## Supplementary Discussion

### 1.1 Why were previous estimates of TER too high?

1.1.1 Model parameterization

The (R)USLE model is widely used to spatially estimate rill and sheet erosion rates (topsoil erosion by water) at various scales. The model is a simple factorial model that can be written as:

Where A is the annual rill and sheet erosion rate (t ha-1 yr-1); R is the rainfall erosivity factor (MJ ha-1h-1yr-1); K is the soil erodibility factor (t ha h ha-1 MJ-1 mm-1): L is slope length factor; S is the slope steepness factor; C is the cover management factor; P is the support practice factor.

The model has been shown to be successful in providing unbiased, reasonably accurate estimates of soil erosion rates measured on erosion plots, especially in the USA (Risse et al., 1993). However, applying the model in other environments at the landscape rather than the plot scale carries important risks. First, the parameter values derived from model guidelines may not be adequate for the area under study. Second, the extrapolation of erosion data from the plot to the landscape scale requires that the values of the topographical factors (slope gradient and length) are correctly calculated.

It is not possible to examine the role of the various model parameters individually as they are all interrelated: an overestimation of rainfall erosivity may be compensated by an underestimation of soil erodibility and vice versa. However, one may assess whether the empirically derived values for a given parameter are indeed in agreement with model guidelines if other parameters are correctly calculated. We examined whether this was the case for soil erodibility.

Soil erodibility (K factor)

Soil erodibility can be calculated from basic soil properties using a (set of) empirical equations relating the soil’s erodibility to the grain size distribution of the top soil layer, its organic matter content, its structure and/or its permeability using an empirical model proposed by Wischmeier and Smith (1978). Alternatively, soil erodibility can be directly calculated from measured soil erosion rates for a soil under so-called black fallow conditions, provided that rainfall erosivity is known. We found two studies were such a methodology was applied and made additional calculations for 41 plots in our database, located in different parts of the CLP where soils were maintained under black fallow conditions (Wang et al., 2013; Zhang et al., 2004)(6, 7). We found that soil erodibility factors that were directly derived from field measurements were, on average, 2 to 3 times lower than model-based estimates (Supplement Table 3). This confirms the result of an earlier study with a more limited dataset. Zhang et al. (2004) used a limited dataset (16 plots on 4 sites) to establish a simple model relating the soil erodibility to the soil’s clay content for the soils of CLP and found that K was strongly overestimated. This model was used by Fu et al. (2011) and provides more realistic estimates than the more general models used in other studies (Supplement Table 3). However, other studies (8)derived soil erodibility values from Wischmeier and Smith (1978)’s model, which at least partly explains why they obtained very high TER estimates (Schnitzer et al., 2013).

Topography (LS factor)

The application of any erosion model on arable land requires knowledge of slope gradient and length: when the (R)USLE is used, this topographic information is used to calculate to so-called LS factor, which represents the relative average erosion rate to be expected on a parcel in comparison to the reference erosion rate measured on a 22.13 m long plot on a slope of 9%. Slope gradient values calculated from Digital Elevation Models (DEMs) are resolution-dependent, but these effects can easily be corrected for (Van Rompaey et al., 1999)(9). Calculating slope lengths for arable land using a DEM is more complicated. The calculation of slope length using topographic information only may result in significant overestimations of the slope length that is relevant for topsoil erosion. On the CLP, fields are only rarely so large that they cover an entire slope. Fields often have different crops, and erosion processes will most often not occur on all fields simultaneously. As a result, slope lengths are in reality much more often limited by parcel boundaries than by natural topographical breaks. The relevant slope length is therefore the average field length, rather than the average topographic slope length. Ignoring this reality will lead to a significant overestimation of slope length and hence of topsoil erosion rates. We were not able to exactly reconstruct the calculation procedures used in previous studies, but it is clear that they yield widely divergent results. Schnitzer et al. (2013) arrive at an average LS factor of 11.90 for the whole CLP, while the application of the procedure proposed by Van Remortel et al. (2004), which uses topographical information only, results in an average value of 5.28 (Van Remortel et al., 2004). We calculated LS values for 307 terraced and non-terraced parcels in our GE sample dataset. These calculations resulted in an even lower value of 2.21 (2.67 for terraced land (note that this value does not account for the effects for terracing, which are incorporated in the P-factor) and 1.94 for non-terraced land). The overestimation of the LS factor is one of the main reasons why TER are overestimated when the (R)USLE is applied at the landscape scale.

The second important reason why classical slope length calculations bias estimates of TER is that the dependency of TER on topography is fundamentally different on arable land in comparison to land under permanent vegetation. Empirical analyses consistently show that, when a significant permanent vegetation cover is present, TER does not systematically increase with slope length (Cammeraat, 2002; Cerdan et al., 2004)(10, 11). This finding was confirmed by our plot data analysis. The key reason for the absence of an erosion-slope length relationship is that the presence of permanent vegetation induces hydrological discontinuity in surface runoff (Dunne et al., 1991). While runoff is known to accumulate in the downslope direction on arable land, if most often does not so on land with permanent vegetation. On the latter, zones of lower infiltrability alternate with zones of high infiltrability, which absorb most of the runoff coming from upslope (Dunne et al., 1991). As surface runoff does not increase in the downslope direction, the TER does neither. Calculating erosion rates from data obtained on short plots and assuming that TER will increase with slope length if permanent vegetation is present will then inevitably lead to an overestimation of topsoil erosion under natural vegetation.

Also, we did not find any relationship between slope gradient and TER under permanent vegetation. While the absence of such a relation may be due to an erosion-surface cover feedback, the latter would require that a significant rock fragment fraction is present in the soil (Govers et al., 2006)(12). This is not generally the case on the CLP. An alternative explanation is that, given the low runoff rates and the discontinuous nature of runoff, erosion under natural vegetation is mainly driven by splash detachment. Although the latter may be affected by slope gradient, it is far less so than detachment by overland flow. The weak slope dependency of raindrop detachment is likely to be smaller than the variability of erosion rates induced by other factors varying between plots such as total vegetation cover and vegetation pattern (Torri and Poesen, 1992). As a consequence, no meaningful pattern could be detected.

## Supplementary Tables

Table 1. Soil loss reduction by terracing as reported in the literature: PY is the plot year; SFE is the sloping farmland plot erosion rate (t ha-1 yr-1); TFE is the terraced farmland plot erosion rate (t ha-1 yr-1), TE is the relative amount of TER measured on terraced land and is equal to TFE/SFE

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Reference | PY | SFE | TFE | TE |
| (Wang et al., 2002)(20) | 8 | 28.66 | 7.15 | 0.25 |
| (Zhang et al., 2008a)(21) | 3 | 0.33 | 0.19 | 0.58 |
| (Xu et al., 2010)(22) | 5 | 7.40 | 3.49 | 0.47 |
| (Shen et al., 2010)(23) | 4 | 0.60 | 0.30 | 0.50 |
| (Cai, 2004) | 5 | 1.17 | 0.37 | 0.32 |
| (Lu et al., 2009)(24) | 1 | 20.33 | 4.55 | 0.22 |
| (Lu et al., 2009)(25) | 1 | 32.92 | 5.19 | 0.16 |
| (Yang, 1999)(25) | 3 | 155.70 | 4.92 | 0.03 |
| (Zhou, 2007)(26) | 2 | 9.13 | 0.19 | 0.02 |
| (Chen et al., 2006)(27) | 2 | 30.79 | 0.77 | 0.03 |
| (Chen et al., 2006) | 2 | 42.25 | 1.88 | 0.04 |
| (Wu and Li, 1998)(29) | 4 | 18.70 | 1.00 | 0.05 |
| (Zhang et al., 2008b)(30) | 9 | 45.16 | 2.11 | 0.05 |
| (Fu et al., 2000)(31) | 3 | 8.32 | 0.53 | 0.06 |
| (Fu et al., 2000) | 3 | 28.56 | 0.97 | 0.03 |
| (Fu et al., 2000) | 3 | 2.26 | 0.24 | 0.11 |
| Mean | | 27.02±37.45 | 2.12±2.23 | 0.20±0.19 |

Table 2. Comparison of measured and predicted erosion rates. Measurements are based on 137Cs inventories. Model predictions are based on the model developed in this study (Eq. 2): SL slope length (m); SD: slope degree (°); MeanCs: mean 137Cs inventory of the slope (Bq m-2); ReCs: reference 137Cs inventory (Bq m-2); ME: measured erosion rate (t ha-1 yr-1); PE: predicted erosion rate (t ha-1 yr-1).

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Sample year | SL | SD | MeanCs | ReCs | ME | PE | Reference |
|  | 240 | 19.7 | 953.89 | 2390 | 57.97 | 114.66 | (Chen et al., 2002)(32) |
| 1997 | 37 | 10.44 | 2026.89 | 2390 | 10.54 | 3.55 | (Li and Lindstrom, 2001)(33) |
| 1997 | 180 | 25 | 827.75 | 2390 | 66.78 | 139.24 | (Li and Lindstrom, 2001)(33) |
| 1998 | 60 | 8.68 | 1502.52 | 1761 | 13.16 | 17.60 | (Li et al., 2007)(34) |
| 1998 | 200 | 19.04 | 891.99 | 1761 | 55.85 | 99.50 | (Li et al., 2007)(34) |
| 2005 | 50 | 17 | 824.6 | 1582 | 44.64 | 41.98 | (Li et al., 2009)(35) |
| 2005 | 90 | 25 | 587.34 | 1582 | 67.61 | 98.46 | (Li et al., 2009)(35) |
|  | 43.8 | 6.5 |  |  | 1.3 | 2.08 | (Quine et al., 1999)(36) |
|  | 8 | 3.3 |  |  | 0 | 0.41 | (Quine et al., 1999)(36) |
| 1997 | 110 | 19.3 | 316.46 | 2250 | 92.50 | 75.30 | (Wang, 2003)(37) |
| 1997 | 64 | 18 | 439.05 | 2250 | 77.43 | 51.75 | (Wang, 2003) |
| 1997 | 52 | 18.2 | 551.43 | 2250 | 66.85 | 47.43 | (Wang, 2003) |
| 1997 | 70 | 22.6 | 327.67 | 2250 | 90.90 | 75.60 | (Wang, 2003) |
| 1997 | 32 | 25.4 | 470.33 | 2250 | 74.24 | 59.95 | (Wang, 2003) |
| 1997 | 24 | 21.9 | 479.11 | 2250 | 73.38 | 42.33 | (Wang, 2003) |
| 1997 | 21 | 6.4 | 552.57 | 2250 | 66.75 | 7.07 | (Wang, 2003) |
| 1997 | 23 | 13.1 | 1160.5 | 2250 | 31.82 | 19.33 | (Wang, 2003) |
| 1997 | 70 | 17.9 | 162.15 | 2250 | 122.83 | 53.67 | (Wang, 2003) |
| 1997 | 52 | 13.4 | 610.67 | 2250 | 62.09 | 30.04 | (Wang, 2003) |
| 1997 | 33 | 23 | 168.05 | 2250 | 121.22 | 53.21 | (Wang, 2003) |
| 1997 | 37 | 31.6 | 611.69 | 2250 | 62.01 | 82.93 | (Wang, 2003) |
| 1997 | 8 | 27.3 | 629.9 | 2250 | 60.64 | 32.83 | (Wang, 2003) |
| 1997 | 105 | 24.6 | 573.45 | 2250 | 65.02 | 104.08 | (Wang, 2003) |
| 1997 | 30 | 21.8 | 641.58 | 2250 | 59.78 | 47.01 | (Wang, 2003) |
| 1997 | 103 | 26 | 537.86 | 2250 | 68.01 | 110.84 | (Wang, 2003) |
| 1997 | 15 | 30 | 257.92 | 2250 | 101.84 | 50.07 | (Wang, 2003) |
| 1997 | 39 | 25.9 | 1664.13 | 2250 | 14.57 | 67.87 | (Wang, 2003) |
| 1997 | 34 | 17.8 | 2089.61 | 2250 | 3.58 | 37.09 | (Wang, 2003) |
| 1997 | 29 | 12.6 | 2125.85 | 2250 | 2.75 | 20.51 | (Wang, 2003) |
|  | 45 | 14 | 1930 | 2676.5 | 24.65 | 29.81 | (Wu and Kou, 1997)(38) |
|  | 10 | 1 | 2640 | 2676.5 | 0.07 | 0.15 | (Wu and Kou, 1997) |
|  | 100 | 10 | 1960 | 2676.5 | 23.2 | 27.50 | (Wu and Kou, 1997) |
|  | 100 | 1 | 2270 | 2676.5 | 11.6 | 2.41 | (Wu and Kou, 1997) |
| 1993 | 24 | 9.8 | 1250 | 2500 | 37.68 | 13.10 | (Zhang et al., 1997)(39) |
| 1993 | 70 | 18.3 | 560 | 2500 | 80.26 | 55.48 | (Zhang et al., 1997) |
| 1993 | 23 | 36 | 440 | 2500 | 92.84 | 73.04 | (Zhang et al., 1997) |
|  | 90 | 10.5 | 1070 | 2540 | 65.00 | 27.90 | (Zhang et al., 1998)(40) |
|  | 48.3 | 24 |  | 2540 | 87.10 | 68.27 | (Zhang et al., 1998) |
|  | 76.6 | 19.2 |  | 2540 | 82.80 | 62.35 | (Zhang et al., 1998) |
|  | 61.1 | 29 |  | 2540 | 94.90 | 97.37 | (Zhang et al., 1998)(40) |
| 1992 | 49.23 | 23.98 | 705.2 | 2540 | 71.32 | 68.85 | (Zhang et al., 2002)(41) |
| 1992 | 77.13 | 19.11 | 771 | 2540 | 66.46 | 62.13 | (Zhang et al., 2002)(41) |
| 1992 | 62.29 | 28.94 | 557.2 | 2540 | 84.09 | 98.09 | (Zhang et al., 2002)(41) |
| 1992 | 88.82 | 11.21 | 1068 | 2540 | 48.56 | 30.38 | (Zhang et al., 2002)(41) |

Table 3. Comparison of estimated and measured soil erodibility values (K factor, t ha-1(MJ mm)-1 ha h) in CLP. Estimates are derived using the procedure proposed by Wischmeier and Smith (1978). Note that estimates are, on average, two to three times higher than measured values.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Estimated soil erodibility | | | | Measured soil erodibility | | |
| Reference | Range | Mean | Methods | Reference | PN | Mean |
| (Pan and Wen, 2013)(13) | 0.033-0.048 | 0.041 | Forster (1991) (Foster et al., 1991) | (Zhang et al., 2004)(6) | 17 | 0.0163±0.0081 |
| (Li et al., 2006)(14) | 0.013-0.065 | 0.039 | Torri (1997) (Torri et al., 1997) | (Wang et al., 2013)(7) | 6 | 0.0185±0.0079 |
| (Wang et al., 2007)(15) |  | 0.043 | EPIC | This study | 41 | 0.0142±0.0226 |
| (Pang et al., 2012)(16) | 0.032-0.052 | 0.040 | EPIC |  |  |  |
| (Qin et al., 2009)(17) |  | 0.047 | Dg |  |  |  |
| (Fu et al., 2005)(18) | 0.016-0.032 | 0.020 | RUSLE |  |  |  |
| (Gao et al., 2013)(19) | 0.034-0.043 | 0.039 | EPIC |  |  |  |
| (Schnitzer et al., 2013)-RUSLE1 | 0.006-0.119 | 0.051 | EPIC |  |  |  |
| (Schnitzer et al., 2013)-RUSLE2 | 0.001-0.030 | 0.013 | Zhang (2004) (Zhang et al., 2004) |  |  |  |
| Mean |  | 0.04±0.031 | | Mean |  | 0.015±0.023 |

Table 4. Review of previous estimates of the contribution of gully erosion to total erosion in various catchments on the CLP: CAg is the proportion of gullied areas in the catchment (%); Hcs, Gcs and Dcs are the mean 137Cs inventories in the top-soil/sediment of inter-gully, gully and depositional areas, respectively (Bq kg-1); Scg is sediment contribution by gully erosion (%); Eg/h is the ratio of gully erosion to topsoil erosion.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Reference | CAg | HCS | GCS | DCS | SCG | Eg/Eh | Method |
| (Shi et al., 1997) | - | - | - | - | 68.63 | / | sediment record |
| (Feng, 2003) | 47.00 | 5.30 | 0.02 | 0.98 | 81.32 | 4.90 | Cs-137 |
| (Yang et al., 2006) | 54.00 | - | - | - | 67.60 | 1.77 | Cs-137 |
| (Zhang et al., 1997) | 47.00 | 3.90 | 0.02 | 0.90 | 77.00 | 3.77 | Cs-137 |
| (Jing, 1986) | - |  |  |  | 75.57 | / | sediment record |
| (Li et al., 2003) | - | 5.86 | 2.16 | 3.37 | 67.00 | / | Cs-137 |
| (Li et al., 2003) | - | - | - | - | 60.00 | 2.15 | sediment record |
| (Jiao et al., 1992) | 50.00 | - | - | - | 60.00 | 1.50 | literature reviews |
| (Li et al., 2008) | 47.00 | 5.83 | 0.02 | 1.36 | 77.00 | 3.78 | Cs-137 |
| (Li et al., 2008) | 33.00 | 3.47 | 0.02 | 1.15 | 67.00 | 4.12 | Cs-137 |
| (Li et al., 2008) | 42.00 | 3.15 | 2.18 | 2.86 | 30.00 | 0.59 | Cs-137 |
| (Li et al., 2008) | 41.60 | 3.59 | 0.00 | 2.25 | 37.00 | 0.82 | Cs-137 |
| Mean ± STDEV | 45.20±6.53 |  |  |  | 64.01±19.02 | 2.60±1.48 |  |

Table 5 Topsoil (0-20 cm) content of SOC, N and P used in our study to estimate erosion-induced SOC, N and P mobilization (Liu et al., 2011, 2013).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Farmland | Grassland | Forest | Reference |
| SOC (g kg-1) | 12.12 ± 7.48 (n=153) | 8.04 ± 4.68 (n=101) | 10.60 ± 7.48 (n=128) | (Liu et al., 2011) |
| N (g kg-1) | 0.81 ± 0.38 (n=153) | 0.58 ± 0.36 (n=101) | 0.77 ± 0.53 (n=128) | (Liu et al., 2013) |
| P (g kg-1) | 0.73 ± 0.26 (n=153) | 0.51 ± 15 (n=101) | 0.60 ± 0.22 (n=128) | (Liu et al., 2013) |

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