Geospatial modelling in guiding health program strategies in resource-limited settings—the way forward

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Public health decision-making is a complex process that demands careful rational and ethical reasoning based on sound scientific evidence. When evaluating the potential benefits and outcomes of public health programs, policymakers often find themselves in challenging situations due to competing needs, limited resources, and lack of access to quality data, among others. In recent years, mathematical modelling has gained increasing popularity in public health practice for its ability to assist with projecting outcomes of intervention strategies and policies.

The rapid advancement in computational and mathematical modelling approaches holds much promise in improving the precision of public health decision making, particularly with regards to evaluating existing interventions and making predictions about the impact of public health policy. This has led to an upsurge in the application of mathematical models in many different public health contexts, especially in the prevention and control of infectious diseases, such as tuberculosis (TB), malaria, influenza and HIV/AIDS (1-4). Numerous models have been developed and explored as tools to guide the design of prevention and elimination strategies of many diseases. However, few have included assumptions and parameters that would address the dynamics of geospatial characteristics of an epidemic. Geospatial models have only gained attention in recent years and have since been adopted in various infectious disease settings (3,5-8).

The recent paper by Coburn and colleagues provides an illuminating example of the potential for geospatial modeling to guide public health policy and its limitations (9). Their study involves the use of geospatial mapping approaches to improve the efficiency of the national rollout plan of antiretroviral (ARV) therapy in Lesotho (9).

Despite previous evidence showing the benefits of using spatially-targeted allocation strategies in reducing new HIV infections and UNAIDS' continuous effort to promote the use of localized data in guiding HIV service allocations (3,7), many countries have expanded their treatment guidelines by adopting the treatment as prevention (TasP) strategy as a generalized approach for the control of HIV/AIDS (10). While we acknowledge the undeniable benefits of TasP in controlling the overall epidemic, the uniform untargeted distribution of HIV services could neglect localized reservoirs and sub-populations at elevated risk of infection. The implementation of strategies as such must be complemented by locally relevant data, particularly those that are related to the distribution of the burden of disease and risk factors at the district- and sub-district-level. The authors highlighted the importance of capturing spatial heterogeneity of an HIV epidemic at the subnational level by showing the association between HIV prevalence and density of infection (DOI). Coburn and colleagues pointed out that even though the DOI was lower in many rural areas than in urban areas, most of the infected individuals lived in rural settlements, of which many settlements had low DOI. This demonstrated the complexity of geospatial variation of the epidemic in Lesotho, which further reinforces that the degree of spatial variation at the subnational levels cannot be ignored in service planning and resource allocation.

We fully concur with the authors that geospatial mapping is an essential element that should be emphasized and incorporated into public health policy and service planning. Geospatial models are valuable tools that can be employed to examine the combined effect of multiple complex factors. There are many other factors, whether fixed or time-dependent in nature, that are equally helpful in guiding public health implementation strategies, such as socioeconomic status, gender, migratory patterns, and seasonality, among others. We would like to also point out that exploring the joint dynamics of geospatial information and factors such as the impact of migration and connectivity have the potential to further improve the estimation of the overall impact of different implementation strategies, and better inform efficient allocation of resources. Aside from the degree of urbanization and DOI mentioned in the article, there are other spatial variables that could be included in the model to improve precision, e.g., distance to treatment facilities, distance to main roads, current treatment coverage by existing programs, etc. (7). The inclusion of those and other variables could have the potential to improve the precision of the estimations. Unfortunately, the availability of such data and high-resolution maps varies by country and the data are often difficult to access, which will remain as one of the biggest constraints in improving the accuracy of geospatial models, particularly in resource-limited settings.

In the article, the authors expressed their concern in proposing modelling-based implementing strategies that could, potentially, exacerbate the imbalance between rural and urban resource allocation. This is one of the pitfalls among the promises of relying on mathematical models, especially on those with questionable assumptions and built on unreliable data. For example, in the 1990s, the World Health Organization's recommended guidelines for the treatment of TB were to focus on drug-susceptible TB because treating multidrug-resistant TB (MDR-TB) with expensive second-line drugs was believed to be not cost-effective (11,12). The models at the time assumed that MDR-TB is not easily transmitted due to reduced fitness among *M. tuberculosis* strains that acquire resistance-conferring mutations (13). Since then, several studies have shown that MDR-TB can be transmitted efficiently (14-16). Policies developed using models based on those erroneous assumptions could have exacerbated the overall MDR-TB epidemic. It is therefore not uncommon that up until this date, models are usually scrutinized with skepticism and distrust by many. Increasing efforts to formally account for the degree of uncertainty of individual parameters and model assumptions should provide policy makers with increased confidence of achieving pre-specified public health goals (17).

Moreover, the authors brought to our attention a particularly thought-provoking issue: the implications of adopting and implementing geospatially-targeted strategies concerning healthcare equity. Findings from the article challenge the readers to reflect on the ultimate ethical debate in health resource allocation: egalitarianism *vs.* utilitarianism. The study suggested that to optimize resource utilization, a targeted geographical approach to rollout ARV based on the geospatial dispersion pattern of HIV-infected individuals would be more favorable than the existing uniform rollout plan that is based on the burden of disease. It should be noted that, for disease programs in general, the reality is that interventions will be less efficient and cost-effective in low prevalent or hard-to-reach geographical areas. It should be made clear that mathematical models should not prevent the mobilization of resources to address "inefficient" populations and diseases. Here we would like to emphasize on the importance of combining the use of geospatial modelling with the active engagement of local scientists, policy makers as well as other relevant stakeholders. Only through a deep understanding of the local environment can modelers effectively address the needs and constraints that are specific to the local context in their final model. While directing prevention and treatment efforts to locations with high population density and high prevalence should have greater impact and be more cost-effective, the implication of these findings on program design and resource allocation needs to be further explored and debated (7).

In the current climate of increasing resource limitations and fiscal constraints in HIV prevention and control, the implementation of HIV prevention and treatment strategies, same as many other public health interventions, can no longer afford to be a "blanket approach". This is especially true in the sub-Saharan Africa region. Optimizing the impact of prevention and treatment activities is therefore a top priority. The significance of geospatial models in assisting with guiding policy directions should not be undermined. On the contrary, their potential utility should be emphasized, highlighted and their use promoted for guiding policy decisions. To ensure healthcare equity and the optimal use of models, there needs to be sustained communication efforts between modelers, policy-makers and the local expertise (18). In addition, there is an urgent need to develop systems that can collect locally-relevant data in a consistent standardized manner across different settings, which will serve as the foundation for the development of sound geospatial models that can become critical tools in maximizing resource allocation efficiency and achieving our goals in ending the global AIDS epidemic.

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Footnote

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