USLE, RUSLE and WEPP models used in mining restored hillslopes

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ABSTRACT

One of the main problems affecting mining restoration is erosion, which limits the development of functional soils and plant communities. The eroded sediment pollutes and degrades the natural river systems. The objective of this work is to test some of the most used models: USLE (Wischmeier and Smith, 1965, 1978) and RUSLE 1.06 (Toy and Foster, 1998) and WEPP (Nearing et al., 1989), for the case of slopes derived from mining reclamation. The study area is a dump in El Moral coalmine (Utrillas), 60 km. north of Teruel city. We selected three artificial slopes, one with a topsoil substrate and two overburden-covered in order to measure the sediment production during a year. After the comparison between estimated and measured erosion rates two conclusions can be stated: a) RUSLE 1.06 gives the best estimations in most of the cases. However WEPP in its annual option and for the topsoiled slope, works better than RUSLE1.06.

Key words: USLE, RUSLE, WEPP, erosion, and mine reclamation.

INTRODUCTION

Surface mining produces a very intensive environmental impact since it affects to the three main elements of the landscapes (geomorphology, soils and vegetation). In fact, the materials moved up by mining activity in the world reaches up to 15-22 Gt per year, a magnitude similar to that transported by the rivers of the planet (Hooke, 2004). Land reclamation is in practice the main tool to mitigate such environmental impact. Soil erosion strongly conditions reclamation success because it restricts the development of functional soils and plant communities (Espigares et al., 2009). On the other hand, eroded sediment pollutes and degrades natural water courses (Addis et al., 1984; Sawatski, et al., 2000).

The use of erosion models has been recommended in order to predict the stability of the designed relief forms (Evans & Loch, 1996). SIBERIA can be considered the most advanced model in this field. It predicts long-term evolution of the topography (Willgoose and Riley, 1998; Hancock, 2000). Also, in Australia, a methodology has been developed for relief design in mining that combines the Curve Number Method for hydrology, RUSLE-MUSLE for sediments, and the GRASP model for herbaceous plant growth (Loch and Sell, 1998). RUSLE 1.06 (for mined lands, construction sites and reclaimed lands) estimates the annual surface erosion by water (Toy and Foster, 1998).

The main objective of this work is to compare three of the more used models in order to test their soil erosion predictions in artificial slopes derived from surface mining reclamation

MATERIALS AND METHODS

Field data used to test the estimations of the models come from *El Moral* field site, in Utrillas coalfield, (Central-east Spain). The area description as well as the experimental layout and most of the input and outputs values of the models are shown in Nicolau (2002).

Two types of slopes were monitored according to their substrate (Table 1): the one is covered by an overburden material from the *Escucha* Formation composed by fine sands and silts and the other with a topsoil substratum from natural soils (Leptosols and Cambisols). The first ones have developed dense rill networks with a very low plant establishment. The topsoiled is sheet erosion dominated showing a successful establishment of vegetation (plant cover higher than 50%). A summary of the characteristics of the selected slopes is shown in table 1. Revegetation consisted on a sowing with perennial herbaceous (grasses and leguminous).

Soil samples were taken for analysis (texture, organic matter, cationic exchange capacity, soil moisture, USDA, 2004) in order to estimate the necessary variables for each model. To complete the data collection, daily temperature and precipitation were collected at the *Montalban* weather station from the National Meteorology Institute data collection. This information was used to complete the CLIGEN file of the WEPP model.

Figure 1.- Slope monitorization.

Table 1.- Slopes characteristics.

Hillside	Length (m)	Slope (%)	Area (m^2)	Altitude (msnm)	Rill Density (m/m^2)	Treatment	Cover		Rock (%)
							%	Species	
1	53	32.49	159	1140	0.24	Topsoil	35	*Festuca rubra, Festuca arundinacea, Poa pratensis and Lolium perenne*	11
2	41	34.43	102.5	1160	1.92	Sterile	5	*Medicago sativa*	6.4
3	44	34.43	110	1160	1.21	Sterile	5	*Medicago sativa*	6.4

In addition, input data were introduced into the models. Both the type of land use and *b* value (vegetation effect on erosion control) was changed in RUSLE model, and the value of initial cropping system and initial soil saturation (SAT) in WEPP model.

RESULTS AND DISCUSSION

The USLE model overestimates erosion rates in the three slopes with respect the empirical data (Fig.2). It is noteworthy in the slope 1 (3500%), in the other two, overestimation decreases, assuming no major difference of 80%. The overestimation of erosion rates from all erosion models have been very sign, Nearing (1990). In the current model this has been noted by Kinnell, 2003.

Fig.2. USLE model results.

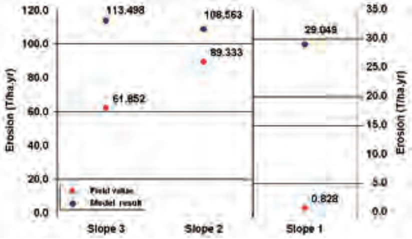
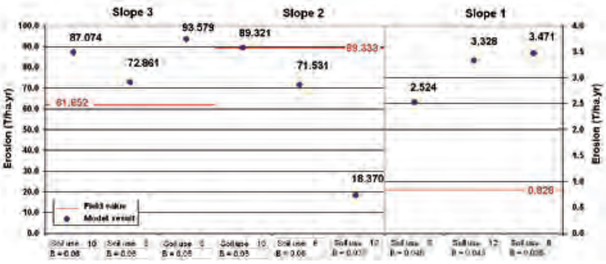


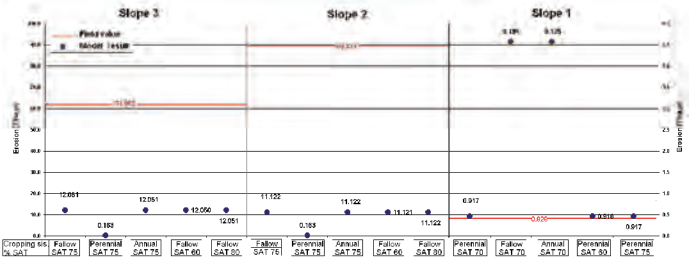
Fig.3. RUSLE model results.



RUSLE model produces an overestimation of erosion rates (Fig.3), but much more moderate. Is noted the high accuracy of the model predictions on the slope 2 and 3: In contrast, the highest difference is produced on the slope 1. The obtained data in the study contradict some previous work, Kapolka et al., (2001). However, our results are similar to those obtained by Kinnell (2003). The ability of the model to simulate erosion rates in constructed reliefs was highlighted earlier by Evans et al. (1996).

In calibration, in slope 1 shows that land use that better reflects the actual slope characteristics, is num.6, semi-coarse ground, rather than specifically designed for these conditions, topsoil disturbed fill. Furthermore, in accordance with this change, the b value that works best is the coarse soil (0,045), not the initially estimated, corresponding to the equality between rill and interril erosion (0.035). However, for the slopes 2 and 3, the land use that reflect best the field characteristics is num.10, subsoil disturbed fill, the indicated for these specifically conditions. The best b value in these cases has been 0.05 for slope 2 and 0.06 for slope 3.

Fig.4. WEPP model results.

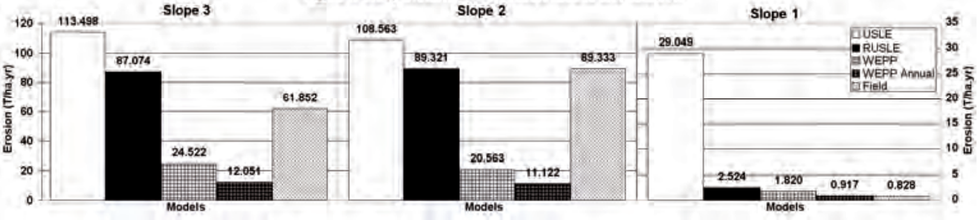


With respect to the WEPP model, a general underestimation of erosion rates is observed, except in slope 1 (Fig.4). In this slope the estimation is very accurate. The WEPP model overestimation in high-intensity storms has been shown by Tiwari et al. (2000). However, in slopes 2 and 3 the opposite occurs. This is explained by the model tendency to underestimate erosion in areas with high soil loss rates Reyes et al. (2004). For his part, the conjunction of these two factors has been described by Tiwari et al., 2000.

The results during the calibration proccesses shows that the initial cropping system which better reflects the conditions present in the field is perennial for slope 1 and fallow for slopes 2 and 3. For its part, has been observed that SAT value has less related to erosion values offered by the model. In the case dealt, the ideal value is 75% for slope 1, and 80% for slopes 2 and 3, with less value of porosity for the same value of rainfall.

In slope 1 (Fig.5) the model that is closer in its estimations is the WEPP model with its annual simulation option. The rest of the simulations, except USLE, are one order of magnitude above, although the values are more or less comparable. There are no references on the application of WEPP to constructed slopes. However, the closer WEPP simulations regarding RUSLE have been noted by Stolpe, (2005) in agricultural lands. In slopes 2 and 3, RUSLE estimations are very close to the field data. In this case WEPP simulations resulted erosion values far below than field values. USLE models gives higher estimation values than field values.

Figure 5. Comparison between models results and field data.



As sown in results of slope1, it can be said that the model USLE is not useful for erosion simulations on constructed slopes with low rates of erosion and an effective vegetative cover. By contrast, the model more realistic under these conditions is the annual simulation option of WEPP model, whose values are remarkably similar to empirical data. For his part, the results sown in slopes 2 and 3, indicates that WEPP and USLE models are not useful for slopes with high rates of erosion and an inefficient management and vegetation cover, the first by underestimating rates sharply and the second by a modest overestimation of them. In contrast, RUSLE model adjusts its values, so outstanding, with reality

CONCLUSIONS

The USLE model produces a general overestimation of the soil loss rates on restored mining slopes, and this is more pronounced where the slope characteristics produced lower erosion rates. The RUSLE model produces a modest overestimation of the soil loss rates, and this is more pronounced under lower erosion rates. Finally, in WEPP model, the underestimation is generally higher in high erosion rates, slopes 2 and 3. As a final conclusion can be asserted that the model RUSLE is the most suitable of the three, in general, to simulate the erosion on restored mining slopes and to the specific conditions reported, according to adequately in all three cases.

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