A, B, TIM GAINEY/ALAMY

Figure 1 | Food-supply changes in rural areas contribute to global obesity. The NCD Risk Factor Collaboration study[2] reveals that increases in body mass index in rural populations in most regions of the world, including low- and middle-income countries, are driving the global rise in obesity. Changes to the food supply in rural areas — from traditional staples (**a**) to modern ultra-processed foods (**b**) — combined with access to motorized transport and mechanized farming equipment in rural areas are contributing factors. **a**, A street market in Yenumula Palli, Andhra Pradesh, India. **b**, A village shop in Puttaparthi, Andhra Pradesh.

main focus of geographically targeted obesity-prevention programmes and policies around the globe has been to address urban obesity. Examples of urban-focused interventions include physical-activity policies such as the *ciclovias* of Latin America that close urban streets to stimulate walking and cycling; the construction of cycle paths in urban areas; the design of urban buildings to enhance movement; and the focus on creating spaces for walking and playing in cities, including creating parks. Initiatives that involve working with retailers and shops that sell food have also mostly taken place in cities. Apart from a small number of policies, such as the provision of government-sponsored shops selling cheap, healthier food in remote rural areas in Mexico, rural populations have been largely ignored.

The study by the NCD Risk Factor Collaboration challenges us to create programmes and policies that are rurally focused to prevent increased weight gain — a major global gap. Several fiscal and regulatory approaches can reach rural areas globally. These range from programmes that combine comprehensive marketing controls, school-food controls and labels on ultra-processed foods, such as those instituted in Chile[7], to the taxation of unhealthy ultra-processed foods and beverages, as in Mexico[8,9]. These are national programmes that require national legislation and are being implemented in an increasing number of LMICs. However, countries must coordinate multiple regulatory and fiscal programmes similar to those in Chile to truly have an impact on people's behaviour. ■

Barry M. Popkin *is in the Department of Nutrition, Gillings School of Global Public Health, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina 27516, USA.*
e-mail: popkin@unc.edu

1. Malik, V. S., Willett, W. C. & Hu, F. B. *Nature Rev. Endocrinol.* **9**, 13–27 (2013).
2. NCD Risk Factor Collaboration. *Nature* **569**, 260–264 (2019).
3. Zhai, F. Y. *et al. Obesity Rev.* **15**, 16–26 (2014).
4. Jaacks, L. M., Slining, M. M. & Popkin, B. M. *J. Nutr.* **145**, 352–357 (2015).
5. Popkin, B. M. & Reardon, T. *Obesity Rev.* **19**, 1028–1064 (2018).
6. Huffman, S. L., Piwoz, E. G., Vosti, S. A. & Dewey, K. G. *Matern. Child Nutr.* **10**, 562–574 (2014).
7. Corvalán, C., Reyes, M., Garmendia, M. L. & Uauy, R. *Obesity Rev.* **20**, 367–374 (2019).
8. Colchero, M. A., Popkin, B. M., Rivera, J. A. & Ng, S. W. *Br. Med. J.* **352**, h6704 (2016).
9. Batis, C., Rivera, J. A., Popkin, B. M. & Taillie, L. S. *PLoS Med.* **13**, e1002057 (2016).

GLOBAL HYDROLOGY

A river that flows free connects up in 4D

Humans have altered the natural flow of rivers, adversely affecting biodiversity and the services that these watercourses provide. The mapping of millions of kilometres of rivers reveals the extent of human interference. SEE ARTICLE P.215

N. LEROY POFF

On page 215, Grill *et al.*[1] report their use of the latest high-resolution hydrographic and land-use data to produce the first detailed, replicable global map of rivers whose flow has been largely unaffected by human activities. This not only adds greatly to our knowledge of where such rivers remain, but also reveals which rivers have been impaired through severing of the multidimensional river-flow continuum. Such mapping affords insight into how and where river management might be used to restore flow connectivity and thus boost ecosystem function and productivity.

Rivers are among the most productive and biodiverse ecosystems on the planet. Their bounty reflects an intimate connection of flowing water with the landscapes they drain, and with the landforms they create along their journeys to inland seas or the oceans. As small streams flow off the land and coalesce into larger rivers, they transport sediment and nutrients downstream to build natural habitats and fuel biological productivity.

Importantly, the flow of water occurs not only down the river channel (longitudinally), but also laterally onto floodplains and vertically through the river's bed and adjacent groundwaters. These different pathways of connectivity allow for the exchange of nutrients, organic matter and organisms in all directions, and underlie a river's capacity to generate valuable ecosystem services and benefits, including clean drinking water, inland fisheries and seasonal floods that agriculture can take advantage of. Rivers that are completely connected in the three spatial dimensions of flow and that vary naturally in their relative magnitudes over time (the fourth dimension) are wholly functionally intact — they are

Figure 1 | The Irrawaddy River, Myanmar. Grill *et al.*[1] report that the flow of only 37% of rivers longer than 1,000 kilometres, including the Irrawaddy, are unaltered by human activities.

ANDREA PISTOLESI/GETTY

considered to be fully free-flowing rivers.

Many human activities disrupt the natural flow pathways of rivers. For example, dams that span river channels distort the movement of water, sediment and organisms from upstream to downstream. Dykes and levees sever main river channels from their lateral connections to productive floodplains. And vertical disconnection occurs when land surfaces are covered with impervious surfaces as a result of urbanization and road building.

Grill *et al.* quantified six pressure indicators of human impact that sever the natural flow connectivity of rivers. These include river fragmentation, flow regulation, sediment trapping, water consumption and two measures of floodplain infrastructure development (road density and urbanization extent). Guided by a review of the literature in this field and by the research team's extensive knowledge, the authors calculated weighted averages of the six interacting pressure indicators to obtain a 'connectivity status index'. Rivers with an index value exceeding 95% of maximum spatial and temporal connectivity were defined as free-flowing rivers.

By mapping the 4D connectivity of almost 12 million kilometres of rivers globally, the researchers found that 97% of rivers shorter than 100 km are free-flowing, but only 37% of those longer than 1,000 km flow freely along their entire course (Fig. 1). Most of these rivers are restricted to remote parts of the Arctic, and to the Amazon and Congo basins. In many developed countries or regions (including the United States, Europe, southeast Asia and southern Australia), even free-flowing rivers longer than 500 km are greatly reduced in number. Interestingly, only 23% of free-flowing rivers now connect to the oceans, indicating the extent to which estuarine and marine environments are being deprived of nutrients and sediments formerly delivered from the land[2].

Perhaps unsurprisingly, most of the disconnectivity is caused by the world's estimated 2.8 million dams (structures associated with reservoir areas greater than 1,000 m^2). Dams fragment river systems, altering the natural flow regime and disconnecting channels from floodplains for long distances downstream. They also retain suspended sediments that would otherwise pass to the oceans. In line with these effects, Grill *et al.* find that the dominant pressures impairing the world's non-free-flowing rivers are longitudinal fragmentation (which accounts for 68.8% of lost connectivity), flow regulation (23.5%) and sediment starvation (4.2%). Urbanization, road building and water consumption comprise the remaining connectivity losses.

The authors' analysis is limited by a problem that often affects studies of this sort — global data available to estimate mechanisms of disconnection are of low resolution at the local scale. Nevertheless, it provides a crucial new perspective on the global distribution and status of rivers that can guide future research. By providing the computational source code used in the analysis, Grill *et al.* enable others to recalculate the main results, and to carry out regional studies using available higher-resolution data. Such efforts could be invaluable for biodiversity conservation, for example, because measures of the intactness of rivers and floodplains can serve as signposts for habitat-protection programmes.

Grill and colleagues' research also affords insights into worldwide challenges for freshwater management. Previous global mapping of river status has focused on stressors that directly influence biodiversity and water security[3]. By contrast, this new work focuses on factors that disconnect flow pathways, thereby indirectly constraining biodiversity capacity and the biological productivity of rivers, which can help us to better understand the functional integrity of rivers. For example, highly spatially connected rivers are more likely to support the complex biological and chemical processes that remove pollutants and excessively high quantities of nutrients derived from sewage and agricultural runoff.

Looked at from this perspective, Grill and colleagues' study suggests that the functional capacities of rivers are highly degraded on a global scale, with major implications for sustainability. For example, fresh water is considered to be a key resource for human well-being, and its availability has been thought to be far from a 'planetary boundary' that would cause concern[4]. However, the functional impairment of rivers owing to disconnectivity[1] and other factors[3] will have diminished their ability to provide clean fresh water and other ecosystem services, or the biodiversity essential for continued human well-being — which suggests that their global sustainability is more precarious than is currently recognized.

In a similar vein, United Nations Sustainable Development Goals specifically call for secure, clean drinking water for human populations, and the protection and restoration of water-related ecosystems that provide services and benefits (go.nature.com/2vsfidw). However, the manifold pressures on rivers as a result of population growth, and the conflicting demands for achieving global water, food and energy security, make it difficult to balance these needs with the maintenance of river ecosystem function and biodiversity. Attaining this balance will increasingly rely on rigorous, state-of-the art analyses and data visualization, as exemplified by Grill and colleagues' study. Quantifying the status and extent of our limited natural resources provides essential information about how to prioritize preservation and restoration efforts, to achieve tangible improvements in the health of our ecosystems and sustainable benefits for humans. ■

N. LeRoy Poff *is in the Department of Biology, Colorado State University, Fort Collins, Colorado 80523, USA, and at the Institute for Applied Ecology, University of Canberra, Australia.*
e-mail: n.poff@colostate.edu

1. Grill, G. *et al. Nature* **569**, 215–221 (2019).
2. Syvitski, J. P. M. *et al. Nature Geosci.* **2**, 681–686 (2009).
3. Vörösmarty, C. J. *et al. Nature* **467**, 555–561 (2010).
4. Steffen, W. *et al. Science* **347**, 1259855 (2015).