Catena 165 (2018) 551–566

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

The importance of soil data availability on erosion modeling

Nikolaos Efthimiou

Agricultural University of Athens, Department of Natural Resources Management and Agricultural Engineering, Faculty of Water Resources Management, Iera Odos 75, 11855 Athens, Greece

ARTICLE INFO

Keywords:
Erosion
Soil erodibility factor
K factor
Soil samples
RUSLE
Kalamas River

ABSTRACT

The accurate estimation of soil erodibility is essential for the proper simulation of erosion. The parameter, describing the soil's susceptibility to the erosive actions of precipitation and surface runoff, is expressed in the RUSLE (Revised Universal Soil Loss Equation) by the K factor. The latter is at most cases empirically estimated (due to the scarcity of soil data) discarding key attributes like organic matter content and granulometry. The study aims to assess the effect of the different K factor computation methodologies (empirical, based on bedrock lithology and stratigraphy; analytical, based on soil data) on soil erosion, at the Kalamas River catchment, located at Epirus, Northwestern Greece. To that end, RUSLE was implemented (both annually and multi-annually for the period 1987–02) at its two comprising subcatchments (Soulopoulo Bridge, Kioteki), once for every different K approximation. The study area's geology was described based on the Greek IGME (Institute of Geological and Mining Exploration) geological maps (1:50,000). The soil data (field samples) were provided by the Greek NAGREF (National Agricultural Research Foundation), the EU (European Union) and the Greek PCAGGCA (Payment and Control Agency for Guidance and Guarantee Community Aid). Provided that all other parameters (R, LS, C, P) remain unchanged, the model's results were depended on the alternative K factor values. Regarding the latter, the implementation (thus the K computation methodology) that performed best was the analytical one by displaying the highest convergence between simulated and “observed” {calculated based on field measurements, provided by the Greek PPC (Public Power Corporation)} sediment yield.

1. Introduction

Soil erosion is a gradual process that occurs when the impact of water detaches and removes soil particles causing the soil to deteriorate. The phenomenon constitutes a major global environmental problem threatening agricultural productivity, water quality, infrastructures etc.

The accurate estimation of erodibility, being one of soil's most important qualities, is essential for the proper simulation of erosion, since every different soil type's behavior directly affects the catchment's sediment production potential. The parameter, describing the soil's susceptibility to the erosive actions of precipitation and surface runoff, is expressed in the widely used USLE (Universal Soil Loss Equation) model (Wischmeier and Smith, 1978) and its revised RUSLE form (Renard et al., 1991) by the K factor. Among the different equations developed (Dangler and El-Swaify, 1976; Young and Mutchler, 1977; Williams, 1995; Torri et al., 1997; Romkens et al., 1997) for its estimation (based on soil properties) the K factor one is the most commonly implemented. Panagos et al. (2012, 2014) estimated soil erodibility at European level based on samples available from the LUCAS (Land Use/Cover Area frame Survey) topsoil data (Toth et al., 2013) using the original nomograph of Wischmeier et al. (1971).

According to Morgan (2005), erodibility mainly depends on each soil's intrinsic mechanical and chemical properties combined with the effect of external determinants {e.g. local climate, topography, bedrock, land use pattern and amount of manmade disturbance (tillage, cultivation)}.

Erodibility varies with soil texture, aggregate stability, shear strength, infiltration capacity and organic and chemical content. Regarding the soil texture, large heavy particles are more difficult to be transferred, while fine cohesive ones are more resistant to detachment – Richter and Negendank (1977) state that soils with silt content > 40% are highly erodible, while according to Evans' (1980) approach the most susceptible to erosion soils are the ones with clay content between 9 and 30%. Aggregate stability depends on the content of base minerals (high content increases stability, contributing to the chemical bonding of the soil aggregates) and the type of clay minerals (e.g. soils containing kaolinite, being resistant to expansion when wetted, have low erodibility). Shear strength is a measure of the soil's cohesiveness and resistance (frictional, among adjacent moving particles) to the shearing forces of gravity, moving water and mechanical loads and it is used for the description of soil particles detachability from raindrop impact and

E-mail address: efthimiounik@yahoo.com.

https://doi.org/10.1016/j.catena.2018.03.002
Received 24 April 2017; Received in revised form 19 February 2018; Accepted 4 March 2018

surface flow. Infiltration capacity is influenced by pore size, pore stability and the form of the soil profile – soils with low stability aggregates (e.g. containing vermiculites, getting swollen when wetted) have low infiltration capacity since they can't maintain their pore size and spaces even. The organic and chemical content influence aggregate stability as well (infiltration and water retention capacity are increased when the organic content is high) affecting surface runoff (conversely decreased) – when the organic content is $< 3.5\%$, the soil is considered erodible (Evans, 1980), while a high proportion of easily dispersible clays affects erodibility (negatively) as well. Parameters like soil depth (deeper soils have higher water capacity, retaining larger amounts of water before causing runoff, thus being more resistant to erosion) and the presence of rock fragments (affect soil permeability) should also be considered.

Considering the above, the study aims to assess the effect of two different soil erodibility (K) factor computation methodologies (empirical, analytical) on soil erosion. To that end, RUSLE was implemented (both annually and multi-annually, for the time period 1987–02) at the two comprising subcatchments (Soulopoulo Bridge, Kioteki) of the Kalamas River, once for every different K factor approximation. The empirical one was based on the lithology and stratigraphy of the basin's underlying bedrock {described by the Greek IGME (Institute of Geological and Mining Exploration) geological maps (1:50,000)}, corresponding to its vulnerability to disintegration and its capability of sediment production. Given that soil data are often scarce and field trials are expensive and time consuming, K is more easily estimated that way, yet key attributes like organic matter content and granulometry are discarded. The analytical one was based on the methodology proposed by Wischmeier and Smith (1978), using 70 soil samples provided by the Greek NAGREF (National Agricultural Research Foundation), the EU through the LUCAS database and the Greek PCAGGCA (Payment and Control Agency for Guidance and Guarantee Community Aid) through the AUTH (Aristotle University of Thessaloniki), which was the contractor assigned to conduct the field measuring program and process the data acquired. Given the linear character of the model's equation, and provided that all other parameters (R, LS, C and P) remained unchanged, the difference among the two approaches results was only depended on the alternative K factor values. The effect of each factor on soil erosion was subsequently assessed, by evaluating the convergence between simulated and observed {calculated based on field measurements, provided by the Greek PPC (Public Power Corporation)} sediment yield.

The study area was chosen considering the Kalamas' River role as the region's growth driver, as well as the availability of the necessary data at both of its subcatchments, allowing the expansion and amplification of the drawn conclusions.

Overall, the attempt to attest the effect of the soil erodibility delineation methodology on soil erosion simulation, by comparing two different K factor approximations (analytical, empirical) through the implementation of RUSLE on a mountainous Mediterranean type catchment, both annually and multi-annually (once per each approximation, for a considerable time period) and the comparison of the modeled results against "observed" (synthetic, given the sediment rating curve method) sediment yield values constitute the innovation introduced by the present study.

The study can provide a good basis in terms of (at least) a preliminary soil erosion estimation and identification of the most vulnerable areas at the specific basin. This approach, combined with field observations {in order to provide the evidence (e.g. presence of rills, gullies, heavy sedimentation at the foot of hills) to support the necessity of taking protective measures against erosion} and possibly the additional implementation of a modern comprehensive model, can integrate into a valuable tool for the application of a targeted policy {e.g. technical infrastructure construction (terraces, sediment retention dams etc), change of farming techniques [contour ploughing, cultivation of crops that protect soil from erosion, afforestation, reduced tillage, plant residues and grass margins, as identified in the GAEC (Good Agricultural and Environmental Conditions) of the CAP (Common Agricultural Policy) for reducing erosion in arable lands (Borrelli et al., 2016)], institutional and administrative measures (hydrologic design/forecast/warning/protection)} in order to address the phenomenon's adverse (technical/social/environmental/economic) effects, improve the living standards of the local population and contribute to the area's development.

2. Materials and methods

2.1. Study area and measurements

The Kalamas River catchment is a mountainous Mediterranean type watershed located at Epirus, Northwestern Greece, resting within the Epirus Water District. It is comprised of two successive subcatchments namely Soulopoulo Bridge and Kioteki (named after the homonym gauging stations at their outlets), with the former being integrated within the latter and separated in regard to the aforementioned stations' location. At the present study, the area downstream the Kioteki gauging site, including the flat alluvial plain of the river Delta, was not considered (Fig. 1).

The basic subcatchment attributes are presented in Table 1.

The study area's land use, described considering the European CORINE (Coordination of Information on the Environment) Land Cover (CLC) Version 2000 classification, is extensive with forests and woodland covering its greater part, followed by wetlands and pastures. The cultivated areas {generic arable lands, mainly comprised of tree (citrus) and seasonal (cotton, maize, wheat etc) crops} are less extensive. Overall, the land use map identified 18 different types of land cover at the Soulopoulo Bridge basin and 22 types at the Kioteki one (Table 2, Fig. 6). The minor lowlands are mainly located at its outlet towards the Ionian Sea. The hydrographic network is dense due to the region's intense geomorphology and the high rainfall depth and intensity.

The study area's geology was described based on the Greek IGME geological maps (1:50,000). Given the Kalamas basin location {within the external Hellenides (Pindos, Ionian) geotectonic zones} the bedrock (mainly) consists of sedimentary materials. In general, the formations met are primarily quaternary alluvial deposits (terraces, talus cones and scree etc) limestones and flysch, while clays, marls, conglomerates, schists, gypsum and dolomites are also present. The Soulopoulo Bridge subcatchment is mainly occupied by limestones {permeable formations that display high infiltration rates, being moreover characterized according to the Greek Ministry of Development (2005) by the development of karstic systems (subterranean drainage systems, sinkholes, depressions and springs) which allow rapid subsurface water movement (thus, resulting to decreased runoff and subsequently discharge at its outlet) – the infiltrated amount of water discharges downstream, contributing to the increase of discharge at the Kioteki gauging station} and alluvial deposits (also permeable formations, characterized by primary and secondary porosity) – the latter can be found at the catchment's outlet as well, while the remaining part of the Kioteki basin is characterized by the extensive presence of flysch (impermeable to water, favoring surface runoff).

The (daily) precipitation measurements were acquired from eight pluviometric stations sited within the catchment's boundaries (Fig. 1), overseen by the Greek MEECC (Ministry of Environment, Energy and Climate Change) and the Greek PPC.

The Greek PPC has conducted the (daily) discharge and (random sampling) simultaneous discharge-sediment discharge measurements (Q-Qs pairs), at the Soulopoulo Bridge and Kioteki gauging sites.

The mean daily discharge values resulted from the implementation of the daily water stage measurements on the stage-discharge curves. The latter were constructed based on the daily water stage and monthly flux velocity records at the specific cross-sections (Soulopoulo Bridge, Kioteki).