Humans as geologic agents: Comment and Reply

COMMENT

Bryan Gregor
Department of Geological Sciences, Wright State University, Dayton, Ohio 45435, USA

Wilkinson (2005), in his timely warning about humans as erosional agents, establishes a baseline (prehuman) rate for soil erosion of 24 ± 11 m/m.y. using Ronov’s (1983) mass-age distribution of Phanerozoic series. This translates into ~7.2 x 10^9 tonnes per year, assuming an erosional surface of 115 x 10^6 km², and is in quite good agreement with earlier estimates (Table 1). Strictly speaking, the contribution of carbonates and evaporates ought to be excluded (since they mostly bypass the soil reservoir), as should (in mass-age-based estimates) sediments formed from the products of marine erosion. Thus the average rate of soil erosion in prehuman times was probably closer to 5 than to 10 x 10^9 tonnes a year, making the losses due to human activity appear perhaps even more unsustainable than Wilkinson claims. (The average for the detrital component in Table 1 is 6.4 x 10^9.)

There is, however, an unavoidable uncertainty in baseline rates derived from the mass-age distribution: their short-term variance. They are, as Wilkinson points out, averages smoothed over millions to tens of millions of years, whereas the rates we are comparing them with are (geologically) instantaneous. We have no idea of how the prehuman rate may have fluctuated over intervals of, say, 1,000 yr. The smoothing effect is well seen when comparing the rate derived from epochs (Wilkinson with that based on periods (Gregor, 1985): The standard deviation of the means goes from 46% in the former case to 10% in the latter. We need to be cautious about blaming humans for the entire difference between the baseline rate and the present one, though it seems plain that humans must account for a substantial part of it.

Another concern (besides the anthropogenic component) is the overall balance between soil loss (erosion) and soil formation (weathering). One of the entries in Table 1 (Gregor, 1970) is, in fact, an estimate of the present weathering rate, assumed equal to the prehuman rate of erosion on the assumptions that human activity has not yet significantly affected global weathering and that in prehuman times the weathering rate kept pace more or less with the long-term average rate of erosion. (The continuous record of land plants since Silurian time on the one hand, and the apparent absence of very thick paleosols on the other, would appear to support this assumption of a quasi-steady-state soil reservoir.) If this is granted, the average detrital component of the long-term erosion rate (6.4 x 10^9 tonnes per year, Table 1) can stand as proxy for the rate of soil formation.

Human erosion seems to be leveling off at ~10^{11} tonnes per year (Wilkinson, 2005, Fig. 3). The natural component, which is small in comparison, can be in error without much affecting the balance. Cropland and pasture amount to ~50 million km²; perhaps construction sites will add another 5 million. Taking an average depth of 1 m makes a (mainly agricultural) soil reservoir of some 10^{11} tonnes, with an input w from weathering of roughly half the global average, approximately 3 x 10^9 tonnes a year. The outputs are 10^{11} tonnes per year (human) and ~3 x 10^9 tonnes per year (natural).

Supposing the overall erosion rate to be proportional to the mass of the reservoir (first order decay), the mass remaining at any time, t, will be

\[ M(t) = M_0 \exp(-kt) + \frac{w}{k} \left[ 1 - \exp(-kt) \right] \]

where \( k = \frac{10^{11} + 3 \times 10^9}{10^{12}} \), or 0.001.

This admittedly simplistic model produces a soil loss of 9% after 100 yr and 38% after 500 yr. This is not very alarming, perhaps, to a society accustomed to looking ahead four years at a time, but disturbing enough when seen as part of a growing set of constraints on Earth’s carrying capacity that includes faulty water supplies, overstressed marginal lands, and that only slightly more distant threat of adverse climatic change.

REFERENCES CITED

Spronck, R., 1941, Mesures hydrographiques effectuées dans la région divagante du fleuve Congo: Bruxelles, Institut Royale Colonial Belge, 156 p.

TABLE 1. SOME ESTIMATES OF THE GLOBAL PREHUMAN EROSION RATE

<table>
<thead>
<tr>
<th>Source</th>
<th>Notes</th>
<th>Rate (10^9 tonnes per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Judson (1968)</td>
<td>Amazon and Congo basins*, plus N. America adjusted for human activity</td>
<td>9.3 Detrital 6.4, Dissolved 3.2 Total 9.6</td>
</tr>
<tr>
<td></td>
<td>Amazon and Congo basins alone</td>
<td></td>
</tr>
<tr>
<td>Garrels and Mackenzie (1970)</td>
<td>South America†</td>
<td>Detrital 7.3, Dissolved 4.5 Total 11.8</td>
</tr>
<tr>
<td>Gregor (1970)</td>
<td>Dissolved sodium in rivers</td>
<td>10.5</td>
</tr>
<tr>
<td>Gregor (1985)</td>
<td>Mass-age distribution of Phanerozoic systems (Carboniferous through Tertiary)</td>
<td>10.2 ± 1.0</td>
</tr>
<tr>
<td>Wilkinson (2005)</td>
<td>Mass-age distribution of Phanerozoic series§</td>
<td>Detrital 5.4, Dissolved 1.8 Total 7.2 ± 3.3</td>
</tr>
</tbody>
</table>

*Data from Gibbs (1967) and Spronck (1941).
†Data from Livingstone (1963) and Holeman (1968).
§Data converted for this paper from meters per m.y. to tonnes per year assuming an erosional surface of 115 million km² and average density of 2.6 tonnes/m³.

REFERENCES CITED

Spronck, R., 1941, Mesures hydrographiques effectuées dans la région divagante du fleuve Congo: Bruxelles, Institut Royale Colonial Belge, 156 p.