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Figure 1 | An urban gully in Kinshasa, Democratic Republic of the Congo.

Environmental science

The human toll of gully formation in cities

Noah J. Finnegan

Gullies are incising into rapidly developing tropical cities. An analysis in the Democratic Republic of the Congo casts light on the extent and effect of this on city dwellers. **See p.952**

Across the global south, a newly recognized geohazard is carving cities apart: gully erosion, the process by which a concentrated flow of rainwater cuts channels many metres deep through soil and weak rock. Catastrophic gully erosion has long occurred in agricultural landscapes, but it is now happening in tropical urban areas at accelerating rates – destabilizing the margins of rapidly growing cities, destroying infrastructure and displacing people. The problem is severe in the Democratic Republic of the Congo (DRC; Fig. 1). On page 952, Mawe *et al.*¹

report a large-scale assessment of urban gully erosion in the DRC, revealing a worrying extent and impact of the problem.

Gully formation is a self-reinforcing process: once overland flow (run-off) of rainwater becomes focused, it incises channels into soil or rock that, in turn, concentrate that flow more effectively. In agricultural regions, gully erosion is a well-known driver of soil loss and land degradation². But this process is now proliferating in fast-growing tropical cities, such as in Brazil³ and in sub-Saharan Africa^{3–6}. Urban

gullies grow swiftly, converting habitable land into steep canyons and destroying houses in the process. However, the overall scale of the problem has not been well documented and so the human toll is poorly quantified.

To address this knowledge gap, Mawe *et al.* analysed satellite images and mapped 2,922 gullies across 26 cities in the DRC. This effort revealed that urban gullies nearly always originate from recently cleared roads, usually in sandy soils, before expanding into populated urban fringes. Road construction in the DRC generates more run-off than native soils do, leading to gully incision and expansion at points where concentrated run-off drains from roads onto erosion-prone slopes⁷. The authors' analysis suggests that about 118,600 people have been displaced by urban gully formation and expansion in 2004–23 in the DRC alone – a toll that rivals or exceeds the severe impacts of better-known hazards in Africa, such as landslides and volcanic eruptions.

Urban gullies are poised to worsen. As cities in the global south continue to grow, a combination of land clearance, unregulated construction and increasingly intense rainfall owing to climate change is likely to accelerate gully formation. Indeed, Mawe and colleagues estimate that the annual rate of displacement

caused by urban gullies in 2020–23 was roughly double that of 2005–19.

By quantifying the human toll of an under-recognized geohazard, this study provides a strong motivation for mitigation efforts. Unsurprisingly, residents of cities in the DRC have already experimented with numerous approaches for stabilizing gullies, including constructing check dams to slow gully water flow and encourage sediment redeposition; hardening gully heads and walls with concrete; and replanting vegetation to increase the erosional resistance of gully walls and heads⁸. The only mitigation solutions that seem to successfully arrest gully expansion, however, are those that channel run-off from roads directly into reinforced canals that divert flow away from gullies⁸.

That said, Mawe *et al.* note that the high cost of such mitigation measures shows that prevention of gully formation, rather than stabilization of existing gullies, is probably the most viable path for managing this hazard. For example, engineering solutions that minimize the concentration of road run-off by enhancing its ground infiltration — such as shallow drainage channels known as swales — could be useful. Another strategy, already used as a mitigation measure, could be to divert flow away from erosion-prone slopes, thereby combating erosion from road drains and preventing the formation of gullies to begin with⁹. However, such preventive approaches would need to be both economical and scalable to be effective.

Mawe *et al.* focused on the DRC, but their work highlights a broader, still-open question: how widespread and severe is urban gully erosion elsewhere in the global south? Although gully erosion has been documented in other tropical cities, data on the scale of displacement and destruction remain scarce. Comparative studies in other countries will help to clarify the scope of this emerging hazard.

Those studies should also provide an overview of the geological, topographical and climatic settings that ultimately control where urban gullies form and, just as importantly, where they don't. Such information would be invaluable for testing mechanistic models of the coupled hydrological, biological and erosional processes that drive gully initiation, growth and stabilization in these tropical settings. Such a comprehensive perspective is what is ultimately needed to inform strategies that enable cities to grow sustainably.

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Prebiotic chemistry

How peptides might have formed on early Earth

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For life to emerge on Earth, peptides must first have formed without the aid of enzymes — but how? Reactions of sulfur-containing molecules might have been key. **See p.933**

Tremendous progress in the field of prebiotic chemistry has shown how simple compounds available on ancient Earth could have given rise to the molecular building blocks of life¹. The current challenge is to work out how these building blocks could have assembled into functional polymers, such as peptides and nucleic acids, in the absence of biological systems. Prebiotic peptide assembly from amino acids is particularly difficult to establish, given that the intricate biological machinery used today to synthesize peptides obscures the origins of the process. On page 933, Singh *et al.*² report chemistry that could plausibly have facilitated a key step of peptide synthesis during the prebiotic era.

In extant biology, the first step of peptide synthesis is a reaction known as aminoacylation, in which an amino acid is attached to a transfer RNA (tRNA) molecule. The energy needed to promote this reaction is delivered by enzymes, which chemically activate the amino acid by converting this building block into a more-reactive molecule (an adenylated amino acid). In the prebiotic world, however, the energy would need to have been sourced either from the surroundings (for example, heat in the environment) or, more plausibly and consistently with modern biology, through a non-enzymatic chemical activation mechanism.

Compounds that could have acted as chemically activated amino acids in prebiotic aminoacylation processes have previously been proposed (see ref. 3, for example), but are often 'over-activated'. This is a problem, because the over-activated molecules tend to react with themselves, rather than with RNA. Although self-reaction does produce peptides, this process does not open up a clear path for the evolution of genetically

encoded peptide synthesis. It is also inefficient, frequently leading to the formation of a side product that inhibits further extension of the peptide chain.

Singh *et al.* now report a type of chemically activated amino acid known as aminoacyl-thiols. These sulfur-containing molecules are not as highly activated as previously proposed systems: they are sufficiently reactive to facilitate the aminoacylation of RNA but, crucially, do not self-react to form peptides (Fig. 1). The reason for this finely tuned behaviour is not entirely clear, but probably involves electronic effects and the conformations adopted by the reactants. More research is needed to establish an explanation.

In biological peptide synthesis, aminoacylation occurs specifically at the 3'-terminus of the tRNA molecule. The authors observed that aminoacylation of short, single-stranded RNA molecules by aminoacyl-thiols was not specific, occurring at various positions along the length of the molecules. But when Singh *et al.* tested short double-stranded RNA molecules, aminoacylation did occur predominantly at the 3'-terminus — giving rise to structures similar to those found in tRNAs when an amino acid has been attached.

Singh *et al.* also observed that the yields of product obtained in their aminoacylation reactions could be increased by attaching a ribozyme (an RNA catalyst) at the 5'-terminus of the RNA. This ribozyme was previously reported to catalyse aminoacylation reactions with adenylated amino acids⁴ — indicating that ribozymes might have initially promoted reactions with aminoacyl-thiols, but then catalysed reactions with adenylated amino acids as prebiotic chemistry developed.

In biological peptide synthesis, once the aminoacylation reaction has attached an

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