Cell Reports Sustainability

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Commentary

Access to human-mobility data is essential for building a sustainable future

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https://doi.org/10.1016/j.crsus.2024.100077

Mobile devices, and other tracking technologies, generate detailed data on the movements and behavior of billions of people worldwide. At present, these data are predominantly used to pursue corporate interests. We argue that improving access to human-mobility data is essential for addressing urgent conservation and sustainability goals. Close collaboration between industry and the research community has the potential to generate substantive environmental and societal benefits.

In the face of catastrophic climate change and biodiversity loss, understanding the inextricable linkages between the health of people, animals, and ecosystems is of paramount importance (the One Health concept[1]). While the global impacts of landscape modification are being extensively studied,[2] we know much less about the compounding role of the movements of humans and their vehicles (hereafter referred to as "human mobility"). This is surprising, given that human mobility is likely a key driver of many important processes. For example, humans often disturb wildlife, even in protected areas,[3] and can reshape ecosystems through the transport of invasive species.[4] Conversely, human movement can increase the risk of conflict with wild animals[5] and exposure to zoonotic diseases.[1]

Sustainable development requires an interdisciplinary approach that honors the highly dynamic nature of how humans interact with the environment.[6,7] Mapping human mobility is key to achieving this goal, yet relevant data are usually collected, curated, and marketed by private companies—remaining effectively out of reach for research purposes. This situation suddenly changed in early 2020, as the coronavirus disease 2019 (COVID-19) pandemic plunged the world into crisis, and the analysis of human movements was of clear, life-saving importance. Responding to this tragedy and urgent need for information, several companies (e.g., Apple, Facebook, Google, SafeGraph) made data temporarily available to governments and researchers at no cost. By doing so, human-mobility data played a critical role in investigating infection dynamics and designing non-pharmaceutical interventions,[8] providing a striking illustration of how data sharing can make important contributions to societal welfare.

During this period of crisis, some of us helped form a research consortium, the COVID-19 Bio-Logging Initiative, realizing that lockdown-induced reductions in human mobility (the "anthropause") would enable powerful mechanistic insights into human-wildlife interactions on a global scale.[6,9] Colleagues quickly shared high-resolution movement tracks ("bio-logging data") for thousands of wild animals for collaborative analyses, but we struggled to source suitable human-mobility data for context. The data products that had temporarily become accessible were not available for all regions of the world and were often aggregated in ways that rendered them unsuitable for our purposes.[7] Our fast-growing network was forced to creatively use the lockdown period, and variation in the stringency of lockdown measures, as coarse proxies for changes in human mobility[10] or to restrict analyses to regions where data were available through partnerships (e.g., SafeGraph's COVID-19 Data Consortium in the United States).

Reflecting on our experience, we were struck by how difficult it is for most researchers to source data for quantifying human movement and activity patterns, especially at larger scales. Increased access to human-mobility data is urgently needed to help us paint a much more complete picture of the complex dynamics that shape human-environment interactions. Here, we argue that changing the access model for human-mobility data is essential for devising robust plans for a sustainable future.

The missing piece

The market for mobile devices continues to grow, with about three-quarters of the world's population aged 10 years or older owning a cellular phone in 2022.[11] Many devices have the ability to keep track of their users' movements and behavior,

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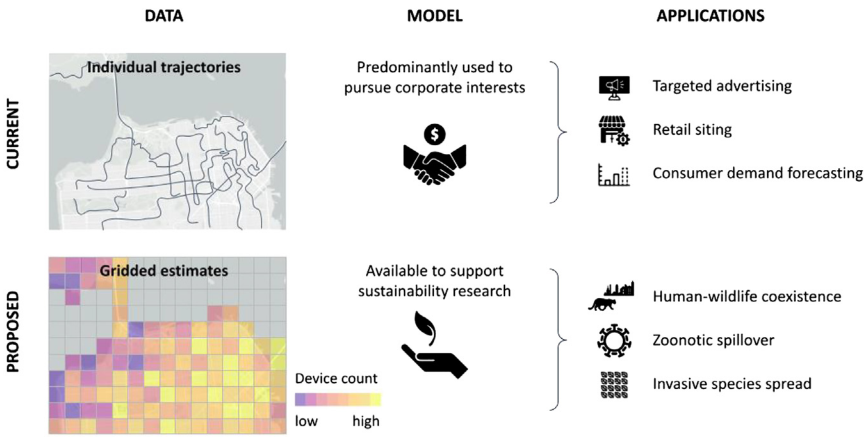

Figure 1. Changing the access model for human mobility data
Under the status quo, human-mobility data derived from mobile devices are typically curated by private companies that sell data products and applications for a range of purposes. Maps schematically highlight the difference between data comprising individual movement trajectories and spatially gridded estimates of human mobility. We argue that gridded estimates of human mobility should be made available to researchers to support efforts to address urgent conservation and sustainability goals.

following initial consent. Simply placing a call, sending a text message, or utilizing a mobile app can generate a time-stamped location record. Providing access to one's detailed geolocation information is often a necessary requirement for unlocking the full functionality of mobile apps, such as receiving local weather forecasts or real-time traffic updates.

While this level of tracking might be unnerving to some, it is important to recognize that we are continually leaving physical and digital traces in the environment as we go about our everyday lives. Even in the context of biodiversity monitoring, where detecting humans is not usually the primary purpose, our activities are often inadvertently captured. For example, participatory science data encode human movements,[12] camera traps and passive acoustic monitoring systems record human images and voices,[13] and environmental DNA samples contain recoverable human genetic information.[14]

The power of human-mobility data for informing conservation efforts has already been demonstrated in the marine realm. Access to vessel trajectories (globalfishingwatch.org) has been critical to understanding the effectiveness of marine protected areas as well as the scope and impact of illegal, unreported, and unregulated fishing.[15,16] But despite these compelling marine applications, terrestrial studies are comparatively rare as relevant data remain largely inaccessible.[7]

Human-mobility data are usually controlled by private companies and used to pursue corporate interests, such as designing "personalized" location-aware advertisements. Although many companies are willing to provide access to their human-mobility data in principle, this often requires dedicated funding or personal connections, thereby effectively excluding large parts of the research community. In cases where data are made publicly available, such as during the COVID-19 pandemic, access is often opportunistic, and long-term support is not guaranteed. While even brief bouts of data access can provide valuable insights, changing usage terms hinders research development. Furthermore, publicly shared data are often not suitable for research purposes due to lack of clear documentation, inflexible baselines, or the specific form of spatiotemporal aggregation. Finally, because the landscape of data ownership, curation, and provision—along with privacy laws—is rapidly changing, available human-mobility datasets often only provide a snapshot in space and time, affording insufficient coverage for meaningful analyses of environmental processes.

Importantly, we believe that the data required for conservation and sustainability applications would avoid valid privacy concerns (Figure 1). In many cases, human-mobility data consist of trajectories of individual mobile devices containing details of the movements and behavior of potentially identifiable people. This type of data is required for some research applications, such as contact tracing for public-health planning. But, in the use cases we envision, great benefit could be gained with datasets that do not reveal individual trajectories but instead aggregate locations over space and time (e.g., number of mobile devices per 1 km^2 per day).

Generating societal good

The current data access model clearly hampers progress in conservation and sustainable development. Overcoming these challenges will require bold rethinking of current practices and intensified collaboration. We propose that a new framework for sharing human-mobility data could capitalize on lessons learned from the successful adoption of remotely sensed data as a public good. These data were originally used for military applications, held many concerns over privacy and potential security violations, and were prohibitively expensive for widespread use in research applications.[17] Nevertheless, recognizing the transformative value of remotely sensed data for a vast range of non-military applications, governments advocated and supported widespread access. Nowadays, openly accessible, remotely sensed data represent an important public resource that is integral to assessing the state of the planet and planning for a sustainable future.[18]

Drawing on parallels to the history of remote sensing, we propose that national governments and intergovernmental organizations work with companies to make aggregated versions of their human-mobility data freely available for research purposes. To avoid potential misuse, we suggest that, at least initially, aggregated data are shared only at coarse, but consistent, spatiotemporal resolutions (e.g., 1 km^2). Developing a new data access model will require close collaboration across a diverse network of stakeholders, as well as dedicated funding and other support. But, ultimately, any possibility of success will depend chiefly on the willingness of data holders to engage in this push for developing sustainable solutions that account for the movements of humans and their vehicles (note that we broadly refer to "data holders" here to acknowledge the fact that data ownership varies between countries as a result of differences in data-privacy legislation).

In this regard, we think it is essential to highlight potential follow-on benefits of data sharing. Importantly, providing access to aggregated data would not preclude companies from retaining a market for more detailed or bespoke data products, such as those based on individual movement trajectories. In fact, the free availability of aggregated versions has potential to generate significant further demand for more advanced data products by proving the utility of the data to a larger user base.

Furthermore, improved data sharing could become an important component of a larger move toward corporate digital responsibility.[19] Incentives could arise as companies are increasingly required to report their environmental impact. Data holders could intensify their efforts to develop corporate initiatives that share aggregated human-mobility data for use in conservation and sustainability research or offer commercial products that aid other companies in reporting, or mitigating, their own impact.

As we argue for greater data access, it is critical to acknowledge the sensitive nature of human-mobility data. It is essential to ensure that people do not feel their privacy is being violated through the use of mobile-device-generated data. We believe that researchers should commit to not using individually identifiable information. The spatially gridded data products we advocate for would remove people's identities, but protecting location privacy is a non-trivial issue; continued research is needed into how best to aggregate human-mobility data to preserve individual geolocation privacy while maximizing utility for a broad range of research applications.

Concluding remarks

Although access to human-mobility data has the potential to transform our ability to plan for a sustainable future, it is important to recognize important limitations. Human-mobility data are biased both in their collection and accessibility. For example, at the global scale, data collection varies geographically due to major differences in mobile-device use, wireless-connectivity costs, and network coverage.[11] Furthermore, differences in national-level legal frameworks (e.g., the European Union's General Data Protection Regulation) limit how data can be collected, shared, and used, and human behavior can affect data capture (e.g., users are known to vary their usage of mobile apps[20]). As with any data type, it is important to critically assess how biases could affect the generalizability of studies and to report findings with appropriate indication of uncertainty.

As the world becomes increasingly digital, our personal information is taking on a legacy that is largely beyond our control. We see advocating for access to human-mobility data as part of larger collective efforts to push for data sharing and transparency (e.g., data4good.center). Doing so is particularly relevant as sustainability decision making begins to view environmental and social justice as priorities (e.g., America the Beautiful, United Nations Sustainable Development Goals). Recognizing human-mobility data as integral to broader sustainability efforts is a crucial first step toward ethically and responsibly generating knowledge that benefits both society at large and the natural world. In fact, we likely have yet to uncover the full disruptive potential of human-mobility data for strengthening conservation and sustainability efforts, as this information will become increasingly available for research purposes.

ACKNOWLEDGMENTS

This article is a contribution of the COVID-19 Bio-Logging Initiative, which is funded in part by the Gordon and Betty Moore Foundation (GBMF9881) and the National Geographic Society (NGS-82315R-20) (both grants to C.R.) and endorsed by the United Nations Decade of Ocean Science for Sustainable Development. We sincerely thank our colleagues for discussion in the development of this article, including Urška Demšar, Iryna Kuksa, and members of the Steering Committee of the COVID-19 Bio-Logging Initiative. We also gratefully acknowledge support from the Kuni Endowed Junior Faculty Fellowship at the Bren School of Environmental Science & Management (to R.Y.O.); NASA FINESST (80NSSC22K1535) and the Yale Institute for Biospheric Studies (to D.E.S.); the National Biodiversity Future Center via the PNRR funds (Mission 4, Component 2, Investment 1.4) of the Italian Ministry of University and Resarch, Project CN00000033 (to F.C.); and the Natural Sciences and Engineering Research Council of Canada (to J.L.).

AUTHOR CONTRIBUTIONS

Conceptualization, R.Y.O., M.C., D.E.S., and C.R.; writing – original draft, R.Y.O. and C.R.; writing – review & editing, all authors; visualization – figure preparation, R.Y.O. and M.C.; funding acquisition, R.Y.O. and C.R.

DECLARATION OF INTERESTS

The authors declare no competing interests.

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