscopy, and Earth Observation (EO) data, an assessment of soil erosion in over 50 countries across the global tropics was successfully conducted. Given that the methodology provides robust results that can be rapidly replicated at scale and the importance of soil erosion for land degradation, we argue that soil spectroscopy and EO will play a key role in enabling landscape-scale assessments. Thus, they could be used as tools and methods for measuring and tracking soil and land health changes at scales relevant to multiple stakeholders.

Regionalization of the SWAT+ model for projecting climate change impacts on soil erosion: An application in the Nile basin

Albert Nkwasa[1*], Celray James Chawanda1, Ann van Griensven[1,2]

[1] Hydrology and Hydraulic Engineering Department, Vrije Universiteit Brussel (VUB), 1050 Brussel, Belgium
[2] Water Science & Engineering Department, IHE Delft Institute for Water Education, 2611 AX Delft, The Netherlands
*Corresponding author: Albert Nkwasa (albert.nkwasa@vub.be)

Several studies have shown a relationship between climate change and changes in soil erosion. However, there are limited modeling applications that study this relationship at regional to continental scales mainly due to data availability and cost of computation for large scale. This study proposes a methodological framework using the SWAT+ model to predict soil erosion at a regional scale in data-scarce regions using global datasets. We implement a framework that (a) incorporates topographic factors from high/medium resolution DEMs (b) incorporates crop phenology data (c) introduces an areal threshold to linearize the soil erosion in large model units and (d) apply a hydrological mass balance calibration. We test this methodology in the Nile Basin using a model application with (revised) and without (default) the framework. Results show improved soil erosion estimates in the revised model when compared to previous local studies. The revised model also shows improved spatial correlation of simulated soil erosion estimates with measured catchment sediment yield ($r^2 = 0.34$) and with reported soil erosion estimates ($r^2 = 0.37$). In addition, there are considerable differences between revised and default models in soil erosion projections even at local scales especially for the eastern part of the Nile. This shows that proposed modelling framework has an influence on the simulated soil erosion values and corresponding projected change. We conclude that the proposed methodological framework can guide on how to apply a SWAT+ model for regional soil erosion modelling and projection, especially in data-scarce regions.

A GIS-based Simulation and Visualization Tool for the Assessment of Gully Erosion Processes

Michael Maerker[1*], Dietrich Schröder[2], Adel Omrana[1,3*]

[1] Department of Earth and Environmental Sciences, Pavia University, Via Ferrata, 1- 27100 - Pavia, Italy
[2] Department of Geomatics, Computer Science and Mathematics, University of Applied Sciences Stuttgart, Germany.
[3] Department of Science and Mathematical Engineering, Faculty of Petroleum and Mining Engineering, Suez University, Egypt

Gully erosion is known to affect soil productivity, limit land use, and to pose threats on infrastructures in many parts of Europe, particularly in the Mediterranean but also in areas with Loess deposits or susceptible soils. Many gullies grow rapidly to large sizes, making effective control technically difficult and often too expensive. On the other hand gullies efficiently produce and transport sediments from slopes into the drainage network causing offsite damages. However, gully erosion has been largely neglected in common quantitative soil erosion assessments because it is difficult to model. In this paper we present a new GIS based gully erosion assessment tool that allows the necessary input data preprocessing, the modelling based on Sidorchuk's DIMGUL/STABGUL models as well as the output visualization. To assess the susceptibility of soils and substrates to gully erosion, the triggering factors must be identified and analyzed. Here we used innovative techniques like AUV, spectrometry as well as geoelectric devices to derive the relevant input parameters. For this study, a simulation of gully development over time was implemented in Python based on the topographic characteristics of the test watershed, soil properties, and measured runoff. The results are very promising and allow a 2D/3D visualization of the time series of gully evolution.

Investigating the convergence of multiple land degradation processes across the global arable landscapes

Remus Prăvălie[1,2]

[1] University of Bucharest, Faculty of Geography, 1 Nicolae Bălcescu Street, 010041, Bucharest, Romania, pravalie_remus@yahoo.com
[2] Academy of Romanian Scientists, 54 Splaiul Independentei Street, 050094, Bucharest, Romania

The planetary spatial footprint of multiple land degradation processes on arable lands, which can be considered a major component of global agricultural systems, is still insufficiently well understood. This study analyzes the land degradation footprint on global arable lands, using complex geospatial data on certain major degradation processes, i.e. aridity, soil erosion, vegetation decline, soil salinization and soil organic carbon decline. By applying geostatistical techniques that are representative for identifying the incidence of the five land degradation processes in global arable lands, results showed that aridity is by far the largest singular pressure for these agricultural systems, affecting ~40% of the arable lands' area, which cover approximately 14 million km^2 globally. It was found that soil erosion is another major degradation process, the unilateral impact of which affects ~20% of global arable systems. The results also showed that the two degradation processes simultaneously affect an additional ~7% of global arable lands, which makes this synergy the most common form of multiple pressure of land degradative conditions across the world's arable areas. The absolute statistical data showed that India, the United States, China, Brazil, Argentina, Russia and Australia are the most vulnerable countries in the world to the various pathways of arable land degradation. Also, in terms of percentages, statistical observations showed that African countries are the most heavily affected by arable system degradation.

Session 7

Early Career Research on Soil Erosion

Role of land use changes in soil piping: the Bieszczady Mts. (SE Poland)

Anita Bernatek-Jakiel[1], Michał Jakiel[1]

[1] Institute of Geography and Spatial Management, Jagiellonian University, Kraków, Poland

Soil piping is a widespread land degradation process that in some areas in the world may lead to the significant soil loss exceeding severe soil erosion rates. In recent decades, when the land use/land cover (LULC) changes are widely observed, the question on the impact of LULC changes in soil piping remains open. This study aims to recognize the role of LULC changes in soil piping in the Bieszczady Mts., where soil pipes occur in Cambisols. The study area is subjected to significant LULC changes, i.e., in 19th century most of the area was used as arable lands and pastures, which were abandoned during the World War II. Now the reforestation is observed. The analysis has revealed that soil piping forms develop in areas where now and 150 years ago there were grasslands/pastures, and where grasslands/pastures existed in the past and then were abandoned, whereas there are almost no forms in areas covered by forest since the mid-19th century. This study has proven that LULC changes impact significantly soil pipe formation, and that pastures/grasslands are one of the most prone to soil piping land use type.

Monitoring soil erosion processes at elementary agricultural catchment scale (northern France)

Morgan Delaporte [1], Claire Alary[1], Christine Franke [2], Gabriel Billon[3]

[1] LGCgE, IMT-Nord-Europe, CERI MP, 764 boulevard Lahure, 59508 Douai Cedex, France
[2] MINES ParisTech, PSL University, Centre of Geosciences, 35 rue Saint-Honoré, 77305 Fontainebleau Cedex, France ;
[3] LASIRE, Université de Lille, Av. Henri Poincaré, 59491 Villeneuve-d'Ascq, France

In France, erosion by water run-off is estimated to 1.5 t ha^{-1} yr^{-1} and can reach 10 t ha^{-1} yr^{-1} in the large agricultural area of northern France. The Canche River watershed (1294 km^2) in the Hauts-de-France region has been studied since 2016 to better understand its high sensibility to soil erosion. This study presents the monitoring of an elementary agricultural catchment from the Canche River watershed. The Pommeroye catchment (0.54 km^2) disposes of a multiparameter high frequency (10 min) monitoring station (turbidity, liquid yield, conductivity, automatic sampling) completed by monthly field monitoring of the soil surface characteristics. This monitoring aims to understand detailed erosion processes such as hysteresis phenomena or the impact of anti-erosion management at catchment scale. To support these measurements, drone overflights are carried out to calculate the volume of soil moved or stored in ravines and at fascines between two distinct erosion events.

Feedbacks between water erosion and soil thinning

Pedro Batista, Daniel Evans, Bernardo Cândido, and Peter Fiener

Soil erosion rates frequently exceed the pace at which new soil is formed. This imbalance can lead to soil thinning (i.e., truncation) whereby subsoil horizons, and the underlying parent material, emerge progressively closer to the land surface. These subsurface horizons may have contrasting physical, chemical, and biological properties from those of the original topsoil. Hence, soil thinning can induce changes in topsoil erodibility – a fact that has been largely overlooked in erosion modelling research and could affect long-term projections of soil erosion rates. Here we present a model-based exploration of the potential feedbacks between water erosion and soil thinning, using measured data from 265 agricultural soil profiles in the United Kingdom. We simulated annual erosion rates on these soil profiles with the Modified Morgan-Morgan-Finey model, assuming time-constant land cover, topographic, and rainfall parameters. As the original topsoil was successively removed, our model gradually mixed the subsurface horizons into a 20 cm ploughing layer. We applied this modelling framework on a yearly time-step over a 500-year period, or until the ploughing layer reached the bottom of the lowermost soil horizon. Soil texture, stone cover, and soil organic carbon content for the ploughing layer were recalculated for each time-step through a mass-balance model. Soil bulk density and soil moisture content at field capacity were estimated for each time-step by pedo-transfer functions developed from our own dataset. In addition, we employed a Monte Carlo simulation with 100 iterations per year to provide a forward error assessment of the modelled soil losses. We found that simulated erosion rates on 42 % of the soil profiles were sensitive to truncation-induced changes in soil properties during the analysed period. Among the profiles sensitive to soil thinning, 68 % displayed a negative trend in modelled erosion rates. This was largely explained by decreasing silt contents on the surface soil due to selective removal of this more erodible particle size fraction and the presence of clayey or sandy substrata. Moreover, an increased residual stone cover shielded the surface soils from detachment by raindrop impact and surface runoff. The soil profiles with a positive trend in erosion rates were characterised by the presence of siltier subsoil horizons, which increased topsoil erodibility as they were mixed into the ploughing layer. Overall, our results demonstrated how modelled erosion rates could be sensitive to truncation-induced changes in soil properties, which in turn may accelerate or slow down soil thinning. These feedbacks are likely to affect how we calculate soil lifespans and make long-term projections of land degradation.

Using a parsimonious Soil Erosion Model to parametrize Dynamic Rainfall – Soil Loss Response

Thomas Brunner[1,2]

[1]Federal Agency for Water Management - Institute for Land and Water Management Research (BAW-IKT), Pollnbergstraße 1, 3252 Petzenkirchen, Austria
[2] University of Natural Resources and Life Sciences, Vienna – Institute for Soil Physics and Rural Water Management (SoPhy), Muthgasse 18, 1190 Wien, Austria

A spatially distributed, event-based modification of the Revised Morgan-Morgan-Finney (RMMF) model is calibrated and validated with measured runoff and sediment data from 142 rainfall experiments performed in AT, HU, ITA and CZ. The main change from the original model is the implementation of an infiltration model for the runoff calculation. The rainfall simulations used were performed on a range of different soil characteristics, they partially used constant rainfall intensities, while some used different temporal patterns of the irrigation intensity. Natural rainfall events on erosion plots are also used in the validation. The perspective goal of the study is to use the model to simulate the effects of best management practices on (small) catchment scales.

Links between catchment erosion and sediment connectivity: case study in the semi-arid Rogativa catchment, Southeast Spain

Niguse Abebe[1], Jantiene Baartman[2], Bart Vermeulen[1], Joris Eekout[3], Joris de Vente[3], Carolina Boix-Fayos[3], Ton Hoitink[1]

[1] Hydrology and Quantitative Water Management group, Wageningen University, Wageningen, The Netherlands;
[2] Soil Physics and Land Management group, Wageningen University, Wageningen, The Netherlands;
[3] Soil and Water Conservation Department, CEBAS-CSIC, Murcia, Spain

In this study, we aimed to link catchment erosion and sediment (dis)connectivity under the effect of rainfall and land use changes over a period 1952-2018. Rainfall, land use/ cover, soil type and organic content, and DEM data were used to analyze the catchment erosion using the Revised Universal Soil Loss Equation (RUSLE) and linked to sediment connectivity index (IC), calculated using the SedInConnect 2.3 tool. The period 1952-2018 categorized into four periods, 16 years of each to quantify and compare the erosion and sediment potential distribution at raster cell-scale in the catchment. Sediment delivery ratios were calculated based on the IC maps and also independently derived from measured sediment yield behind 58 check dams that were installed in 1976/77. The soil erosion and connectivity index map showed that there is relatively high erosion and connectivity in the lower parts (near the gullies and streams) than on the hillslopes and found small difference among the periods.

Analysis of erosion processes and rates by in-situ measurements and multi-temporal TLS and UAV surveys. Preliminary results from the Vallcebre badlands (NE Spain)

PHD student: Ona Torra Truncal (UPC)

Supervisors: Marcel Hürlimann, Càrol Puig-Polo (UPC)

Badlands are defined as high-erosion areas (in some cases exceeding 100 Mg $ha^{-1}y^{-1}$) located in soft lithological materials, with little or no vegetation. The proximity of these areas to the drainage network causes surface runoff and its consequent erosion, in some cases representing 20%-80% of the average catchment sediment yield. In the present study, geomatic data capture techniques such as Terrestrial Laser Scanners (TLS) and Unmanned Aerial Vehicles (UAV) surveys were applied and compared with in-situ measurements from the sediment traps and gauging stations. Three scales were selected in a badland situated in the Upper Llobregat River basin (Spain): two north- and south-facing slopes (8 and 12 m^2 respectively), the sub catchment scale (0.9 ha) and the catchment scale (132ha). The volume of eroded sediment has also been quantified, and its correlation with climatic and terrain parameters has been analyzed.

An update of the spatial and temporal variability of rainfall erosivity (R-factor) for the main agricultural production zones of Austria

Due to the high spatiotemporal variability of rainfall erosivity, it is crucial to use spatially well-distributed and temporally current rainfall data for improved soil erosion risk assessment. This study aimed to update the rainfall erosivity estimation for Austria and its main agricultural production zones based on a larger number of rainfall stations and a more recent time series than previous studies. The temporal and spatial R-factor distribution was estimated and an R-factor map was created using the 1 km2 rainfall grids from the SPARTACUS dataset. The agriculturally important eastern regions of Austria were found to have the highest rainfall erosivities during the summer months. Considerable differences in local R-factor estimation were found compared to previous studies.

A review of soil erosion assessment by RUSLE model using Remote Sensing and GIS in India

Tara Meghana Kaila[1], Vamsi Golla[2]

[1] Erasmus Mundus scholar in soils and global change, University of Gent, Belgium. tarameghana.kaila@ugent.be
[2] Master's student, Department of International Tropical Forestry, University of Göettingen,Germanay.

Soil erosion as a result of uneven rainfall distribution during monsoon periods in India is one of the major sources of soil degradation especially near river basins which are most vulnerable zones for water erosion. Mitigation of such risks is an urgent need for soil management this can be done by assessing the magnitude of soil erosion risks. But it is always a challenging task, mainly because of inadequate availability of relevant data, which is a common problem in under-developed and developing countries. Modelling can provide a quantitative and consistent approach to estimate soil erosion and sediment yield under a wide range of conditions. In the present study, the soil loss model, Revised Universal Soil Loss Equation (RUSLE) integrated with GIS has been reviewed which was used to estimate soil loss in the Shivaganga Basin located in the southwestern part of India (Ganasri et al, 2015).

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Ganasri, B.P. and Ramesh, H., 2016. Assessment of soil erosion by RUSLE model using remote sensing and GIS-A c

Land use drives topsoil decline across Kenya: Modelling soil erosion patterns, consequences and mitigation

Christopher Feeney (presenting), Amy Thomas, David Robinson, Pasquale Borrelli & David Cooper

High erosion rates of fertile topsoil drives land degradation, particularly so in the tropics. We model topsoil erosion, lifespans and carbon, nitrogen and phosphorous fluxes across Kenya. We subtract predictions under natural vegetation cover from predictions under present-day land cover, establishing “natural resource debts” to contextualise existing land degradation. Debts are greatest in croplands on steep slopes with high rainfall, declining in gentler terrain under woody vegetation. Statistical modelling shows the importance of topography and land cover on topsoil structure, which may help to target interventions against land degradation. We predict reductions in erosion rates on croplands with adopted soil conservation practices comparable to returning these same areas to their natural state. While Kenya is an example, our workflow is applicable to assess land degradation trends, including mitigation, elsewhere.

Assessment of Agricultural Ditch Stability with the Analytical Hierarchy Process.

Daniel Aviles, PhD.

Keeping agricultural drainage ditches properly functional is vital for maintaining food production capacity. Given that factors, such as soil erosion, and mass movements, affect the functioning capabilities of agricultural drainage ditches, they need to be periodically maintained. Deciding where maintenance work needs to be prioritized is a challenging task. Here, the Analytical Hierarchy Process is proposed as a tool to assess where maintenance should be focused. The criterias considered are: Soil erosion susceptibility, mass movements manifestations, presence/absence of soil deposits in the main channel, presence/absence of vegetation in the main channel and presence/absence of established vegetation in the channel banks.

Soil spectroscopy models for the parameterization of hydrogeological models

Varvaris Ioannis[1]

[1] Eratosthenes Centre of Excellence, Limassol, Cyprus

A better understanding of surface run-off processes can assist in a more accurate estimation of the degree and amount of surface erosion and slope vulnerability over the space. A hydrogeological modeling system can be used to predict the influence of land use on precipitation-runoff processes on a field scale. Simulating water flow requires explicit knowledge of the effective soil properties. However, the spatial variability in soil physical and hydraulic properties within an agricultural field adds significant uncertainty to the modeling results. Furthermore, conducting extended field and laboratory measurements are time-consuming and costly processes. A concept was developed as a hydrogeological tool for covering the absence of knowledge regarding the parameterization of the input parameters in hydrogeological models. Existing soil spectroscopy models were used to predict soil-water retention characteristics and hydraulic properties. The suggested tool can be used for assessing the impact of agricultural management practices on soil erosion and assist in developing agricultural management policy maps.

Improved soil erosion predictions based on Sentinel-2 and deep learning techniques

[1]Samarinas N., [1]Tziolas N., [2]Coblinski J., [1]Karyotis K., [1]Tsakiridis N.

[1] School of Agriculture, Faculty of Agriculture, Forestry, and Natural Environment, Aristotle University of Thessaloniki, 54123 Thessaloniki, Greece
[2] INRAE, URSOLS, Orléans, F-45075, France

Soil erosion recognized as a vital importance indicator for land degradation and the Revised Universal Soil Loss Equation (RUSLE) is one of the most common predictive erosion models which has demanding input requirements. Despite the need for quantified information at high spatial resolution, the existing digital soil maps consist of rather coarse grid resolution or are based on not up to date legacy data. The aim of this work is to integrate in the RUSLE, enhanced soil spatial products (SOC, Clay) as generated by Sentinel-2 data and advanced deep learning techniques. The deep learning architectures contain state of the art building blocks such as Convolutional Neural Networks. The RUSLE has been implemented under two different simulations; one with the use of coarse already existing soil maps and the other with the use of the enhance soil spatial products generated by the proposed methodology for an agricultural site in Poland.

Synthetic conditioners to mitigate splash-induced erosion in intensive leafy green farming

Silvia Arpano

With multiple crop cycles per year, and a 21-28 day span between seeding and harvest, farming leafy greens can stress the soil structure. The agronomic consequence is the formation of a soil cap, that reduces water-use efficiency and impedes crop emergence. Traditional techniques of soil structure re-establishment are not compatible with the current crop management. This study investigated the effects on soil crust of a single spray application of a synthetic soil conditioner, Polyacrylamide (PAM), to two crops, Spinach (Spinacea oleacea) and Coriander (Coriandrum sativum).

The results show a 24, 41 and 59% decrease in splash erosion in plots treated with 40, 80 and 120 kg ha^{-1} PAM respectively. Emergence occurred significantly earlier and faster for plots treated with PAM, but there was no statistical difference in soil hydraulic conductivity in Coriander. Similar results were observed for Spinach, adding Calcium Nitrate reduced soil splash by 58% compared to Control. Better emergence and water management resulted in higher yield (+31% for Coriander at 80 kg ha-1, +47% on Spinach). In conclusion, one single PAM application helps in preventing splash erosion in intensely-cultivated soils, ameliorates bare soil's resilience against crust formation, that results in a positive effect on crop production.

Land Degradation Mapping for assisting SOILGUARD's (H2020 Project) experimental design

Melpomeni Zoka - Dr. Nikolaos Stathopoulos

BEYOND: Centre of EO Research & Satellite Remote Sensing, Institute for Astronomy, Astrophysics, Space Applications and Remote Sensing, National Observatory of Athens, Athens, Greece, 18/05/2022

SOILGUARD is an ongoing Horizon2020 project (June 2021 – ongoing) that aims to co-create a conceptual and analytical framework with the potential to become the global standard for future assessments of soil biodiversity status and to contribute to soil multifunctionality and to environmental, social and economic wellbeing. This framework will be validated in an innovative experimental design, combining multiple study sites across biomes and regional land degradation gradients with in-situ climate change simulations. The land degradation gradients are crucial for setting up the cross-biome network of the experimental sites (over 200) located in 7 European and 3 International NUTS-2 (or equivalent) regions. The topic of this presentation will be the generation of the land degradation gradients, which is based on the integration of FAO's Soil Organic Carbon and ESDAC-JRC's RUSLE soil erosion datasets.

Runoff and Soil Erosion Under Different Soil Surface Roughness

Sophia Bahddou

This study explores the changes in soil surface morphology due to the rainfall, as well as the effect of both the magnitude and orientation of soil surface roughness (SSR) on runoff, infiltration and soil erosion. Four soil surface treatments were used: up- and down-slope oriented roughness; across-slope oriented roughness; random roughness; and a smooth soil surface. Rainfall was simulated at an intensity of 90 mm hr-1 for storm durations of 15 and 30 minutes. Soil erosion was generated at the subprocess level (i.e. by raindrop splash and overland flow, occurring simultaneously). In the initially rough soil surfaces, the roughness decreased after the rainfall event while it increased in the initially smooth surface. Random roughness generated more runoff and soil loss and less infiltration than the other treatments. Oriented roughness across-slope did not always reduce runoff and soil loss. In all treatments, sediment concentration was higher at the beginning of the rainfall event.

Impact of soil erosion on soil health

Gaytri Soni

Junagadh Agricultural University

Globally soil loss occurs due to erosion, which extremely affects soil health of soil, ocean and freshwater. Basically soil erosion occurs by wind and water. Sediments transportation and depositional process may lead to soil organic matter. Loss of upper soil layer may induce lower soil fertility, so farmers apply more fertilizers for more crop production. It also induces reduction in microbial population. To reduce harsh effect of erosion on world, it is needed to adopt soil conservation methods in more and more areas.

Development of rainfall simulators for soil erosion research

MSc Vukašin Rončević[1*], dr Nikola Živanović[1]

[1]University of Belgrade – Faculty of Forestry, Kneza Višeslava 1, ZIP 11000 Belgrade, Serbia
*Corresponding author's email address: vukasin.roncevic@sfb.bg.ac.rs

To conduct experimental research related to soil erosion there was a need to create and apply rain simulators, both in the laboratory and in the field. Also, the initiative came from the idea of making equipment that would ensure further research, produce high quality data and create a database that could be easily integrated together. In the paper is represented methodology of development of rainfall simulator through several phases. According to the given methodology three rain simulators were designed one after the other: portable field simulator with sprinklers, dripper simulator with one dripper and simulator with more than one dripper. All three have already been developed while the third is in the process of calibration and validation. In order to successfully implement the development of rain simulators, it is necessary that its design and performance meet the needs of research (given criteria) in accordance with available resources.

Session 8

Landslides and Soil Erosion

New perspectives on the Europe-wide landslide susceptibility assessment (ELSUS)

Andreas Günther[1], Paola Reichenbach[2], Martina Wilde[3], Marta Jurchescu[4], Jean-Philippe Malet[5], Javier Hervás[6]

[1] Federal Institute for Geosciences and Natural Resources (BGR), Hannover, Germany (anderas.guenther@bgr.de)
[2] Consiglio Nazionale delle Ricerche, Istituto di Ricerca per la Protezione Idrogeologica (CNR-IRPI), Perugia, Italy
[3] Institut für Geographie und Geologie, University of Würzburg, Germany
[4] Insitute of Geography, Physical Geography Dept., Bucharest, Romania
[5] Institut de Physique du Globe de Strasbourg (CNRS UMR 7516), Université de Strasbourg/ EOST, Strasbourg, France
[6] European Commission, Joint Research Centre (JRC), Ispra, Italy

In 2013, the first Version of the European Landslide Susceptibility Map (ELSUS) was released through the European Soil Data Centre (ESDAC) of the European Commission. The map was prepared following guidelines formulated by the European Landslide Expert Group, and was based on a semi-quantitative susceptibility assessment employing spatial multi-criteria evaluation using three spatial criteria (namely shallow subsurface lithology, slope angle and land cover / land use) that was calibrated and validated with a generic pan-European landslide inventory. In 2018, an updated version of ELSUS was released through ESDAC that offers a higher spatial resolution, an enlarged coverage and employs more reliable information on shallow subsurface lithology. Additionally, the landslide inventory was considerably enlarged. Consequently, the overall predictive performance of ELSUS was enhanced by 10 %.

For future progress on ELSUS, it is immanent to prepare typologically differentiated landslide susceptibility maps for slides/flows and falls/topples, possibly exploiting additional suitable environmental information. Additionally, more quantitative (statistical and/or AI-based) modelling attempts should be adopted and tested. For the evaluation of landslide hazard scenarios over Europe, climatic and seismological information may be incorporated into the assessment. The most crucial step forward in ELSUS is possibly the preparation and maintenance of a harmonized and standardized landslide inventory throughout Europe at the overview scale. This inventory should also incorporate information on landslide consequences, so as to be able to generate spatial information on the impact of landslides in Europe.

Monitoring and impact assessment of landslides using Earth Observation

Marios Tzouvaras

PhD, MSc, DIC, MEng
Research Associate
ERATOSTHENES Centre of Excellence (https://eratosthenes.org.cy/)
Cyprus University of Technology (https://www.cut.ac.cy/)
Department of Civil Engineering & Geomatics

Landslides are one of the most devastating natural hazards worldwide, triggered by various factors that can be monitored via ground-based and/or satellite-based techniques. Cyprus is in an area of high susceptibility to such phenomena. Extensive field campaigns including geotechnical investigations and geophysical excavations are conducted to monitor land movements, and, at the same time, determine the geological suitability of areas. Synthetic Aperture Radar (SAR) satellite sensors have been widely used for detecting and monitoring landslides and other ground deformation phenomena using Earth Observation based techniques. The presentation will aim to demonstrate how the use of Copernicus open-access and freely distributed datasets, and more specifically SAR can be used to monitor and assess the impact of landslides in selected case studies in Cyprus. Coherent Change Detection techniques in combination with NDVI obtained from optical data can be used for the rapid detection and monitoring of such phenomena. Calculation of statistical significance and validation of methodology are essential for the evaluation of the performance the proposed methodology.

Engineering Geological Databases for Coastal Areas in Poland

Marta Szlasa, marta.szlasa@pgi.gov.pl, Polish Geological Institute - National Research Institute, Department of Engineering Geology, Warsaw, Poland

In the presentation, the author shows the results of Polish Geological Survey project called Engineering Geological Database (EGDB). EGDB is geological engineering geospatial database hosted by Polish Geological Institute (PGI). The presentation focuses on chosen coastal areas (cliffs), where risk of landslides related to erosion is high and may cause problems for people and infrastructure. Examples of different geological and geotechnical maps already published are shown. Example of difficult geological, geotechnical and environmental conditions are presented as well as methods of geotechnical investigations. As a result, examples of different types of coastal protection are presented, which were implemented by maritime office based on PGI recommendations.

Soil erosion and landslide susceptibility mapping using Rock Engineering System methodology. The case of Mandra fatal flash flood (2017) in Western Attica, Greece

Nikolaos Tavoularis

Dr. Engineering Geologist National Technical University of Athens
Regional Authority of Attica / Directorate of Technical Works, Greece (email: ntavoularis@patt.gov.gr)

According to the adoption of the "Thematic Strategy for Soil Protection" by European Commission, two of the eight main soil degradation processes (threats) to which soils in the EU are confronted, are erosion and landslides-flooding. Land degradation in its various forms is a fundamental and persistent problem. Specifically, landslides are a major threat in particular areas across Europe, often leading to serious impacts on population, property and infrastructure.
The European Soil Data Centre (ESDAC), located at the European Commission's Joint Research Centre is in charge (among other EU policy areas) of developing, implementing, and assessing soil protection and sustainable development, including taking measures for the prevention of further degradation. To this direction, land use and land use changes, spatial planning and urban development, water management and water protection policies are some characteristic examples of policy areas that ESDAC focuses on.
Regarding the above-mentioned, a case study from Mandra fatal flash flood (which took place on 14-15 November of 2017) in Attica Region (Greece), is presented with the intention to explore the role of soil erosion in relation to land degradation (e.g., landslides). Investigations from different stakeholders have been executed from 2017 till now, and the outcomes of those have been taken under consideration by Technical Authority (Directorate of Technical Works) of Attica Region to design and implement a priori mitigations measures against potential upcoming new extreme rainfall episodes in the near future. Soil erosion lines have been delineated and have been validated by an already generated regional Web-GIS landslide susceptibility map of Attica Region (DIAS project) which fulfilled in June of 2021 by a research team (https://gis.attica.gov.gr/en/node/1216). This map identifies specific zoning areas which are more susceptible to slope failure.
The study presents, briefly, soil erosion lines from Mandra fatal event along with the landslide susceptibility analysis for Attica Region (which Mandra belongs to), the most densely populated area in Greece. The produced susceptibility map is a cartographic product in a regional scale (1:100,000) generated for the Attica County via a semi-quantitative heuristic methodology named Rock Engineering System (RES) and a prototype technique originally developed by the Oregon Department of Geology (USA).
The way this landslide susceptibility map validates events such as those of Mandra's soil erosion, can further help or at least can propose modelling approaches that can respond to new developments in the European policies (e.g., data, maps, technical reports) such as those of the European landslide susceptibility map version 2 ((ELSUS v2) and ELSUSv2_six_datasets & metadata or more over to the improvement of large-scale assessments which can further generate landslide hazard and risk maps.

Susceptibility to mass movements at different scales

Paola Reichenbach[1], Andreas Günther[2] and Mauro Rossi[1]

[1] CNR-IRPI, via Madonna Alta 126, 06128 Perugia, Italy
[2] Federal Institute for Geosciences and Natural Resources (BGR), Stilleweg 2, 30655 Hanover, Germany

The variability of landslide phenomena in terms of types, velocity and size makes it difficult to establish a unique methodology for the definition of landslide susceptibility. In addition, the extent of the study area and the characteristics of the available data influence the selection of the modelling approaches. For these reasons, different susceptibility models adopting a variety of mapping units and thematic information are proposed in the literature for the prediction of landslide occurrence. A systematic review of the literature illustrates and describes relevant information on landslide susceptibility modelling and terrain zonation. In addition, examples of susceptibility zonation prepared at four different scales (i.e., continental, national, sub-national and catchment scale), allow to highlight different data types and resolutions, different mapping units, and various statistically-based modelling approaches. The examples provide an opportunity to identify proprieties of the geo-environmental data and of the main characteristics of the modelling approaches at different scale.

LAND-SUITE a set of tools for landslide susceptibility zonation

Mauro Rossi[1*], Txomin Bornaetxea[2], Paola Reichenbach[1]

[1] CNR-IRPI, via Madonna Alta 126, 06128 Perugia, Italy
[2] Euskal Herriko Unibertsitatea (UPV/EHU), Barrio Sarriena s/n, 48940 Leioa, Spain

LAND-SUITE is a suite of tools for statistically-based landslide susceptibility zonation implemented in R. It can be applied using different mapping unit types (pixel, slope units, administrative units), with distinct configurations and data resolution at diverse spatial scales. The tools are implemented to perform different partitions of the training/validation dataset several validation tests (temporal, spatial, cross validation). The software is not implemented to substitute the geomorphological/geological experience and competence of the operator, but facilitate the preparation and the selection of the variables/data required for the statistical analysis providing support for geomorphological hypotheses. The tool allows to verify and discuss initial assumptions that support the preparation of statistically-based susceptibility zonation. LAND-SUITE is then able to use an ensemble of supervised machine learning techniques to estimate susceptibility posed by geo-hydrological hazards, to provide separate estimates of the model performance in calibration and validation and to quantify and qualify the model errors and uncertainties.

Achieving high spatial resolution: UAV vs t-LiDAR point clouds for monitoring postfire effects

Simoni Alexiou[1*], Ioannis Papanikolaou[1], Georgios Deligiannakis[1], Aggelos Pallikarakis[1], Klaus Reicherter[2]

[1] Laboratory of Mineralogy-Geology, Department of Natural Resources Management and Agricultural Engineering, Agricultural University of Athens, 75, Iera Odos Str., 11855 Athens, Greece
i.pap@aua.gr; gdeligian@aua.gr; agpall@aua.gr
[2] Institute of Neotectonics and Natural Hazards, RWTH Aachen University, 52062 Aachen, Germany; k.reicherter@nug.rwth-aachen.de
*Correspondence: sim.alexiou@aua.gr

The emerging technology of UAV Photogrammetry method and the tLiDAR, a well-established method, were applied, resulting in high accuracy topsoil change detection especially for rapidly changing environments such as post-fire sites. Our methodology through the multitemporal comparison of high-resolution 3D point clouds led to detection of early landslide fractures as well as topsoil erosion rates estimation. UAV-SfM performed better in local conditions (assessing annual rill erosion rate up to 48cm) and early small scale landlslide phenomena (new cracks measuring up to 27m length and 25±5cm in depth, while tLidar performed better in slope wash detection in steep slopes with limited vegetation obscureness.

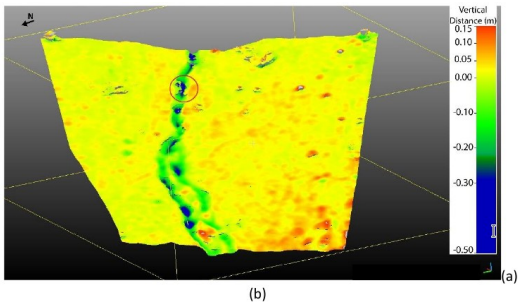

Figure 2: Evia S1 total annual erosion (m) using (a) UAV-derived data.

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Gully-landslide interactions in southeast Nigeria: implications for food security

I.E. Osumgborogwu

Department of Geography, University of Manchester, Manchester, M13 9PL,
Ikenna.osumgborogwu@manchester.ac.uk

Gully erosion and gully-induced landslides are the dominant environmental challenges in southeast Nigeria with significant effects on the availability of land for cultivation, crop productivity and land degradation. A mixed-method approach: analysis of remotely sensed data, field observation and use of structured questionnaire (160 correctly filled and returned) is employed to understand implications of gully-landslide interactions on food security in parts of southeast Nigeria. Results show that extensive land-use changes correlated with increased gully length ($p < 0.05$, adjusted $r^2 = 0.33$). Field observation suggested that landsliding is a dominant process of gully evolution through gully head retreat and areal expansion. Gully-induced landslide identified at visited gullies were shallow debris slides, complex failures, soil fall and block failures. Sensitivity analysis showed a sustained reduction in factor of safety with increased slope angle, thus as gullies evolve and gully slope walls increase, susceptibility to landsliding increases. Questionnaire survey showed that destruction of farm roads, inaccessibility to farmland, loss of farmland and economic losses were the direct implications of gully erosion and gully-induced landslides. 58% of respondents observed they have been forced to abandon their farms due to gully-landslide interactions. It follows therefore that as gullied areas increase due to extensive land-use changes and landsliding, more farmlands will be lost. This leads to reductions in farm produce and likely increase in prices of available food products in the market. Therefore, the accessibility of a farmer whose farmland is destroyed by gullying to nutritious food in sufficient quantity declines due to lost farmland and reduction in purchasing power. These conditions increase susceptibility to food insecurity, hunger and malnourishment.

Session 9

Climate change and soil erosion

Soil air entrapment - a new factor in soil erosion modelling to assess the climate impact

Climate-change studies for Saxony/Germany showed: Precipitation intensities of extreme events will increase until 2100. In Middle Europe, such extreme events will arise more and more often as convective precipitations due to thunderstorms after drought periods. Despite predicted higher precipitation intensities soil erosion models (for example EROSION 3D) simulate decreasing soil erosion rates in the second half of the century due to lower initial soil moistures in consequence of higher temperatures and greater solar radiation. In the particular case of dried out soils modelled infiltration curves do not match the results examined in field tests: Calculated curves displayed a higher infiltration rate than measured curves due to the entrapped air within the soil pores. Rainwater which cannot infiltrate becomes surface runoff and increases soil erosion. This effect is even intensifying when flash floods – caused by high intensity rainstorms – overflow soils and cover them by an area-wide water film. Then, soil air is encapsulated in the sediment body and hinders rainwater to infiltrate. The study aims the implementation of a "soil air entrapment factor" into soil erosion models like EROSION 3D and its first applications on field- and catchment scale. The factor was developed in order to predict soil loss by extreme precipitation events coming up against dried out soils.

Global Rainfall projections for 2050 and 2070

Panos Panagos et al., European Commission, Joint Research Centre (JRC).

We estimated the future global projections of rainfall erosivity for 2050 and 2070 climatic scenarios using the Global Rainfall Erosivity Database (GloREDa) and an ensemble of 19 downscaled CMIP5 general circulation models for three scenarios (RCP2.6, RCP4.5 and RCP8.5). For 2050, the mean global erosivity may increase in the range 26.2% - 28.9%, scaling positively with the RCP scenario (2.6, 4.5, 8.5) in most global regions. Within the ensemble of 19 model endmembers for 2050, at least seven scenarios project an increase of >30%. For 2070, the mean global erosivity may increase in the range 27–34%, similarly scaling positively with the degree of anthropogenic forcing (RCP scenario).

Projection of future soil loss under changing climate across mid-hills in Nepal Himalaya

Rocky Talchabhadel

The mid-hills of the central Himalayan region are identified as extremely vulnerable and sensitive regions concerning climate change due to their steep topography and diverse climate. The precipitation pattern is the most important agent and dominant parameter used in the research to modulate soil loss. More than 90 % of rainfall erosivity occurs during the monsoon season (June to September) in Nepal Himalayas. Spatially and temporally variability of precipitation leads to excessive soil losses across the landscape, leading to the greatest threat to environmental, social, and economic resources and meeting the sustainable development goals. This study analyzes different climate models under different shared socioeconomic pathways of CMIP6 to quantify projected impact on soil erosion. Rainfall erosivity and associated soil loss are estimated for the historical (1971-2000 as a baseline) and four future periods (F1: 2021-2040, F2: 2041-2060, F3: 2061-2080, F4: 2081-2100). Assessing the projected variation of rainfall erosivity is crucial to identifying soil erosion susceptible regions and periods. Climate models under different scenarios confirm the shifting nature of soil loss and are linked with the rainfall erosivity factor. Under changing climate, soil erosion is expected to increase with rising extreme rainfall events. The study findings have several implications for prioritizing effective conservation measures and developing mitigation strategies.

Assessing impacts of climate change on soil erosion and sediment in cold river basins

Climate change induced hydrological altercations can lead to excessive land degradation of a river basin and poses a threat to environmental sustainability. Particularly, cold river basins are vulnerable to climate changes due to snowmelt, glacial retreat, and permafrost. Therefore, there is a pressing need to assess the impacts of changing climate on the erosion and sediment transport in cold river basins. In this study, we present a unified learning of the institutional erosion and sediment transport in a cold river basin using an integrated modelling framework. It is found that the sediment processes are changing in cold regions due to climate change linked decline of permafrost, glacial thinning, early snowmelt, and the changing pattern of freeze thaw cycle. Finally, this study provides further insight we have studied over the years, and recommendation for a change of strategy that are essentially to improve erosion and sediment management in cold climate regions.

Applying RUSLE for soil erosion estimation in Romania under current climate and future climate change scenarios

Patriche Cristian Valeriu[*]

[*]Romanian Academy, Iasi Branch, Geographic Research Center

The study investigates soil erosion in Romania through RUSLE model. We used the 25 m resolution EUDEM to derive slope and slope length factor in SAGA GIS software. The rainfall erosivity factor was extracted from the RUSLE 2015 model for the Romanian territory. The annual crops for the year 2021 and CLC 2018 were used for computing crop and crop management factor. We tested 4 different manners of quantifying the soil erodibility factor. The best model was selected by validation with measured soil erosion rates. The CHELSA database was used to predict future possible evolutions of the rainfall erosivity factor. This was accomplished by computing a non-parametric estimation model of the current rainfall erosivity on the basis of the modified Fournier index and by extrapolating this model to future Fournier index values.

Assessment of soil erosion in urban landscapes using the G2 model and climate scenarios

Siniša Polovina[1]*, Boris Radić[1], Ratko Ristić[1], Jovan Kovačević[2], Vukašin Milčanović[1], Nikola Živanović[1]

[1]University of Belgrade, Faculty of Forestry, Kneza Višeslava 1, 11030 Belgrade, Serbia;

boris.radic@sfb.bg.ac.rs;
ratko.ristic@sfb.bg.ac.rs;
vukasin.milcanovic@sfb.bg.ac.rs;
nikola.zivanovic@sfb.bg.ac.rs

[2]Faculty of Civil Engineering, University of Belgrade, Bulevar kralja Aleksandra 73, 11000 Belgrade, Serbia; jkovacevic@grf.bg.ac.rs

Correspondence: sinisa.polovina@sfb.bg.ac.rs

Soil erosion is one of the most important contemporary problems of soil degradation and represents a threat to the functioning of urban areas, which was the reason for choosing the territory of the Master plan of Belgrade (Serbia) as the research area. The calculation of soil erosion loss was analyzed using the G2 model, which belongs to the group of empirical models. The assessment of soil degradation was analyzed based on the current land cover and the application of simulations of changes in climate parameters according to the RCP8.5 climate scenario, which is expected for the middle of the 21st century (2046-2065). The aim of applying this methodology is reflected in the assessment of soil losses based on climate change, which is defined as the middle of the 21st century if there is no change in land cover for the observed future period.

Assessment of Climate Change and LULC changes on Soil Erosion using RUSLE: A Case Study

An accurate estimation of soil erosion is essential to support land and water resources development, management, and planning in a watershed. The present study aimed to assess climate and Land use and Land cover (LULC) changes on soil erosion using the Revised Universal Equation (RUSLE) of the Kamla river basin, North Bihar. The soil erosion was estimated in both present (2010-2020) and future periods (2020-2030, 2030-2040) using derived rainfall data from downscaled Global Climate Models (GCMs) (MIROCS, CanESM, GFDL-LSM2M, MPI-ESM-LR, and NorESM) and projected LULC from CA-Markov model. The results revealed that in the present condition, the average annual soil loss increased from the years 2010 to 2020 due to increasing rainfall intensity and seasonal floods. However, it will increase in future periods (2030-2040). Thus, the study's findings may be useful for the decision-makers and managers in soil erosion control in the Kamla river basin and support its development, management, and planning.

Impact of Changes in Land Use and Climate on Flow and Sediment Loads in Upper Ma Catchment, Nothwest of Vietnam

Ngo Thanh Son*

bFaculty of Natural Resources and Environment, Vietnam National University of Agriculture, Vietnam

*Corresponding authors: ntson.hua@gmail.com (Son)

Over the course of the last decades, Viet Nam has been facing severe changes in the land use and climate. Climate changes scenarios predict these changes to be amplified in the upcoming decades. Yet, the hydrological response to these land use and climate changes remains poorly characterized, which threatens effective soil and water management strategies. In this study, we combined ground monitored time series data with the Soil and Water Assessment Tool (SWAT) model to assess the impact of past land use and foreseen climate changes on hydrological processes and sediment yield for the upper Ma river basin in northern Viet Nam. Land-use maps were derived from two Landsat satellite images recorded in 1994 and 2015, and climate scenario from IPCC, 2016. Results show that SWAT could be well calibrated and validated for the catchment. For runoff, the values of Nash-Sutcliffe efficiency (NSE), R2, and percent bias PBIAS were 0.84, 0.85, and 2.61 during calibration period and 0.75, 0.81, and -8.30 during validation period, respectively. For sediment yield, NSE, R2, and PBIAS during calibration period were 0.73, 0.76, and -3.61 and 0.87, 0.88, and -1.46 during validation period, respectively. Land use change in the study area increased surface runoff, ET, water yield, and sediment load considerably while decreased percolation, and ground water. These changes are attributed to deforestation and expansion of field crop. Climate change in the period 1994-2004 and 2005-2015, led to an increase of all hydrological components, however, decreased sediment load. This can be explained by a decreasing precipitation in some specific regions and also the transition of normal rainy season in the northwestern Vietnam. The combination of land use and climate changes impacts caused increase of ET, surface runoff and sediment yield. Overall, the changes in land use affected hydrological components and sediment yield more than the changes in climate in the upper Ma river basin. Finally, the results obtained from this study indicated that SWAT can be capable of simulation long term change in the hydrological components and sediment yield of a large river basin and can provide useful information to develop effective land use and water resource planning and management strategies.

Assessing soil erosion susceptibility to rainfall variation in the farming systems of the Central Highlands of Sri Lanka

Sumudu Senanayake[1,2], Biswajeet Pradhan[1 *,3,4]

[1]The Centre for Advanced Modelling and Geospatial Information Systems (CAMGIS), School of Civil and Environmental Engineering, Faculty of Engineering and IT, University of Technology Sydney, Sydney, 2007 NSW, Australia
[2]Natural Resources Management Centre, Department of Agriculture, Peradeniya, 20400, Sri Lanka.
[3]Center of Excellence for Climate Change Research, King Abdulaziz University, P. O. Box 80234, Jeddah 21589, Saudi Arabia
[4]Earth Observation Center, Institute of Climate Change, University Kebangsaan Malaysia, 43600 UKM, Bangi, Selangor, Malaysia
*Correspondence: Biswajeet.Pradhan@uts.edu.au; or biswajeet24@gmail.com

Healthy soil ecosystems induce crop productivity in the farming systems. The present climate variation and human intervention are threatening the health of soil ecosystems. The recent trends of rainfall variation accelerate soil erosion in many parts of the world. Researchers have identified that the tropical and subtropical regions of most of the developing nations are highly vulnerable to climate hazards. In this research, the Central Highlands of Sri Lanka, which is a tropical island in the Indian Ocean, was selected as a case study to assess soil erosion and predict soil erosion susceptibility concerning rainfall variation to prevent soil erosion hazards in farming systems. Soil erosion assessments were conducted using vegetation indices (NDVI/EVI), with an empirical soil model of the revised universal soil loss equation (RUSLE). The extreme rainfall indices (SDII, PRCPTOT, R99p, CDD, and CWD) and innovative trend analyses were performed with five agro-meteorological station data, to identify rainfall variation for the period of 2000 to 2020. The Mann-Kendell and Sen's slope tests were conducted to find out the significance of these trends. The soil erosion predictions were carried out using several machine learning approaches such as artificial neural networks (ANN), support vector machine (SVM), and an adaptive network-based fuzzy inference system (ANFIS). The rainfall data with the climate scenario (GCM models – CIMP6) were employed to predict soil erosion in 2040 under RCP 2.6 and RCP 8.5 scenarios. The average annual soil erosion rate in the year 2000 was estimated 9.08 Mg ha-1 yr-1, and it increased to 11.8 Mg ha-1 yr-1 in 2020. The highest elevation in the middle part of the Central Highlands (Nuwara Eliya) shows a significantly increasing trend of rainfall intensity from 2000 to 2020. The results show the western part of the Central Highlands becoming wetter and highly vulnerable to soil erosion and terrigenous mass movements such as landslides and debris flows, etc. The findings revealed that the climate-induced soil erosion is greater than human-induced (land-use change) soil erosion. In addition, this study predicted the average annual soil erosion rate may reach 10.18 Mg ha-1 yr-1 and 12.4 Mg ha-1 yr-1 in 2040 under RCP 2.6 and RCP 8.5 climate scenarios, respectively. This evidence shows that agricultural activities in the farming systems in the western part of the Central Highlands will be more vulnerable due to rainfall-induced soil erosion and an immediate restoration plan needs to protect the health of the soil ecosystem.

Prolonged rainfall and land use change drive sediment source dynamics and environmental damage

Hari Ram Upadhayay*, Yusheng Zhang, Steven J. Granger, Adrian L. Collins

Net Zero and Resilient Farming, Rothamsted Research, North Wyke, Okehampton, Devon, EX20 2SB, UK

Interaction between rainfall and agricultural land drives fine-grained sediment pollution in aquatic systems and is associated with a multitude of environmental and economic repercussions. In this study we report the response of different sediment sources in a catchment in southwest England during two meteorologically contrasting winters (2018-19 and 2019-20), when the catchment received 9% less and 20% more rainfall than the long-term average, respectively. Compound-specific stable carbon isotope signatures were used as diagnostic fingerprints of arable, pasture, woodland and stream bank sediment sources. Sediment source apportionment based on bound fatty acids revealed a substantial shift in dominant contributions, from stream banks (70 ± 5%) in 2018-19, to arable land (52 ± 7%) in the extreme wet winter 2019-20. Increases in sediment loss from arable (~3.9 times) and pasture (~2.4 times) land during the 2019-20 wet winter were also measured. Economic modelling estimated that at the catchment scale environmental costs associated with the delivery of fine sediment were ~8 times higher during the wet winter of 2019-20 and were in the range of £345- 445 ha-1. This study shows that prolonged heavy rainfall can change dominant catchment sediment sources which, in turn, can result in important off-site economic consequences.

Linking soil erodibility studies with pigment and suspended sediment load on a Mediterranean watershed after intense rainstorm.

Malta is being rapidly exposed to developmental activities occurring inland and along its coastline which in turn trigger erosion and flooding in the event of high-intensity rainfall. Most of the rainwater containing several contaminants from urban and agricultural areas is lost as runoff into the coastal waters which in turn has adverse environmental and socio-economic impacts. The extent of sediment erosion and runoff can be investigated starting from the watershed basin downhill till coastal waters. This chapter demonstrates a complete study that links the runoff of sediments along an ecologically sensitive watershed in Malta with the use of multi-disciplinary techniques, including the estimation of soil erosivity coupled with satellite remote sensing of fluxes in chlorophyll-a and total suspended matter in the adjacent coastal waters next to the mouth of the valley. It identifies problematic hotspots along the entire sedimentation process, which holistically, represents a novel study for the Maltese islands

Efficiency of erosion control agrotechnologies for improvement of soil quality and water regime and mitigation of greenhouse gas emissions

Gergana Kuncheva, Viktor Kolchakov, Petar Dimitrov, Milena Kercheva, Vihra Stoinova, Milena Mitova, Galina Petkova

Institute of Soil Science, Agtotechnologies and Plant Protection “N. Poushkarov”, Sofia, Bulgaria

The main results obtained after the first stage of a project funded by the National Science Fund under grant agreement КП-06 Н 46/1 will be presented. The objectives of the project are to investigate the interrelationships between soil erosion and water balance, biodiversity, organic and nutrient storage of Calcic Chernozem (Kastanozems) and greenhouse gas (GHG) emissions via field experiments and model simulations. The agrotechnical and soil protection efficiency of different soil tillage systems applied during winter wheat-maize crop rotation in the Experimental Station for Erosion Control of ISSAPP N. Poushkarov in the village of Trastenik, district Ruse, are evaluated. The efficiency of the applied agrotechnologies on soil quality are evaluated trough a set of soil indicators based on physical (soil water retention and conductivity at different potential, water stability of soil aggregates, thermal soil properties), chemical (soil organic matter content and composition, soil nutrient storage) and microbiological characteristics (microbial biomass, enzyme activity, and number of the main groups of soil microorganisms). The direct effect of the applied agrotechnologies on crops are measured through biometric (biomass, height and leaf area of plants) and energy indicators (accumulated energy and photosynthetically active radiation use efficiency) and modeled by deterministic simulation models (WOFOST). The GHG (CO2 и N2O) emissions are monitored after each soil tillage event. The time series of meteorological and soil moisture data registered by automated stations are used for assessing the dynamics of the components of soil water balance. Soil erosion analyses in the extended temporal (long-term time series) and spatial (watershed) scales are realized through the hydrological model SWAT. The expected results will enhanced the knowledge for the mechanisms which lead to improvement of soil structure and soil moisture regime, increase of soil organic carbon and nutrient storage and reduction of GHG emissions by the applied erosion control agrotechnologies.

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Nuclear techniques and remote sensing in soil erosion research - challenges and opportunities

Snežana Dragović[1], Milan Đorđević[2], Mrđan Đokić[2], Ranko Dragović[2], Miloš Manić[3], Mihajlo Jović[1], Ivana Smičiklas[1]

[1]"VINČA" Institute of Nuclear Sciences – National Institute of the Republic of Serbia, University of Belgrade, Mike Petrovića Alasa 12-14, 11351 Belgrade, Serbia
[2]University of Niš, Faculty of Sciences and Mathematics, Department of Geography, Višegradska 33, 18000 Niš, Serbia
[3]University of Belgrade, Faculty of Geography, Studentski Trg 3, 11000 Belgrade, Serbia

The need for reliable assessments of soil erosion rates avoiding costly monitoring programs has directed attention to the potential for using nuclear techniques for obtaining estimates of soil erosion rates. Remote sensing has also found its application in soil erosion studies for identifying areas exposed to high erosion risk, their mapping, and research on factors governing soil erosion. These two techniques provide helpful information for implementing soil conservation strategies as an essential part of sustainable agriculture and food production. The results from catchment level studies conducted in different regions of Serbia using the ^{137}Cs method and remote sensing are presented, and their main challenges and opportunities are discussed.