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Corrigendum to "Comparative analysis of the Copernicus, TanDEM-X, and UAV-SfM digital elevation models to estimate lavaka (gully) volumes and mobilization rates in the Lake Alaotra region (Madagascar)" published in Earth Surf. Dynam., 10, 209–227, 2022

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We have noticed that we applied an incorrect bias correction when back-transforming the linear log-transformed area–volume relationship. This has resulted in an erroneous a coefficient of the area–volume relationship being used to calculate the lavaka volumes from their aerial extent in 1949, 1969, and the 2010s. Consequently, the earlier reported lavaka volumes and therefrom-derived volumetric growth and mobilization rates were overestimated by a factor 2 to 3. However, our main conclusions regarding the performance of the different DEMs and the results obtained from applying the breakpoint method remain unaffected, as does the main conclusion drawn from this dataset. Our estimated mobilization rates are now in better agreement with reported lake sedimentation rates for the region and still remain 2 orders of magnitude higher when compared to earlier reported long-term erosion rates.

The correct back-transformed and bias-corrected equation, recalculated volumetric growth and mobilization rates values, and some modified interpretations are detailed below.

1 Area–volume relationship

We fitted a linear equation through the log-transformed area (A) and volume (V) data (10-base log-transformation) in order to obtain a more robust fit based on equally distributed residual errors (Guzzetti et al., 2009; Crawford, 1991): $\log(V) = a + b\log(A)$, when back-transforming the coefficients of the fitted linear relationship to a power function, a systematic statistical bias enters, which can be accounted for by adding a bias-correction factor (Ferguson, 1986; Crawford, 1991). In the published article we used an incorrect formula for the bias correction ($V = \exp(a + 2.65\sigma^2)A^b$), where the correct formula to be applied is as follows (Crawford, 1991): $V = 10^a A^b \exp(2.65\sigma^2)$.

The b coefficient remains unaffected by this mistake, but the a coefficient changes when applying the correct bias correction. The correct area–volume relationships and coefficients are as follows:

$$\text{UAV-SfM}: \; V = 0.20 \pm 0.07 A^{1.44 \pm 0.04}, \tag{3}$$

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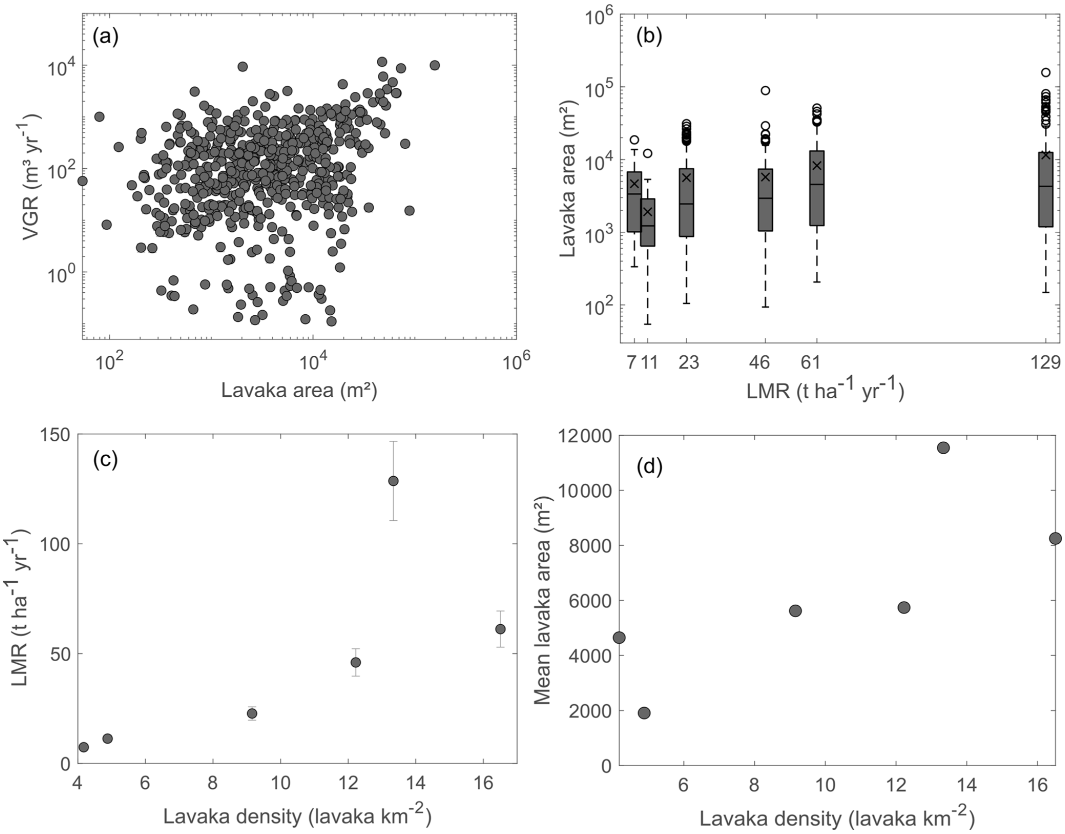

Figure 6. Variations in volumetric growth rates and lavaka mobilization rates. **(a)** Lavaka volumetric growth rates (VGR) are positively related with lavaka area (Spearman correlation coefficient $r = 0.27$, $p = 1 \times 10^{-10}$). **(b)** Lavaka mobilization rates (LMRs) are higher for study areas with larger lavaka. Mean lavaka areas are indicated by the cross in the boxplot. Higher lavaka mobilization rates are linked to higher lavaka densities **(c)**, which are also positively correlated with lavaka area **(d)**. n indicates the number of observations, and the error bars indicate the standard deviation of the mean LMR as obtained from the Monte Carlo simulations taking into account the uncertainties on the fitted a and b coefficients.

$$\text{TanDEM-X}: \; V = 0.13 \pm 0.02 A^{1.48 \pm 0.02}, \quad (4)$$

$$\text{Copernicus}: \; V = 2.69 \pm 0.75 A^{1.13 \pm 0.03}. \quad (5)$$

2 Lavaka volumetric growth and mobilization rates: 1949–2010s

These equations were used to calculate the lavaka volumes in 1949 and 2010s and therefrom-derived lavaka volumetric growth (VGR) and mobilization rates for the period 1949–2010s. When using the UAV–SfM relationship (Eq. 3), a mean and median growth rate of 392 ± 54 and $111 \pm 15\,\text{m}^3\,\text{yr}^{-1}$ are obtained, respectively. When applying the TanDEM-X relationship (Eq. 4) these values are similar: 395 ± 12 and $104 \pm 4\,\text{m}^3\,\text{yr}^{-1}$ for the mean and median, respectively.

Lavaka mobilization rates (LMR in $\text{t}\,\text{ha}^{-1}\,\text{yr}^{-1}$) as derived from the UAV–SfM relationship range between 7 ± 1 and $129 \pm 18\,\text{t}\,\text{ha}^{-1}\,\text{yr}^{-1}$ in our six study areas (Table 2). LMR estimates based on TanDEM-X only deviate 1 % to 6 % from the estimates obtained from the UAV-SfM DEM. The conclusions regarding the factors affecting the volumetric growth and mobilization rates remain the same, where the plots with updated values can be found in Fig. 6.

3 Lavaka mobilization rates put into perspective

As previously argued in the article, the highest lavaka mobilization rates of 129 ± 18 and $61 \pm 8\,\text{t}\,\text{ha}^{-1}\,\text{yr}^{-1}$ correspond to areas characterized by large lavaka and high lavaka densities (13 and 17 lavaka per square kilometer), which is well above the reported average of 6 lavaka per square kilometer for the southern part of the Lake Alaotra catchment (Voarintsoa et al., 2012). We therefore argue that these highest values should be perceived as maximum rates, where the rates of 7–23 $\text{t}\,\text{ha}^{-1}\,\text{yr}^{-1}$ obtained for the regions with lower lavaka densities (SA3, 5, and 6) will be more representative for the wider lake Alaotra region (Table 2). These values are in the same range as the sedimentation rate of $20\,\text{t}\,\text{ha}^{-1}\,\text{yr}^{-1}$ obtained for the dammed Bevava lake (Mietton et al., 2006),

Table 2. Lavaka mobilization rates 1949–2010s. Lavaka mobilization rates ($t\,ha^{-1}\,yr^{-1}$) obtained by applying the A–V relationships from the UAV-SfM (Eq. 3) and TanDEM-X (Eq. 4) DEM to the lavaka areas for the longest time period available: 1949–2010s for SA1005 and 1969–2010s for SA6. Reported values give the median and standard deviation from the 10 000 Monte Carlo simulations where the uncertainties on the fitted a and b coefficients of the A–V relationships are accounted for.

	Mobilization rate UAV-SfM ($t\,ha^{-1}\,yr^{-1}$)	Mobilization rate TanDEM-X ($t\,ha^{-1}\,yr^{-1}$)	Difference UAV-SfM–TanDEM-X (%)
SA1	128.6 ± 18.1	130.1 ± 4.1	−1
SA2	46.0 ± 6.2	45.4 ± 1.3	1
SA3	22.7 ± 3.0	21.9 ± 0.7	4
SA4	61.2 ± 8.2	59.6 ± 1.7	3
SA5	11.3 ± 1.5	11.7 ± 0.3	5
SA6	7.4 ± 1.0	6.9 ± 0.2	6
All SA's	44.5 ± 6.1	44.1 ± 1.3	1

which is located in the southeastern part of the Alaotra catchment. Lake Bevava has a catchment area of $58\,km^2$, with a lavaka density of 8 lavaka per square kilometer (Mietton et al., 2006). The lake sedimentation rate of $20\,t\,ha^{-1}\,yr^{-1}$ is only slightly lower and within uncertainty of the estimated mobilization rate of $23 \pm 3\,t\,ha^{-1}\,yr^{-1}$ for SA3, which has a comparable lavaka density of 9 lavaka per square kilometer. This suggests that a large proportion of the eroded lavaka sediment might reach the rivers or lake when we assume that lavaka constitute of the main sediment source and that sediment from other sources like sheet erosion are negligible.

While our estimated volumetric growth and mobilization rates are 2 to 3 times lower compared to our initial estimates, they still remain 2 orders of magnitude higher when compared to long-term erosion rates from ^{10}Be concentrations of river sediment in the central highlands, which range between 0.16 and $0.54\,t\,ha^{-1}\,yr^{-1}$ (Cox et al., 2009).

Globally reported gully headcut retreat rates range between 0.0002 and $47\,430\,m^3\,yr^{-1}$, with mean and median values of 359 and $2.2\,m^3\,yr^{-1}$ (Vanmaercke et al., 2016). Our estimated mean growth rate of $392 \pm 54\,m^3\,yr^{-1}$ is very similar to this global average, whereas our median rate of $111 \pm 53\,m^3\,yr^{-1}$ is considerably higher, still indicating that lavaka erosion in the lake Alaotra catchment is taking place at a relatively high rate. The recalculated mean and median lavaka depths for our dataset are 8.0 and 6.6 m, respectively, which is still well above the global mean and median depths of 2.1 and 1.3 m (Vanmaercke et al., 2016).

Code and data availability. The Excel file containing the calculated volumes and volumetric growth rates has been updated on Zenodo and can be found at the following link: https://doi.org/10.5281/zenodo.7115521 (Brosens, 2022).

References

Brosens, L.: LBrosens/LavakaVolumes: LavakaVolumes-v2.1 (v2.1), Zenodo [data set], https://doi.org/10.5281/zenodo.7115521, 2022.