Next generation tools for subnational HIV strategic information in sub-Saharan Africa

Report and recommendations from a meeting of the UNAIDS Reference Group on Estimates, Modelling, and Projections

Glastonbury, USA - 8-10th May 2019

REPORT & RECOMMENDATIONS

UNAIDS
JOINT UNITED NATIONS PROGRAMME ON HIV/AIDS
UNHCR UNICEF WFP UNDP UNFPA UNODC ILO UNESCO WHO WORLD BANK

The meeting of the UNAIDS Reference Group on Estimates, Modelling, and Projections was organised for UNAIDS by the Secretariat of the Reference Group (www.epidem.org), managed at Imperial College London and the University of Cape Town. Participants of the meeting are listed at the end of this document.

Oli Stevens, May 2019

Abbreviations

ADX	AIDS Data Exchange
ANC	Antenatal clinic
ART	Antiretroviral therapy
CDC	US Centers for Disease Control and Prevention
CLHIV	Children living with HIV
EPP	Estimation and Projection Package
FSW	Female sex workers
IeDEA	International Epidemiology Databases to Evaluate AIDS
IHME	Institute for Health Metrics and Evaluation
MER	PEPFAR Monitoring, Evaluating and Reporting
NSO	National Statistics Office
PEPFAR	US President's Emergency Plan for AIDS Relief
PHIA	Population-based HIV Impact Assessment
PLHIV	People living with HIV
(P)MTCT	(Prevention of) Mother to Child Transmission
SAE	Small area estimation
UNAIDS	Joint United Nations Programme on HIV/AIDS
WHO	World Health Organization

Background

UNAIDS Reference Group on Estimates, Modelling, and Projections

The Joint United Nations Programme on HIV/AIDS (UNAIDS) relies on impartial scientific advice from international experts in relevant subject areas to provide guidance on how to best calculate estimates and projections of the prevalence, incidence, and impact of HIV/AIDS globally. The UNAIDS Reference Group on Estimates, Modelling, and Projections acts as an 'open cohort' of epidemiologists, demographers, statisticians, and public health experts to provide scientific guidance to UNAIDS and partner organisations on the development and use of the tools used by countries to generate annual HIV estimates, which are the source for UNAIDS Global HIV epidemic estimates. The group is coordinated by a secretariat hosted at Imperial College London and the University of Cape Town.

Work of UNAIDS Reference Group has been organised broadly into tracks:

- 'Technical update' work streams: These work streams are oriented to conducting research and providing technical feedback and guidance on specific updates for the suite of tools used for annual UNAIDS estimates, i.e. Spectrum, which includes the AIDS Impact Module (AIM), the Estimation and Projection Package (EPP), and the Case Surveillance and Vital Registration tool (CSAVR).
- 'Thematic' meetings: These meetings are focused on convening new research to catalyze innovation on specific aspects of HIV estimates that require substantial conceptual or methodological development

Meeting Objectives

HIV policy and planning have become intensely local in target resources efficiently by identifying and responding to areas of high HIV burden and ongoing HIV transmission. In the most affected settings in sub-Saharan Africa, governments and partner organizations now set and evaluate programmatic targets at the district level, with further demographic stratification, in an effort to ensure populations are not missed as coverage reaches high levels.

Such targets require more granular estimates than what is typically available from data sources such as national household surveys and sentinel surveillance. In response to these demands, sophisticated model-based approaches to estimating subnational HIV prevalence and PLHIV have been developed and applied to aid HIV policy setting.

Objectives of this meeting were to:

- Advance progress on development of next- generation modelling tools that can furnish subnational estimates of key HIV epidemic indicators that are routinely required for national HIV planning and target setting.

- Make recommendations to UNAIDS and partner organizations about the methodological approaches for estimation of the described indicators for 2020 HIV planning cycle.
- Plan further model development and tool implementation for usage in 2020 planning cycle (ready for use January 2020).
- Identify and coordinate promising research directions for further longer-term development.

Outline

The UNAIDS Reference Group held its thematic meeting on *Tools for subnational HIV strategic information for sub-Saharan Africa* in Glastonbury, CT, USA from 8-10th May 2019. The meeting featured presentations and group discussion to generate consensus recommendations. The programme was divided into the following sessions:

1. Reviewing subnational HIV estimation
2. Model presentations
3. Discussant panel
4. HIV data platforms
5. Working groups and recommendations
6. Novel data for paediatric estimation
7. Estimating population viral load suppression

This report presents a summary of the meeting presentations and discussions. The presentations are available to meeting participants at www.epidem.org (others, please contact the Secretariat). The final recommendations can be found at the end of this report.

The recommendations drafted at these meetings provide UNAIDS with guidance on generating HIV estimates, provide an opportunity to review current approaches, and help to identify the data needed to further improve the estimates. Previous meeting reports are available at www.epidem.org. This transparent process aims to allow the statistics and reports published by UNAIDS and partners to be informed by impartial, scientific peer-review.

The list of participants and meeting agenda are included in Appendix I and Appendix II, resp ectively.

Session 1: Review of existing subnational HIV estimation

The objectives of this session were to review:

- the evolution of geospatial modelling techniques,
- the current status of subnational HIV estimation as part of the UNAIDS estimates process, and
- their application in policy making and programmatic target setting.

UNAIDS supports the creation of national HIV epidemic estimates for the majority of countries worldwide. Since 2013, UNAIDS has engaged in geospatial analysis to identify transmission hotspots, and thereby inform strategic resource allocation and programmatic activities. The complexity of geospatial modelling approaches has since increased, and there now exists a range of options, with increasing data demands, that a country may wish to employ to generate estimates at a finer granularity than the national level. Ian Wanyeki provided an overview of subnational estimates supported by UNAIDS during the 2019 estimates round, challenges associated with their generation, and considerations for future modelling solutions, summarized in Box 1.

Box 1. Successes, challenges, and desired features based on UNAIDS experience supporting subnational HIV estimation (presented by I Wanyeki)

Successes

- Many examples of countries putting these subnational estimates to use for HIV policy and planning

Challenges

- Use of standardized & accurate sub national demographics
- Rapidly evolving and varying model specification
- Centralized top down approach for model implementation and generating results
- Currently no official sign off by countries on their sub national estimates
- Lack of access to essential datasets (e.g. PHIA surveys)
- Quality control of all the files
- Data other than ART to inform incidence (i.e. behaviour, VMMC)
- Visual validation of results and comparisons against other data
- Substantial workload and capacity constraints to develop and review subnational estimates at provincial, national and global (UNAIDS HQ) level

Desired features for future model

- Generate key indicators needed for HIV programing at desired subnational level
- Well defined and standardised sub-national areas (where data can be used for improved programming)
- Model that can be run by country teams
- Need for trends over time
- Uncertainty in an easily displayed interpretable fashion
- Child estimates as well as adults

Roxanne Hoek outlined Mozambique's broad use of HIV estimates in target tracking, setting, and donor reporting, providing insight into use of HIV estimates at the country level (Box 2). Since 2017, Mozambique has maintained 11 provincial Spectrum files. This approach reflects the well-established heterogeneity in the epidemic and allows provinces to calculate their own coverage estimates for planning, tracking progress, and target setting. In previous annual estimate rounds, district level estimates were generated by disaggregating provincial Spectrum files guided by district level ANC data, and in 2019, HIVE-Map was used. Future desired features and outputs of subnational estimates included: (1) paediatric estimates, (2) treatment cascade, and (3) multiple years of forward projection. Key challenges identified were communication strategies surrounding substantial changes in district level estimates when switching modelling strategy and the communication of uncertainty.

Box 2. Examples of uses of subnational HIV estimates in Mozambique (presented by R Hoek)

Estimation

- Estimate ART, PMTCT, and EID coverage for global and national reporting.
- Reporting non-routine information (e.g. new infections, AIDS deaths, vertical transmission) to donor agencies (e.g. Global Fund, PEPFAR COP).

Tracking progress

- Tracking progress towards 90-90-90.
- National Institues of Health (INS) national data observatory report.

Target setting

- GOALs model training for 11 provinces to use for planning.
- Target setting based on unmet ART need → new initiation targets → HIV testing targets.
- District level targets calculated by provinces.
- Inputs to PEPFAR data pack (district-level estimates).

Irum Zaidi detailed the granular programmatic data reported by all programme implementers through the PEPFAR Monitoring, Evaluation, and Reporting (MER) Indicators (Figure 1), and described several country examples of how these data are used to enhance patient- and clinic-targeting in programmatic decision making. The PEPFAR programme are increasingly turning attention to strategies to identify and rapidly respond to new HIV infections and sustain HIV prevention. Zaidi enumerated examples of planned future innovations in programme delivery and surveillance to support this:

- Scale up of index and recency infection testing provides further information on where new infections are occurring and enabling rapid treatment and prevention responses at fine resolution.
- Case surveillance and integration of prescription and dispensation data to identify persons likely to be unsuppressed.
- Increased monitoring of HIV prevention cascade indicators for PrEP and VMMC.

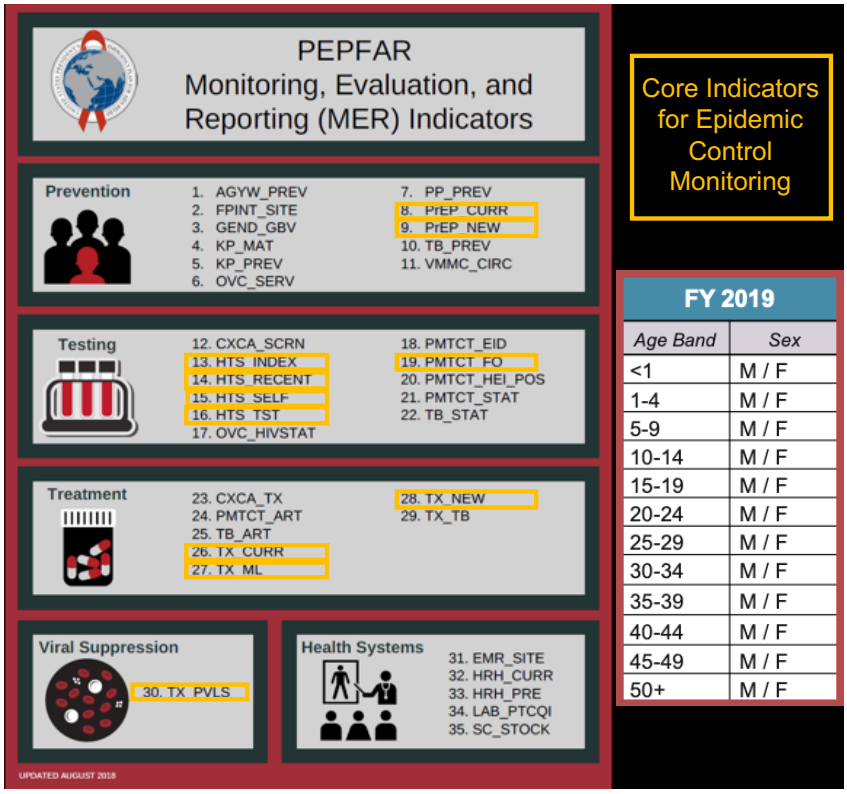

Figure 1. PEPFAR Monitoring, Evaluation and Reporting indicators reported by sex and 5 year age bands

Laura Dwyer-Lindgren closed the session with a review of the modelling approaches used to furnish HIV prevalence estimates at the district level or lower. Existing approaches that have appeared in the literature were classified into broadly seven approaches: inverse distance weighting, kernel density weighting, kriging and associated variants, model based geostatistics and small area estimation. Table 1 summarises key features of each of the approaches. Model-based geostatistics, Bayesian kriging, and small area estimation were assessed as the most desirable foundations for HIV estimation due to: (1) their representation of uncertainty and (2) theoretical ability to be extended to capture covariates, complex processes, and multiple data sources.

Table 1. Summary of approaches to spatial HIV prevalence estimation (presented by L Dwyer-Lindgren)

Approach	**Resolution**[1]	**Uncertainty**[2]	**Covariates**[3]	**Extendibility**[4]	**Examples**
Inverse distance weighting	Point / raster				Messina et al. (2010); Cuadros & Abu-Raddad (2014); Barankanira et al. (2015); Zulu et al. (2014)
Kernel density estimation	Point / raster				Larmarange et al. (2011); Okano & Blower (2016); Larmarange & Bendaud (2014)
Kriging	Point / raster	✓			Coburn & Blower (2013); Cuadros et al. (2015); Schaefer et al. (2017); Kalipeni & Zulu (2008)
Kriging + logistic regression	Point / raster	✓	✓		Cuadros et al. (2017)
Bayesian kriging	Point / raster	✓	✓	✓	Carrel et al. (2016) Kleinschmidt et al. (2016)
Model based geostatistics	Point / raster	✓	✓	✓	Dwyer-Lindgren (2019) HIVE Model
Small area estimation	Polygon	✓	✓	✓	Gutreuter et al. (2019) Joint district model

[1]Some wiggle room – points and rasters can be aggregated to polygons; polygons can be 'resampled' or otherwise translated to point data (with error). See Session 2 – Local Burden of Disease Model

[2]Uncertainty estimates may not capture all sources of uncertainty

[3]Most models that can use covariates don't require it (Bayesian kriging, MBG, SAE).

[4]Approaches which are (theoretically) straightforward to extend to additional dimensions (time, age); multiple data types with different biases and potentially different likelihoods.

Session 2: Model presentations

This session provided technical details of four models for subnational HIV estimation – summarised in Table 2:

- HIVE-Map
- the Local Burden of Disease Bayesian Geostatistical model
- Small Area Estimation, and
- the District Model for joint estimation of HIV prevalence, ART coverage, and HIV incidence (henceforth "District Model")

Secondly, introductions were presented to a number of promising modelling approaches under development.

	HIVE-Map	Local Burden of Disease	Small Area Estimation	District Model
Data inputs	Multiple years of household survey and ANC data	Multiple years of household survey and ANC-SS data	Single year household survey (ANC data as covariate)	Single year household survey, ANC, ART data
Covariates	Sociodemographic and geographic covariates	Sociodemographic, geographic, and novel HIV-specific covariates	Optional[1]	No[3]
Geographic level	Pixel	Pixel	Polygon	Polygon
Flexible to administrative boundary changes	Yes	Yes	No	No
Cross-district service attendance	No	No	No	Yes
Estimation period	Time series	Time series	Year of survey	Year of survey, short projection
Fitting time	Hours	Days[2]	Seconds	Minutes

Table 2. Comparison of models for subnational HIV estimation

[1] HIV prevalence in pregnant women is the dominant covariate in the majority of settings
[2] The model is fit by region, not by country. A country-level fit would greatly reduce fitting time
[3] In the current implementation, rather than by design

HIVE-Map

The HIVE-Map model, used by 10 countries in the 2019 estimates round, was presented by Sam Bhatt. The grid-based Bayesian geostatistical model consumes household survey and antenatal facility prevalence data, supplemented by spatial covariates to produce a 5x5km pixel prevalence surface. Figure 2 illustrates the HIVE-Map workflow. District-level ART data are used with the prevalence model to furnish estimates of ART coverage, and national incidence produced by Spectrum-EPP is disaggregated based on the relative transmission potential per pixel – see here for previous details regarding development and presentation of the HIVE-Map model to the Reference Group.

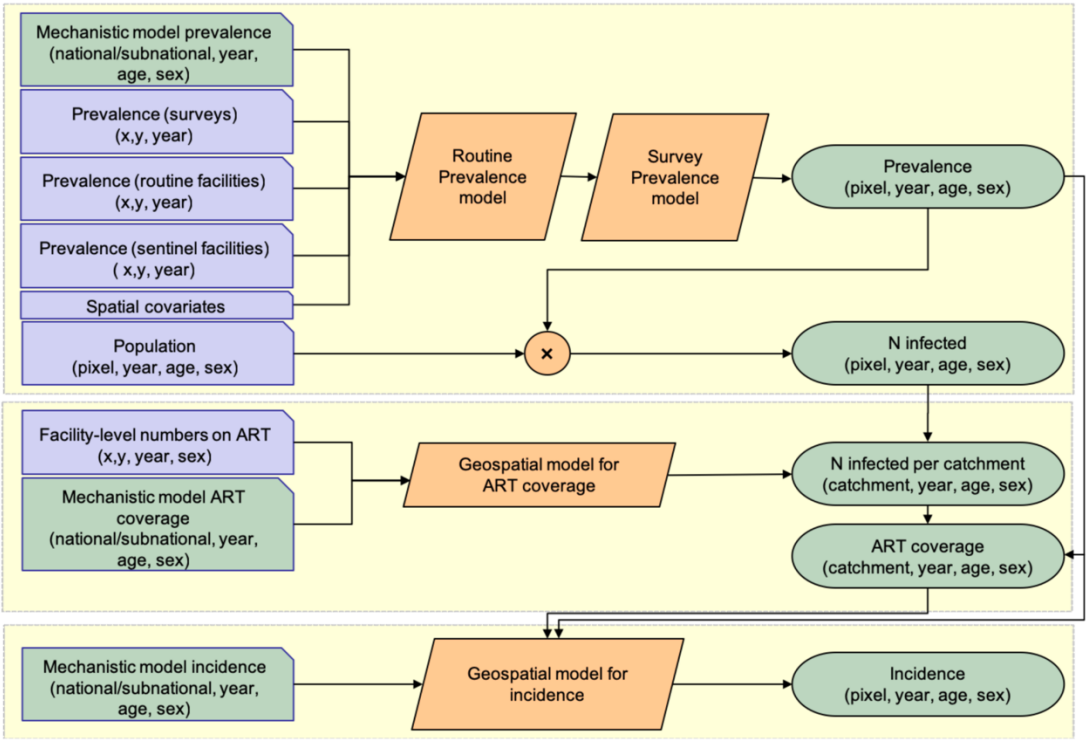

Figure 2. HIVE-Map model schematic.

The accuracy of subnational population data inputs and their consistency with other data sources was identified as a challenge in many settings. Consideration should be given to the use of alternative population layers such as the High Resolution Settlement Layer. As household survey and ANC data measure the same underlying phenomenon, Bhatt views the use of joint modelling of as a necessary next step to improve estimates. Further, the use of direct image processing from satellite imagery will provide covariate data directly linked to social development (e.g. slums, road networks) rather than relying on proxy measures (e.g. aridity, greenness). Incidence estimation should be improved with the addition of facility-level viral load suppression data and compared against ALPHA network and Rakai cohort data for pixel-level incidence validation.

Small Area Estimation

Small Area Estimation (SAE), presented by Steve Gutreuter (Gutreuter et al., 2019), consumes single-year survey domain estimates and optionally supplemented by covariates.

A geospatial technique, SAE produces weighted averages of direct domain and model-based synthetic estimates, using routine covariate data to reduce error associated with district-level disaggregated direct domain estimates (Fig 3).

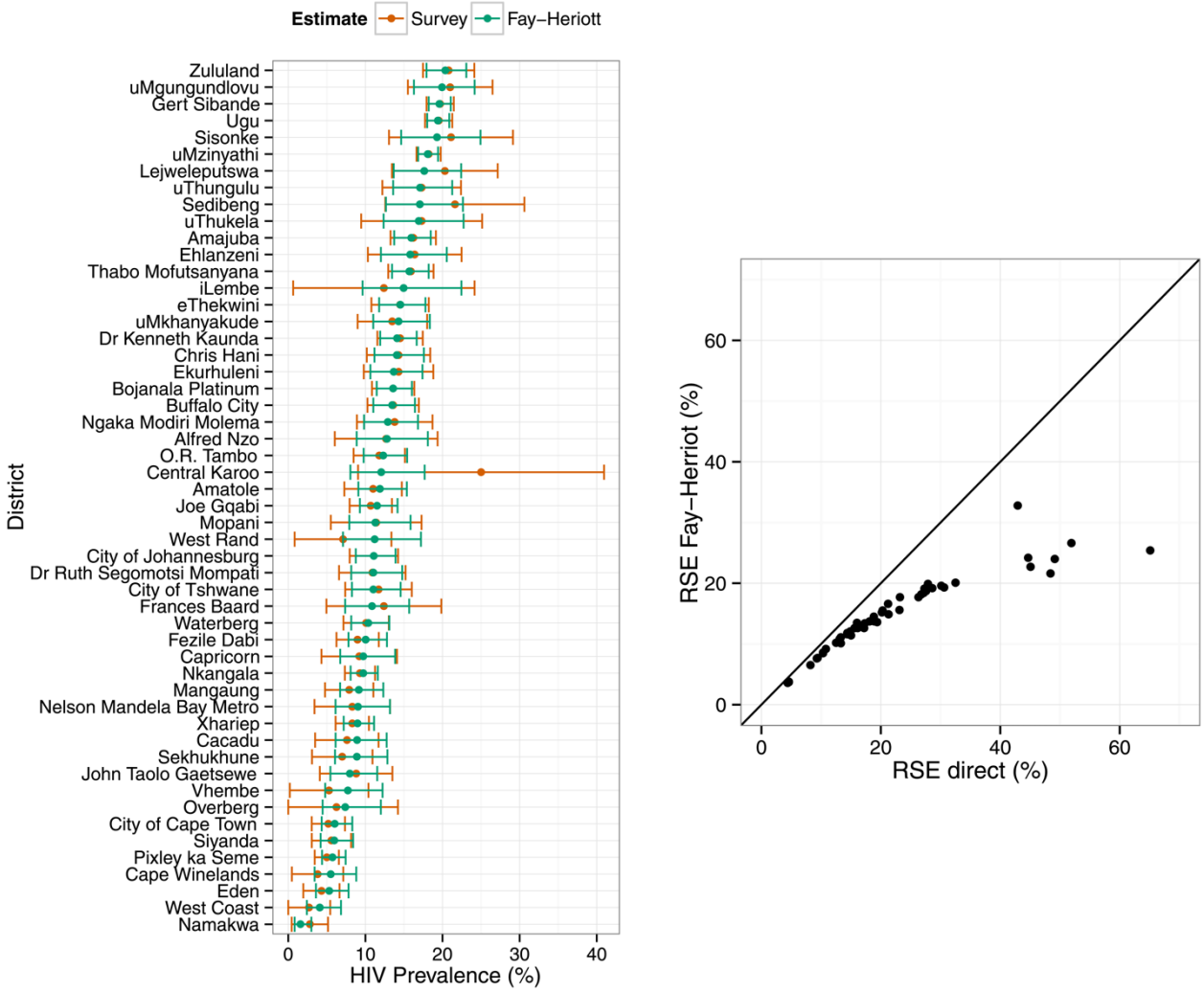

Figure 3. Comparison of direct domain estimates ("survey" or "direct") and SAE estimates ("Fay-Heriott) at the district level of HIV prevalence in South Africa. *Source: Gutreuter et al. (2019)*

Eight in-country workshops covering 9 countries have been conducted to interactively develop small area estimates. Representatives from Ministries of Health and HIV estimates teams ran model code in Rand produced estimates with technical support from CDC statisticians. In all countries for which SAE estimates have been developed, ANC prevalence is the dominant covariate with little added value for other covariates.

Particular challenges identified for the application of area-level models were changing administrative boundaries and hierarchies; and encounter data exhaustion with small age groups when modelled as separate 'nano-domains'. Future implementations may consider hierarchical structures to resolve the latter. Area-level modelling aligns well with programme planning activities and it is a resolution at which covariates are widely available. Gutreuter notes that SAE as currently implemented is unable to estimate viral load suppression, and recommends the use of joint modelling to address estimates of both ART coverage and VLS.

Gutreuter emphasises that for subnational estimates to be useful to countries, any modelling approach must:

- Be easily understood by HIV estimates teams;
- Be quick to run;
- Provide clear and simple comparisons of model outputs against data inputs, and other comparator modelled estimates (e.g. the District Estimates Tool currently provided in Spectrum)

Local Burden of Disease

The Local Burden of Disease model, presented by Laura Dwyer-Lindgren, uses a model-based geostatistics approach to estimate 15-49 HIV prevalence at a 5x5km pixel resolution for sub-Saharan Africa from 2000-2017 (Dwyer-Lindgren et al., 2019). Household surveys and ANC sentinel surveillance data are core data inputs, supplemented by pre-existing covariates (from earlier mapping efforts) relevant to HIV, and 7 novel HIV-specific covariates constructed from survey data (Fig 4). The range of data sources present across the estimation period necessitates survey and antenatal polygon data to be resampled and translated into point data by taking population weighted samples, an improvement over previously-used polygon centroids. Similar to HIVE-Map, covariates are entered into a stacked generaliser, the outputs of which are used as covariates in the final geostatistical prevalence model. The current implementation of the model is stratified by four regions (Western, Central, Eastern, and Southern Africa), which is computationally expensive and much slower to fit than country-level models.

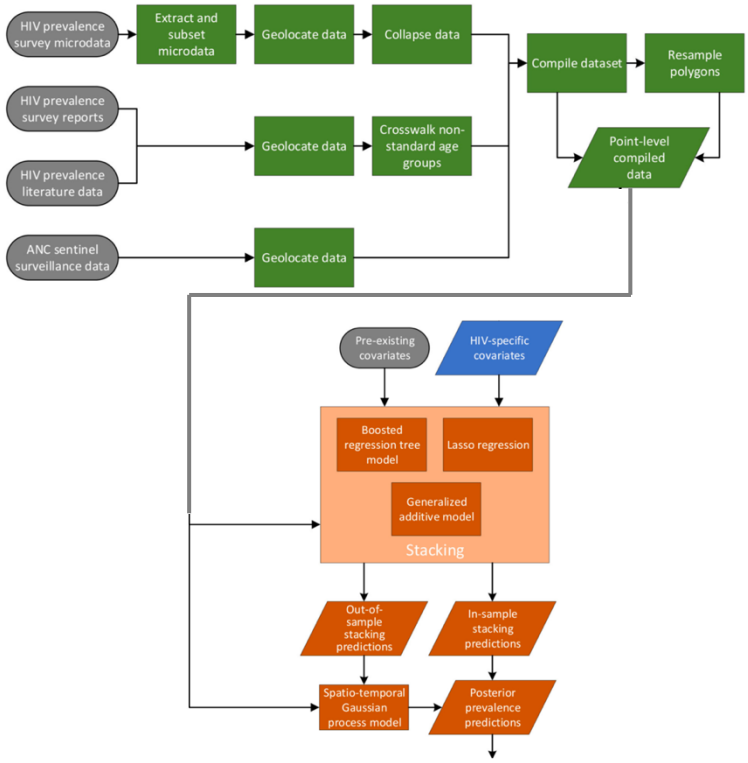

Figure 4. Local Burden of Disease model schematic. *Source: Dwyer-Lindgren meeting presentation, slides 10 & 18*

Results (Fig 1 of Dwyer-Lindgren et al. (2019)) are furnished at the 5x5km level and aggregated by administrative level up to the national level. That pixel-level results can be flexibly aggregated to any given area is a strength over area-level modelling approaches, particularly in light of frequently changing administrative boundaries.

Several standard covariate surfaces were included in the model: travel time to nearest settlement >5000 people, night-time lights, urbanicity, malaria incidence, and population. The Local Burden of Disease study constructed several HIV-specific covariate surfaces using survey data. HIV specific covariates were proportions (Extended Fig 6 of Dwyer-Lindgren et al. (2019)):

- Male circumcision (among men age 15-49).
- Self-reported STI symptoms in the past year (among sexually active adults age 15-49).
- Married or living as married (among age 15-49).
- Condom use during last sex (age 15-49).
- Multiple sexual partners in the past year (men and women separately, age 15-49).
- Ever had sex (women age 15-24).

In models for the Central and Eastern regions, **male circumcision**, **condom use**, and **proportion sexually active young adults** were the most influential covariates. In Western region **condom use** was most important followed by **multiple partners in the past year among women**.

Extensive cross-validation analyses were conducted to assess the model specifications for spatio-temporal structure via the Gaussian processes, covariates, and covariate stacking, ANC bias model, and polygon resampling. Key conclusions of cross-validation analyses were:

- Modelling spatial autocorrelation via the Guassian process substantially improved model performance compared to covariate-only model.
- Inclusion of covariates and stacked covariates each modestly improved absolute error but did not definitively improve or worsen the RMSE or coverage of out-of-sample predictive intervals.
- Inclusion of ANC sentinel surveillance data with independent or spatially structured bias terms modestly improves model predictions.

Future model development will look to:

- Estimate prevalence by 5 year age groups and sex
- Better incorporate polygon data
- Account for population uncertainty
- Translate prevalence estimates into incidence estimates

District Model

The District Model, presented by Jeff Eaton, looks to produce more precise and accurate estimates of prevalence, ART coverage, and incidence than small area estimation by:

1) **Maximising the information used from data sources by jointly modelling HIV prevalence and ART coverage.** Information about HIV prevalence is contained within ART data and vice versa: considering them simultaneously improves model estimates.
2) **Introducing a model-based approach for reallocating ART patients across districts.** Individuals attending ART facilities outside of their district of residence lead to implausible ART coverage levels, in excess of 100% or well below the national average – see presentations by Irum Zaidi in Session 1 and Matt Thomas below.

Model estimates using data from Malawi are presented as a case study. The simultaneous use of prevalence data from household survey and ANC clinics, and ART data from programmatic sources, ANC clinics, and household surveys, with model-based ART cross-district reallocation produced estimates with the smallest error. Results from this model ("Model 6") are shown in Fig 5. Compared to direct estimates:

- Point estimates of prevalence are similar, with increased precision;
- ART coverage estimates are substantially more homogeneous across districts than direct estimates, with all districts under 100% coverage, and have increased precision.

The model identifies sources and sinks of cross-district ART attendance, notably from neighboring districts into cities, and into Chiradzulu district where long-established services are available and it is known individuals go to seek care (Figure 6).

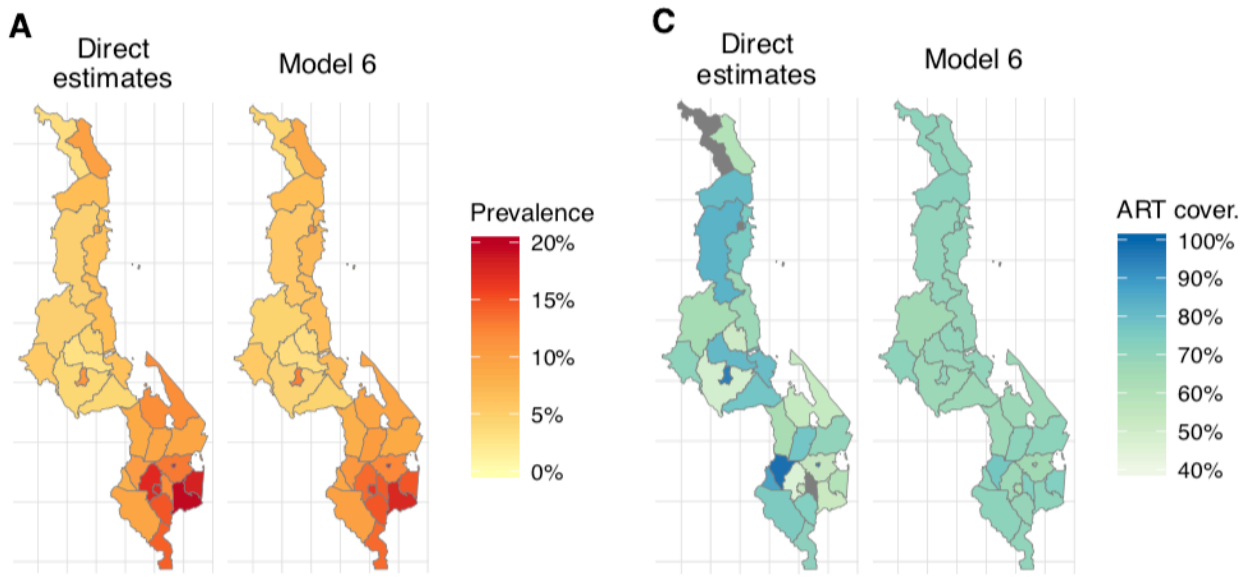

Figure 5. Comparison of direct estimates with District Model ("Model 6") estimates of prevalence (A) and ART coverage (C) in Malawi. *Source: Eaton meeting presentation, slides 24 & 25*

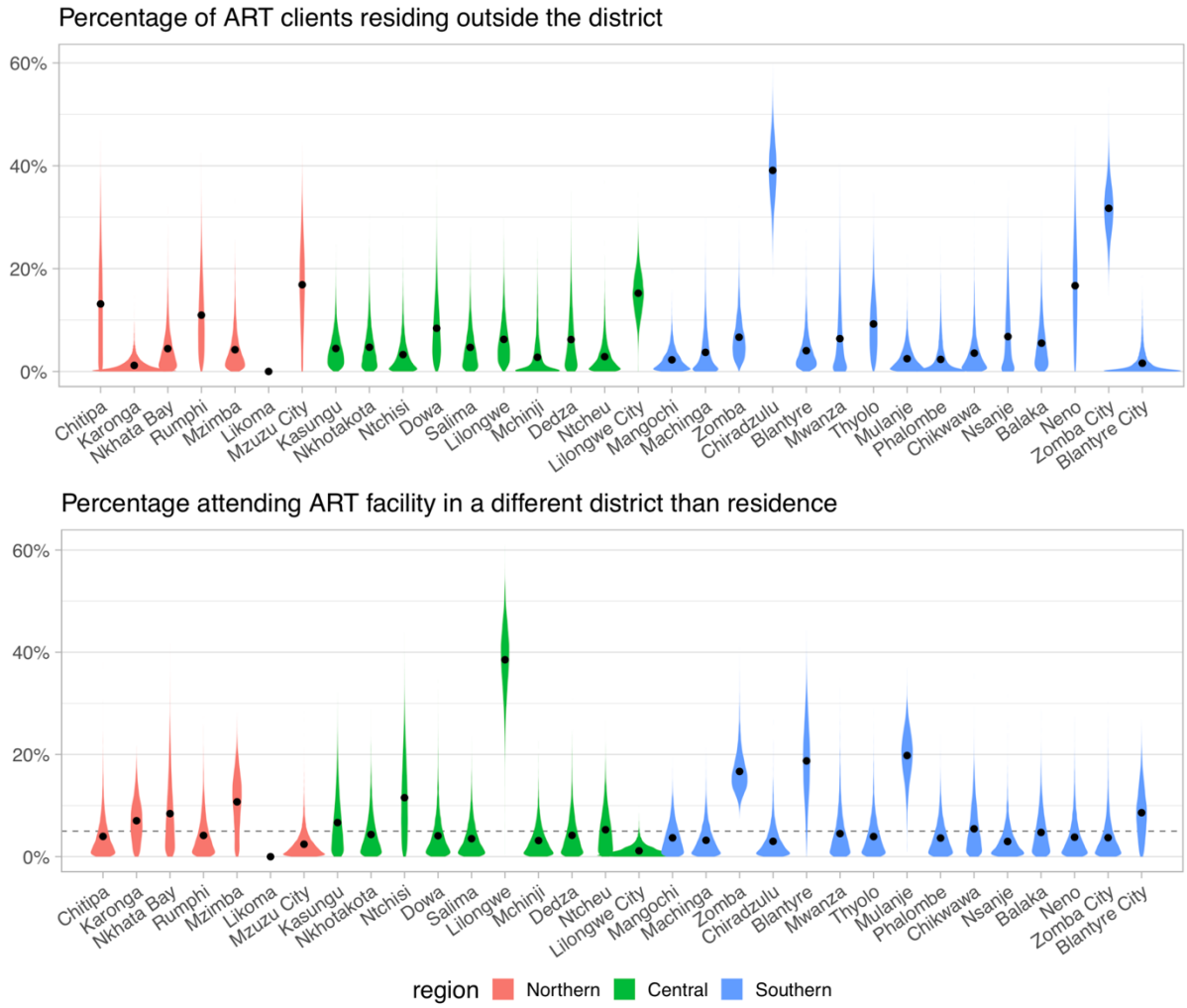

Figure 6. Cross-district ART reallocation in Malawi. *Source: Eaton meeting presentation, slide 27 & 28*

Recent household surveys, including all PHIA surveys, include recent infection testing for estimating national HIV incidence. However, direct estimates of HIV incidence at subnational level from survey data is challenging due to the sparsity of cases. For example, the 2016 MPHIA survey in Malawi found 22 recent infections out of 15,000 adults tested for HIV. When disaggregated by district, 21 of 32 districts have no recent infections (Fig 7A), rendering direct domain estimates impossible. Instead, an approach based on simple transmission dynamics (i.e. risk of transmission is based on the probability of making effective contact with an infected individual) using the above model results for prevalence and ART coverage can be used to estimate incidence. A random effect (u_i in Fig 7C) allows subnational heterogeneity, informed by recency data.

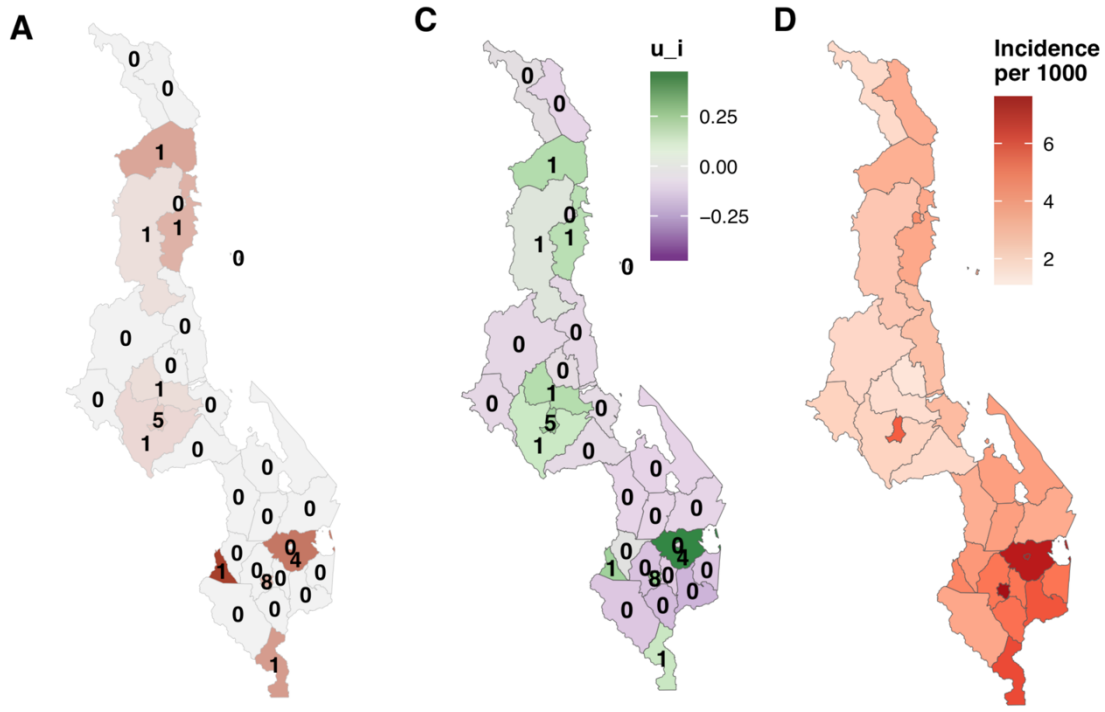

Figure 7. (A) Number of positive recency tests in MPHIA 2016 by district. (C) Model random effect informed by recency data. (D) District Model estimate of incidence per 1000.

Future model development should consider the implementation of spatial structure on prevalence, ART coverage, and ANC bias. The model-based approach for cross-district ART attendance could be similarly applied to ANC clinics, as HIV+ women may selectively seek ANC care at facilities outside of their district of residence where they already engage with ART services.

Summary of commonly encountered challenges and discussion points

Several topics were identify as common challenges across the modelling approaches and group discussion:

- **Data quality**, including:
    - **Subnational demographic population inputs**. A central issue raised by all four models, and especially for the pixel-level models estimating at 5x5km resolution.
    - **Programmatic data.** Though directly incorporating service data into epidemic inference is important to estimate ART coverage and capture subnational heterogeneity, estimates become sensitive to weaknesses in data quality.
    - **Location data.** The geostatistical models would ideally consume input and covariate data at 5x5km resolution, which is not always possible due as some data sources are only available at polygon resolution.
- **Uncertainty**
    - **Communication of wide uncertainty intervals.** Increasingly granular estimates results in wider uncertainty ranges. This is faced by small-area estimate models and geostatistical models with uncertain point estimates at the 5x5km level. It is difficult to simultaneously communicate point estimates and associated uncertainty, particularly in mapping. Several participants suggested reporting only intervals without point estimates, or the use of wider age ranges, but this does not meet the needs of programmatic planning.
    - **Population uncertainty.** Models currently consume population inputs as fixed without uncertainty, and this is poorly managed and expressed within model results.

Olivia Keiser presented four socio-behavioural analyses at the national and individual level. Principle component analysis identified cluster associations with HIV incidence estimates reported by UNAIDS at the national level. Latent-class analyses was applied to individual-level survey data from Malawi to cluster individuals with similar sociodemographic and HIV risk profiles. Clusters characterized by high divorced/widowed persons, older, household heads, and those in employment had high levels of HIV prevalence. Clusters characterized by rural residents had low levels of HIV testing. Further work in progress is using machine learning models to extend the sociobehavioural analyses to predict HIV status.

John VanderHeide described preliminary work fitting the EPP model at the district level using HIV prevalence estimates over the period 2000-2017 from the Local Burden of Disease model (Dwyer-Lindgren). In the present implementation, district-level ART coverage is fixed at the national level and future implementation will include subnational ART coverage and disaggregation by age and sex. Part of this EPP implementation was an admin-2 level internal migration gravity model which predicted the probability of a person moving between 2 locations in the past 12 months based on the relative size and proximity of those locations. This gravity model was trained on geolocated census data. VanderHeide also proposed exploring a spatial hierarchical model for the transmission rate ($r(t)$) component of EPP in future work.

Tim Wolock presented a spatial-temporal model of HIV incidence, capturing regional variation in HIV transmission. A traditional compartmental model is fit in each subnational region, with additional cross-region infection dynamics: incidence in a given region depends on the prevalence in that region and neighbouring regions. Applying the model in Malawi, estimates for prevalence, ART coverage, and incidence are produced for all districts simultaneously, with plausible fits across all indicators and locations. Tim Hallett notes that the model is not accounting for cross-district contacts depleting the number of effective contacts within district, and recommends reviewing model assumptions about balancing sexual mixing.

Improving linkage to care to narrow the gap between first and second 90s is a PEPFAR priority. Ray Shiraishi presented three examples of modelling the HIV linkage process. The prevailing approach to estimating linkage at a given facility is to divided the number of new ART initiations (TX_NEW indicator in PEPFAR reporting) divided by the number of positive HIV tests (HTS_TST_POS indicator). This produces wide ranging and implausible estimates, including those in excess of 100%, because it poorly captures:

- Patients testing and seeking treatment at different facilities;
- The preference for some facilities towards either testing or treatment;
- Community testing facilities which, by definition, have a proxy linkage of zero as they do not offer treatment.

Shiraishi presented work by his team to create agent-based models for the process of probable linkages of individuals from HIV testing sites to ART facilities based on proximity and time of testing and ART initiation. The model, using either patients or facilities as agents,

simulate patient movement between facilities, providing more optimised estimates of internal ($testing_{Facility\_A}$ & $treatment_{Facility\_A}$) and external ($testing_{Facility\_A}$ & $treatment_{Facility\_B}$) linkage (Fig 8). A final model regressed facility-level new ART initiations on total number of ART patients and number of new positive diagnoses at nearby facilities. The model was then used to simulate the impact of a sudden increase in new positive diagnoses at a given facility on ART initiation at neighbouring facilities.

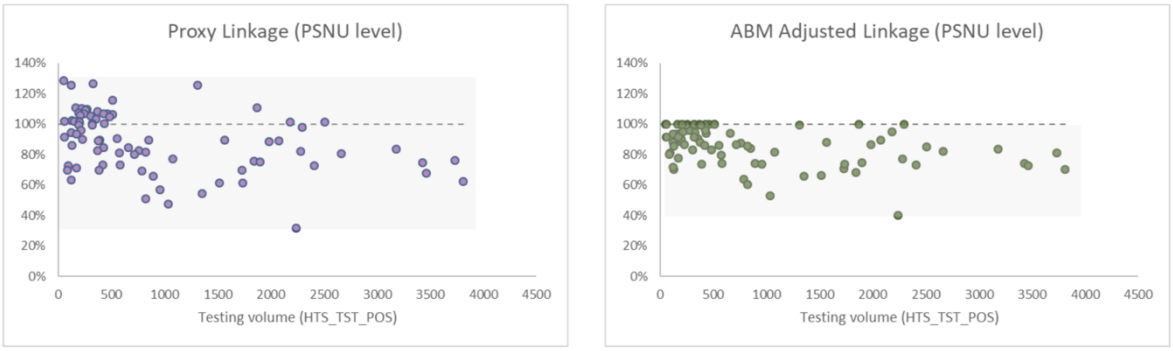

Figure 8. Comparison of proxy measures of linkage to care in PEPFAR sites. Left: Unadjusted linkage. Right: Agent based model-adjusted linkage. *Source: Shiraishi meeting presentation, slide 14*

Matt Thomas presented a catchment model of ART attendance. Facility level ART data are used with catchment probabilities of attending a given facility (Fig 9), based on travel time to facility and a 'favourability factor' (i.e. large hospitals favoured over small community centres), to assign patients to their district of residence, rather than district of treatment. This minimises the effects of cross-district ART attendance, and produces more realistic district ART coverages.

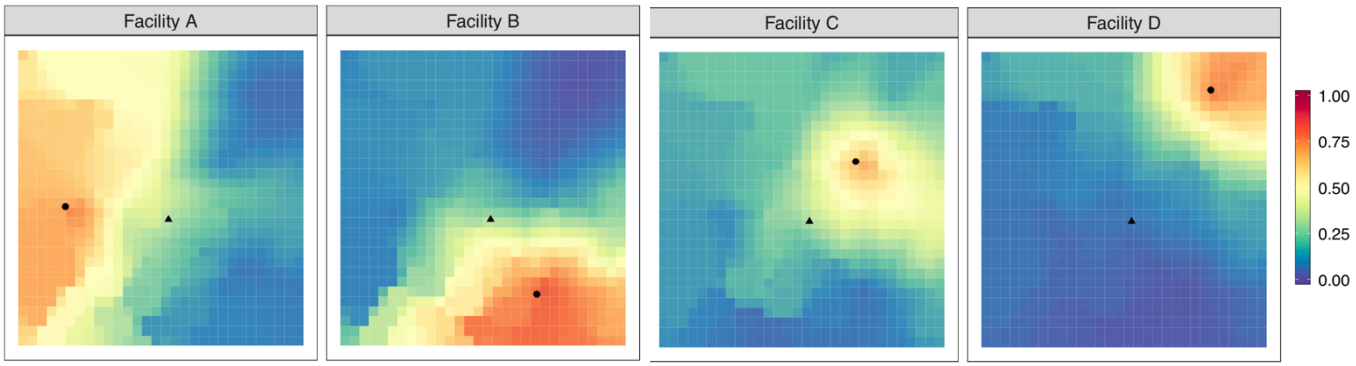

Figure 9. Simulated facility catchment probabilities. *Source: Thomas meeting presentation, slide 9*

Session 3: Discussant panel

Four discussants from health statistics (Leontine Alkema), HIV surveillance (Wolfgang Hladik), spatial statistics (Jon Wakefield), and disease dynamics (Adam Akullian) were invited to evaluate the HIVE-Map, SAE, Local Burden of Disease, and District models. The key thematic areas of their discussion were:

1) **Robust estimation of ART coverage and incidence in data limited settings requires structured models.**
    a. Data-rich indicators such as prevalence are well tackled by machine learning and covariate-driven approaches, though data sparse indicators (incidence, ART coverage) are better approached through joint modelling – favoured by several discussants.
2) **Covariate stacking obscures covariate relationships**.
    a. Representing and resolving uncertainty within estimates is challenging when covariates are stacked.
3) **There is large uncertainty and variation across sources about subnational population estimates.**
    a. Demographic uncertainty should be explicitly represented within HIV estimation
    b. Different population sources should be compared to see their influence on the final HIV estimates.
4) **Effective country ownership of subnational model outputs requires substantive integration of modellers and national experts.**
    a. The use of vignettes and "thought experiments" as presented by Gutreuter and Eaton assist in explaining the conceptual framework of models.
    b. Visualisation and validation of model inputs and outputs against direct data will assist country teams in understanding the estimates.
    c. Models that are quick to run and computationally light enhance the model review, development, and iteration process.
    d. Uncertainty should be well represented and communicated, with the development of metrics to indicate whether the results are data- or model-driven.
5) **Representation of internal migration and cross-district service attendance is desirable.**
    a. Existing viral load result delivery data should be used to validate existing cross-district attendance assumptions
    b. The 2019-2020 PHIA2 surveys could include questions to inform cross-district ART and ANC attendance.

Session 4: Platforms for HIV data

Roxanne Hoek described data systems, platforms, and processes in Mozambique to collect required model inputs. Data systems challenges were identified which should be considered in the modelling process:

- Outdated health facility lists and missing geocodes;
- Paper-based data collection leading to programme data quality issues including overestimation of numbers on ART by 15-20%.

Challenges with previous subnational outputs include:

- Discrepancies between population estimates and NSO census numbers;
- Cross-district ART attendance;
- Communication of results and programmatic planning when model estimates fluctuate year to year; and
- Pushback over the use of regional PMTCT parameters felt to be insufficiently relevant to the national context

Several discussion points arose:

1) Despite data systems challenges, the national Technical Working Group responsible for HIV estimates, there is an imperative that HIV estimates are produced official Ministry of Health data.
2) There is a need for M&E capacity building so that district-level managers are appropriately trained to both collect data for, and correctly use, subnational estimates.
3) Given dynamic model inputs and data systems challenges:
    a. From a country perspective: To date, PLHIV is the subnational indicator from HIVE used at the subnational level for planning purposes. What steps need to be taken to utilise indicators such as ART coverage and incidence at the subnational level?
    b. From a modelling perspective: What is the need for granular estimates when programmatic ART overcount may exceed 20%?

Nate Heard described the evolution of PEPFAR's data collection and collation systems. Thirty-five Monitoring, Evaluation, and Reporting (MER) indicators have been collected by 5-year age bands and sex at site-level resolution since 2015 from over 60,000 geolocated clinical sites. Heard outlined the considerable work taken to validate data inputs and resolve point and administrative polygon geocoding errors.

Data management places a significant burden on Ministries of Health. UNAIDS, in partnership with Fjelltop, is developing a data repository tool – the AIDS Data Repository (ADR) – to facilitate this process, presented by Jonathan Berry. ADR will act as a repository for countries support countries to securely to store, document, and archive the national data sources used to create their HIV estimates, and interface directly with DHIS2, Spectrum, and future modelling tools. It was agreed that to emphasise the central objective of the tool to support countries with management and documentation of their own data, the initially proposed name

("AIDS Data Exchange") should be changed to emphasise the positioning as a repository rather than an exchange.

Session 5: Working groups and recommendations

Session 5 of the meeting consisted of working groups for meeting participants to discuss content of previous sessions and formulate priorities and recommendations for features of short- and longer-term development of geospatial modelling tools. Meeting participants were divided into four working groups and invited to address a set of questions on key objectives and specific features of a subnational modelling approach.

Across the four working groups, there was strong agreement on features of a consensus model for the 2020 estimates round – see table below. In summary, working groups recommended:

An area-level, joint modelling approach with ART attendance reallocation (i.e. The District Model), outputting estimates of:

- HIV prevalence;
- PLHIV;
- CLHIV; and
- ART coverage

by sex and 5-year age groups

Outputs at the district level should be concordant with those produced at the national level in Spectrum – *i.e.* raked 'top-down'. Tools to facilitate evaluation and validation of model results were viewed as key, including against the Local Burden of Disease and Spectrum disaggregation estimates, and should be nested within Spectrum.

In addition to the current implementation of the District Model, the inclusion of ANC-RT prevalence data was recommended, though the added value of covariates was not immediately obvious. Participants recommended that future model development should include:

- HIV incidence (including the scale-up of routine recency testing data);
- awareness of status;
- viral load suppression; and
- the consideration and evaluation of novel HIV covariates as constructed by Dwyer-Lindgren and colleagues.

The continued development of grid-based geostatistical models was recommended, both as validation of current area-level models, and also looking ahead to facility-level estimation where finer resolution estimates will be required. Mechanistic/behavioural models, whilst desirable – particularly for incidence estimation, and integration of VLS and recency data from key populations, were viewed as too complex at this stage.

	Group 1	Group 2	Group 3	Group 4
What are the key questions that a subnational model needs to be able to answer?	Guide resource allocation & programmatic target setting. Priority outputs by age and sex: - Prevalence - PLHIV - ART coverage	Priority outputs by 5yr age and sex: - Prevalence - PLHIV - 2nd 90	Priority outputs: - PLHIV - Prevalence - Incidence - Proportion undiagnosed - Proportion unsuppressed Satisfied with wider age groups than 5 year	Priority outputs: - Prevalence/PLHIV - ART coverage - Incidence (and discriminate between incidence and transmission hotspots) Satisfied with wider age groups than 5 year
What are the specific features of a recommended approach that enable the model to accomplish this?				
1. *Area (polygon) or gridded model.*	For 2020 estimates, an area level model – produces estimates suited for planning and policy. Grid models should be further investigated for facility level estimates	Area level model. Future model development to consider population-defined areas for countries with large admin-2 areas	Area level model	Area level model. Advantages to using the grid approach (changing boundaries & facility level estimation) and should be investigated in future.
2. *Should the model include covariates? (Which ones?)*	Did not address	ANC data	Limited benefit. Consider VMMC	Limited benefit. If ANC is to be used as covariate, a joint modelling approach is preferable
3. *Joint modelling of prevalence and ART.*	Did not address	Priority	Priority	Priority, noting questions about performance in data sparse settings
4. *Cross-district ART attendance.*	Did not address	Desirable	Desirable, though noted that this should be resolved at the data collection/facility level rather than at the modelling level	Desirable, though the model should also report the 'unreallocated' ART coverage - important for resource allocation faced by facilities
5. *Mechanistic modelling of transmission directly in subnational model. (Other interventions?)*	Desirable but too complex at this stage	Desirable, but in the long term	Desirable, but in the long term	Desirable, but in the long term when more behavioural data are available
6. *How to incorporate recent incidence data.*	Did not address	Routine data should not be included at this stage	- Recommend inclusion of recency data from household surveys	Did not address

			- Routine data requires further assessment of bias before inclusion	
7. *Incorporation and presentation of uncertainty.*	Priority. Recommend a dissemination plan to ensure appropriate use of district estimates by countries	Priority	Priority and should be emphasised as part of communicating the results. Model should be easy to use and quick to run	Priority. Model should be quick to run
8. *Population and population movement.*	Did not address	Quality of population structures and estimates is problematic	Priority, but noted that the quality of population structures is an issue that extends beyond the HIV modelling community	Did not address
9. *Time horizon for modelling / instantiation of models.*	Did not address	2 year projection	Did not address	No opinion
10. *Post-hoc calibration to regional or national estimates from the Spectrum model*	Did not address	Top down raking	Top down raking to provincial level results	Top down raking to provincial level results
How should we evaluate model performance and results?	Did not address	- Compare with Spectrum District Estimates tool - Internal cross-validation - External validation with Local Burden of Disease estimates – included within modelling tool for visualisation comparison	- Internal cross-validation - Compare with Spectrum District Estimates tool - Visualisation of outputs should be included within modelling interface	Did not address
What are the priorities for development and refinement over a longer term (3-5) year horizon?	Incidence	- Incidence - Mortality - 1st and 3rd 90 - Routine recency data - Bottom up approach - Grid based models - Improvement in population structures - Case surveillance with index testing	- VLS in key populations - Recency data in key populations - Mechanistic modelling	Did not address

Building on the consensus recommendations of the working groups, Josh Salomon enumerated six issues that required further discussion:

1) The requirement of an explicit spatial structure within area-level modelling

Implementation of the BYM2 model offers a straightforward path to incorporating spatial structure. Dwyer-Lindgren and Eaton recommend a spatial structure for prevalence, and consideration for ANC bias and ART coverage. Dwyer-Lindgren notes that implementing time-varying spatial structures increases model complexity considerably compared to a cross-sectional implementation. The Reference Group recommends the creation of a model specification working group to review and address these issues.

2) Testing a joint modelling approach

Uganda, Zambia, Côte d'Ivoire, and Cameroon are recommended as candidate test countries given larger number of administrative units and unique data considerations. The targeted timelines for testing are:

- Analysis on 4-5 testing countries to be completed by the end of July 2019. Model results will be reviewed at a meeting in August 2019.
- Testing on all remaining sub-Saharan countries by October 2019.
- A completed model is required by 1st November 2019

3) Reconciling district level estimates with national or regional Spectrum files

At present, countries create national or regional Spectrum files, and produce district level estimates through HIVE-Map/Spectrum disaggregation. A joint modelling approach with ART attendance reallocation will produce more accurate and precise estimates of prevalence and ART coverage at the district level.

District Model results:

- Will be similar to Spectrum national file results when aggregated to the national level
- May differ to Spectrum subnational file results when aggregated to the provincial level.
    - Patients may be travelling across provincial boundaries to seek care, and raking to the subnational file totals will undo the benefits of cross-district ART attendance reallocation.
    - Leigh Johnson questioned whether the district estimates need to sum to the regional totals, as different modelling techniques will inevitably give fractionally different point estimates. Mary Mahy noted that these discrepancies will be difficult for HIV estimates teams reconcile and work with.

Outputs such as AIDS deaths and MTCT, currently estimated by Spectrum at the provincial or national level, are not directly estimated by the District Model and produced by proportionally disaggregating (sub)national Spectrum results by district HIV prevalence.

Noting the difficulties in managing and maintaining large numbers of subnational Spectrum files, Jeff Eaton proposed a single national Spectrum file and using the district level model to furnish estimates at first and second subnational administrative levels. This decision is deferred to the August 2019 meeting.

4) Elaboration of age and sex parameterisation

The District Model currently parameterises age and sex as a series of fixed effects. Several suggestions for improvements are proposed:

- the use of a baseline age structure with limited flexibility by area;
- iid random effects with a random slope by area;
- one spline for each sex; or
- a parametric function for age varied by area.

5) Population input data

All working groups and modelling presentations raised the issue of population uncertainty. This is a problem of interest to a wider community than only the HIV modelling community. The Reference Group recommends convening a working group with input from WHO to draw together available population sources and select a default source to use.

6) Fall-back modelling strategies for the 2020 estimates round

Should joint modelling prove infeasible or impractical in settings with sparser data or more inconsistent data than the settings to which it has presently been applied (Malawi and South Africa), the Reference Group agrees that small area estimation including ANC-RT prevalence should be the fall-back option. This will be implemented as an option within the final model and user interface, and will be run for all sub-Saharan countries by October 2019 – see ***Testing a joint modelling approach*** above.

Session 6: Novel data for paediatric HIV estimation

Session summary:

- The Spectrum paediatric model should be calibrated to paediatric survey data
- Age stratified programmatic data should be used to calibrate and validate CLHIV estimates
- There is a need to extend the paediatric model to include estimates of the first 90

Estimates for children living with HIV are created using the Spectrum paediatric model, which relies on assumptions about maternal prevalence, fertility, vertical transmission probabilities, and survival of children living with HIV. The paediatric model in Spectrum does not presently calibrate to country-specific paediatric data in the production of paediatric estimates. The objectives of this session were to discuss existing paediatric data sources to be considered for Spectrum model calibration.

Mary Mahy presented an overview of the Spectrum paediatric model, and highlighted changes introduced for the 2019 estimates cycle:

- Fitting a fertility local adjustment factor to ANC-RT data;
- Differential breastfeeding duration by HIV status – shorter duration for HIV$^+$ women, leading to a decrease in CLHIV. In a small number of countries, the breastfeeding adjustment improved the Spectrum fit compared to PHIA data; and
- Updated ART dropout during pregnancy.

Directly observed paediatric HIV data for validation are limited. PHIA surveys and selected other recent national household surveys have included HIV testing of children, though the second round of PHIA surveys under preparation will not include paediatric testing, limiting future data availability about paediatric HIV.

Discussion following the presentation highlighted that the evidence base for relatively fertility of HIV positive compared to HIV negative women is relatively strong in sub-Saharan Africa, but evidence is much sparser in concentrated epidemic settings. In concentrated epidemics, behavioural factors such as differential uptake of family planning or fertility intentions could be different and stronger determinants of MTCT and CLHIV. The Reference Group recommended collection of additional outcomes in biobehavioral surveys among female sex workers (FSW) to enhance evidence about MTCT and CLHIV in these epidemics, including: birth histories, contraceptive use and fertility intentions, and index testing of children of FSW.

Leigh Johnson described data sources used directly calibrate paediatric estimates in South African. The following data sources are synthesised by the Thembisa model:

- Household survey HIV prevalence among children.
- Number tested and number HIV positive from routine HIV antibody testing among children.
- Number of children on ART.
- Age distribution of children initiating ART.

- Total number of recorded deaths among children.
- Child mortality audits for deaths in health facilities reporting the percentage of child deaths in which HIV was diagnosed and in which children were on ART.

Johnson highlighted several challenges and uncertainties for interpreting paediatric HIV data:

- Sensitivity of PCR and ELISA tests in children;
- Symptomatic children presenting earlier/tested more often;
- Establishing whether children starting ART are truly naïve or reiniatiors; and
- Misreporting of cause of death and calibration to all-cause mortality when non-HIV mortality is uncertain

Many of the paediatric data sources utilized in South Africa are increasingly available in other countries that use Spectrum to create paediatric HIV estimates, such as household survey prevalence, routine HIV testing data among children, and number initiating ART by age. Other data sources, such as paediatric deaths and cause of death are not available elsewhere. Extending Spectrum to calibrate to multiple paediatric data sources would provides greater confidence in paediatric estimation and enables paediatric 90-90-90 estimation. During the 2019 estimates, several HIV estimates teams expressed the desire for the first90 model to be extended to paediatric estimates, and it is agreed this is a priority.

The CEPAC-Paediatric model, presented by Andrea Ciaranello, is a detailed microsimulation model of paediatric disease progression, clinical outcomes, effects of alternative ARV regimens, and the paediatric treatment cascade. Natural history parameters are carefully calibrated and validated with observational data about the risk of opportunistic infection (OI) and death, CD4%, from IeDEA paediatric cohort data. Model assumptions about ART efficacy are calibrated are calibrated to clinical trial data.

Katie O'Connor described PEPAR Monitoring, Evaluation, and Reporting indicators pertaining to paediatric HIV programmes and outcomes and described examples of analyses of paediatric HIV data conducted to support PEPFAR programme planning and implementation. Paediatric indicators cover several domains:

- Knowledge of status through routine paediatric testing, PMTCT testing and EID testing.
- Numbers currently on and newly initiating on paediatric ART
- Viral load suppression among paediatric ART clients.

Paediatric age and sex stratifications have changed over time, and are currently reported by sex and ages <1, 1-4, 5-9, and 10-14.

Example analyses of paediatric HIV data included:

- Tests conducted per HIV positive diagnosed, stratified by testing location (TB clinic, malnutrition clinic, index-testing, etc).
- Linkage to treatment amongst those tested positive.
- Paediatric and adolescent VLS, which was substantially lower than that among adults on ART.
- Coverage of timely HIV testing among HIV exposed infants.

- Detailed analysis of loss to follow-up to identify programme gaps (Fig 10).

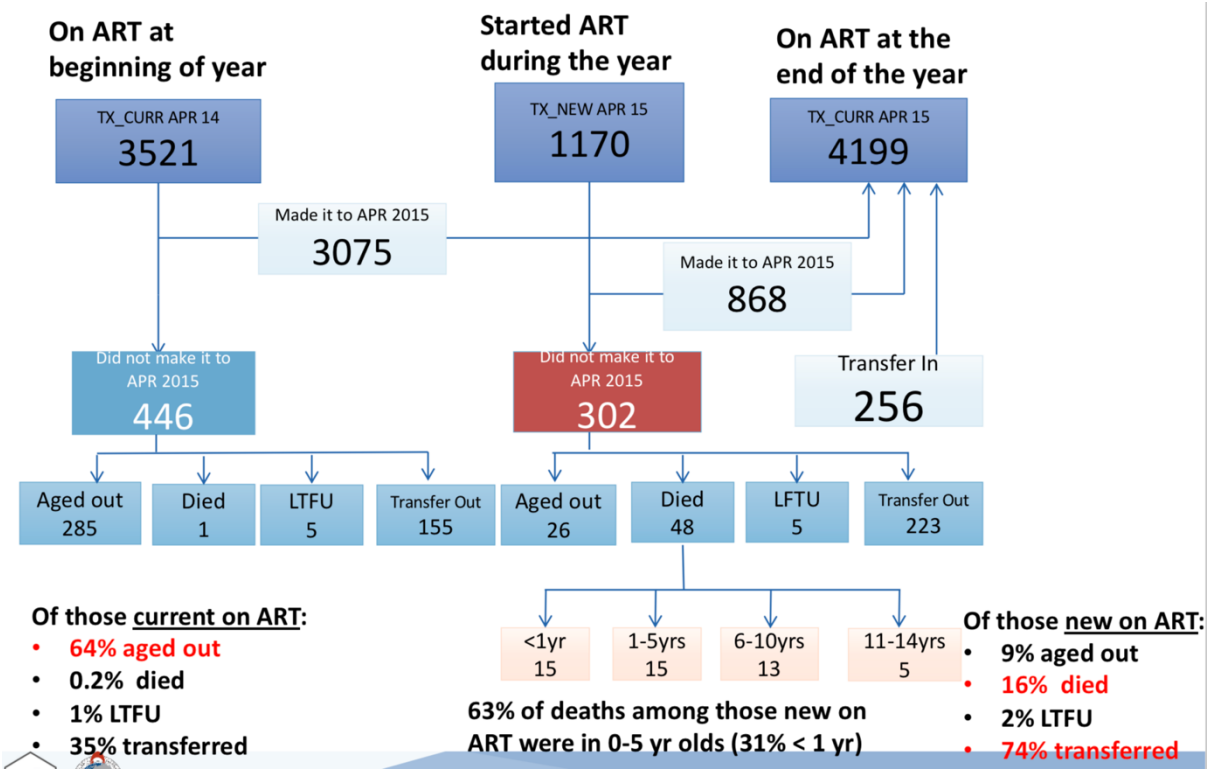

Figure 10. Systematised Paediatric Detailed Loss Analysis using PEPFAR programmatic data. Source: O'Connor meeting presentation, slide 22

Analyses of PEPFAR and in-country programmatic data indicated that some similar data to that used in South Africa are also available in many other countries, which could be used in Spectrum model calibration and estimation in future. The age distribution of CLHIV in PEPFAR data already aligns well with Spectrum estimates. Future estimates should reflect: (1) lower levels of VLS among children, and (2) utilise age-specific ART treatment and treatment initiation data from the most representative available source in each setting.

It was agreed that 2020 Spectrum estimates should be calibrated to paediatric prevalence and ART coverage data from household surveys, though which parameters to vary to incorporate these data remains undecided. Future paediatric estimates at the admin-2 level should incorporate subnational PMTCT and treatment data to account for geographical heterogeneity in programmatic scaleup.

Session 7: Estimating population viral load suppression

Session summary:

- Though VLS is high in those tested, levels of missing data are high
- The characteristics of individuals missing VL data is important. Bias in both directions is plausible
    - Underestimation of VLS: Sicker patients are preferentially tested
    - Overestimation of VLS: Patients with poor adherence are less likely to be tested
- Covariates should be collected so missing data can be imputed
- Differing national thresholds for viral load suppression should be standardised within modelling approaches
- Differentiating between targeted/episodic *versus* routine VLS testing and deduplicating patient data are key

Country level scale up of VLS testing, international guidelines, and challenges for routine VL monitoring were presented by Kim Marsh. The 2016 WHO Guidelines for viral load testing are to be revised in 2020 with three revisions under consideration:

- Earlier first VL test
    - Earlier detection of failure but may over quantify failure
- Lower threshold definition of VLS – 400 copies/ml
    - Enable better detection of drug resistant patients, though point of care/dried blood spot tests may struggle with the required sensitivity. This may be felt particularly in countries where VL testing is only available at national laboratories or a small number of specialised ART clinics
- Single VL test required for drug switching
    - Quicker switch to second line therapy, may lead to unnecessary switching

National VLS threshold guidelines vary widely (Fig 11). UNAIDS use the threshold 1000 copies/ml as recommend by 2016 WHO Guidelines. Standardisation of reporting thresholds is an important consideration for future model-based approaches of determining VLS.

Routine viral load testing policies are available in many countries, either partially or fully implemented, though confusion remains surrounding frequency of testing. 71 countries submitted VL monitoring data in 2017 to GAM, fewer than in 2016, though data are of higher quality as per UNAIDS instruction – only countries with testing coverages >50% are reported.

	<1000	<200	<400	<50	Other
Asia and Pacific	9	Bangladesh		Republic of Korea, Solomon Islands	Singapore (none) Malaysia (<20 copies)
Caribbean	7			Barbados, DR	
East and Southern Africa	9		Botswana, Kenya, Seychelles, South Africa		Madagascar (<250)
Eastern Europe and Central Asia	7	Montenegro		Georgia, Ukraine	
Latin America	5	Chile	Honduras	Brazil, Ecuador, El Salvador, Mexico, Panama, Uruguay, Venezuela	Costa Rica (<20)
Middle East and North Africa	2	Iran		Morocco, Oman, Saudi Arabia	
West and Central Africa	13	Guinea		Gabon	
Grand Total	**52**	**5**	**5**	**17**	**4**

Figure 11. Heterogeneity in national reporting guidelines for viral load suppression (in copies/ml).
Source: Marsh meeting presentation, slide 7

VLS data disaggregated by age, sex, pregnancy and breastfeeding status, and drug regimen should be collect to aid stratified imputation to address missing data. Currently regional imputation is used without stratification, and this is a space for improvement. Developing methods to project cross-sectional data forward in time– e.g. from PHIA surveys, as has been carried out for knowledge of status – would be a welcome addition.

PEPFAR viral load indicators, data, and their use was presented by John Aberle-Grasse. Challenges raised by Marsh in GAM reporting are similarly raised by Aberle-Grasse:

- Despite high suppression levels amongst those tested, a significant proportion of patients are missing viral load data, with several supported countries >50% missing; and
- If countries use a lower national threshold than 1000 copies/ml that is not necessarily recorded

Leigh Johnson described a logistic regression model to estimate true levels of VLS, accounting for incomplete coverage of viral load testing amongst those on ART. The model was fitted to province-level routine VLS data over time reported via the TIER.net and National Health Laboratory Service systems in South Africa. The regression model accounted for variation in percent virally suppressed associated with percent coverage of viral load testing, finding that lower coverage was associated with lower VLS. The model was then used to predict VLS amongst all persons on ART by simulating outputs if VL testing coverage was 100. Johnson also highlighted analyses indicates that VLS testing results are sensitive to time from sampling to analysis (Fig 12), with a longer test turn around associated with higher rates of VLS and should be investigated further.

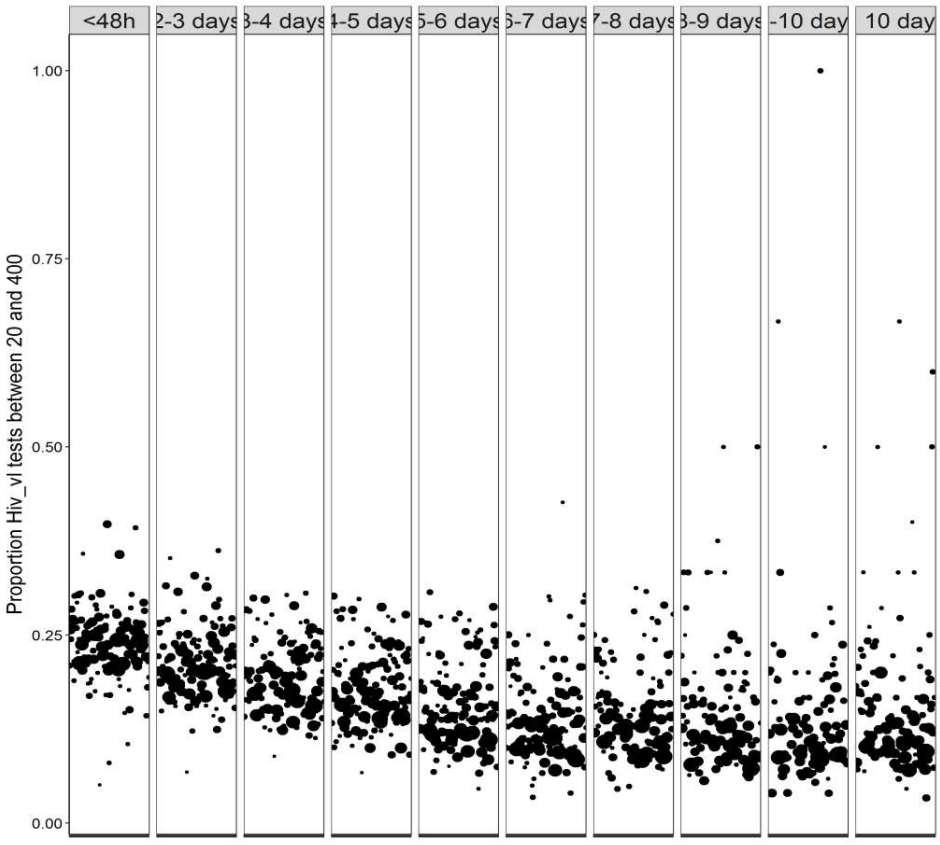

Figure 12. Viral load test sensitivity to time between sample and testing. Source: Hsiao et al (2018), CROI

Key Recommendations

Recommendation/Action Item	Lead Person(s)	Proposed timeline
Sessions 1-5: Next generation tools for subnational HIV strategic information in sub-Saharan Africa		

Consensus model priorities:
• Model accessible to country teams through a user interface including:
  ○ Visualization of model inputs
  ○ Validation of user inputs
  ○ Model fitting
  ○ Visualization of outputs
  ○ Comparisons with input data and other estimates.
• Immediate priority model outputs:
  ○ PLHIV
  ○ Prevalence
  ○ ART coverage
  ○ CLHIV
  ○ Stratified by district level by age and sex
• Longer-term priority model outputs:
  ○ Incidence trends / new infections.
  ○ Awareness of status
  ○ Viral load suppression/population viremia
• Pursue area-level approach for 2020 estimates.
  ○ Consider explicit spatial correlation structure
  ○ Continue development of grid-based geostatistical models and comparing approaches.
• Pursue joint modelling of prevalence and ART coverage, conditional on testing and demonstration in more settings.
• Inclusion of routine ANC prevalence is high priority.
• Inclusion of covariates deemed lower priority – limited evidence for substantial effect on final estimates.
  ○ Explore inclusion of most important LBD covariates: male circumcision, condom usage, proportion sexually active, number of partners.
• Priority to ensure sufficient consistency with national Spectrum estimates – default position is raking of estimates to national estimates ('top-down' estimation).		

1) Workflow, interface, and data inputs • Prepare input data (household surveys, programmatic data, subnational demographic data) and covariates in advance within the AIDS Data Exchange. ○ Recommend name change for AIDS Data Exchange to emphasise primary objective as a tool to support countries develop and maintain their own data and estimates. • Interface should facilitate comparisons model results with data inputs and other sources of estimates such as Local Burden of Disease (LBD).	UNAIDS, Fjelltop UNAIDS, Fjelltop Interface working group	July 2019

2) Model specification
• Output HIV prevalence, PLHIV, and ART coverage, disaggregated by sex and 5 year age bands. Incidence and progress towards the 1st and 3rd 90 are recommended for future development cycles
• Use an area model at the district level
• Model HIV prevalence and ART coverage jointly and include ART attendance reallocation
  ○ Require further exploration of sensitivity to prior assumptions.
• Implement BYM2 model to for spatial structure on HIV prevalence.
  ○ Consider for ANC bias, and ART coverage.
• Determine value of additional covariates (esp. VMMC)
• Extend existing age/sex structure beyond fixed effects
• Fall-back model option: small-area prevalence model including routine ANC testing prevalence.
  ○ This model option will also be included in joint model as an available option.
	Jeff Eaton, Model specification working group	

3) Model testing and validation
• Test District Model on Uganda, Zambia, Côte d'Ivoire, and Cameroon
• Assemble data from all other countries for advance testing.
• Test model options (joint model, SAE model) on all SSA countries
• Decide on calibration of District Model outputs to Spectrum national/regional files
• Validate model estimates for HIV prevalence, ART coverage, and incidence with local data sources:
  ○ Population cohort
  ○ Cluster randomised trial data
  ○ Non-survey LBD data sources
• Validate ART attendance reallocation results with viral load delivery location from PHIA surveys
• Recommend PHIA2 to collect data about service attendance location for those on ART
	Imperial College, CDC
	UNAIDS, PEPFAR, CDC, country teams
	CDC SEM team
	Model specification working group
	Imperial College
	Steve Gutreuter, Ray Shiraishi
	CDC, Imperial College
	PEPFAR, CDC
		July 2019
		July-August 2019
		Aug – Sept 2019
		August 2019
		2020
		October 2019
		2020

4) Subnational population • Form working group to review existing subnational population data sources • Select data source as the default for the District Model	CDC / PEPFAR ICPI Data working group	June 2019 September 2019

Implementation plan and timelines:
• Convene working groups for:
  ○ Data curation
  ○ Model interface and workflow design
  ○ Model specification
• Review model specification and finalize implementation decisions
• Model testing on large number of countries
	Chairs:
	Ian Wanyeki, J Berry
	Mary Mahy, Rob Ashton
	Jeff Eaton, Ray Shiraishi
	Model specification WG
	CDC SEM, Imperial
		May 2019
		August 2019
		Aug - Sept 2019

• Finalize model tool interface specification	Interface WG	July 2019
• Review modelling tool prototype	Model interface WG	Sept 2019
• Model tool beta release and testing	TBC	1 Nov 2019
• Model tool release	UNAIDS	1 Dec 2019

Session 6: Novel data for paediatric HIV estimation		
• Collect birth history, contraceptive use, and abortion data in FSW surveys to fill information gap about PMTCT need in concentrated epidemics. Consider HIV testing of children of FSW in FSW surveys.	CDC Surveillance Branch	
• Incorporate paediatric survey data on prevalence, ART / VLS in model calibration for Spectrum CLHIV estimates. o Review parameters to vary in calibration to paediatric prevalence data.	Avenir Health	September 2019
• Utilise age-specific ART data and age distribution of ART initiation in Spectrum	Avenir Health	2020
• Extend paediatric model to include testing, diagnosis, and case finding data o Provide first 90 estimates among paediatric (similar to shiny90) o Consider calibration to paediatric testing and diagnosis	TBC	2020
• Third 90 estimates should reflect programmatic data indicating lower VLS among paediatric estimates o Review results of 2019 estimates	UNAIDS	September 2019
• Reconcile DHIS final outcome indicator with Spectrum MTCT results o Priority to guide interpretation of routine indicator data versus Spectrum MTCT estimates. o Requires flexible specification in Spectrum to match country-specific time points for final outcome indicator. o Possibly consider calibration of MTCT and paediatric outcomes to Spectrum results	Avenir Health, UNAIDS	September 2019
• Review data to incorporate subnational PMTCT scale-up into district-level paediatric estimates	Jeff Eaton	2020

Session 7: Estimating population viral load suppression		
• Routine VLS data are correlated with survey VLS among ART patients across PHIA countries.	UNAIDS	
• Incorporate finer disaggregation of VLS data disaggregated by age, sex, pregnancy and breastfeeding status into 90-90-90 estimates	Avenir Health	2020
• Develop further guidance for data inclusion and model-based adjustments given level of VL testing scale up and country-specific implementation.	Leigh Johnson	2020
• Review analyses of VL test sensitivity with increasing time from sample to analysis	Leigh Johnson	2020
• Use routine VL testing data and retention data to improve subnational estimates of on ART mortality ○ Consider use of VS data at 6 months and mortality after 6 months from ART-CC data	Leigh Johnson	2020
• Consider the impact of WHO VLS definition decreasing to 400 copies/ml on VLS estimates.		

Agenda

DAY 1

Time	Duration (mins)	Topic	Presenter(s)/ Lead Discussant
Session 1: Review of existing subnational HIV estimation (chaired by Peter Ghys)			
9:00	10	Welcome and introductions	Peter Ghys
9:10	15	Meeting objectives	Josh Salomon
9:25	20	Overview of subnational estimation for 2019 estimates	Ian Wanyeki
9:45	15	Application of subnational HIV estimates in Mozambique	Roxanne Hoek
10:00	20	PEPFAR usage of subnational estimates and model requirements	Irum Zaidi
10:20	30	Review of geospatial prevalence models for HIV	Laura Dwyer-Lindgren
10.50	30	Coffee	
Session 2: Model Presentations (chaired by Tim Hallett)			
11:20	40	HIVE-Map model	Sam Bhatt *(remote)*
12:00	30	Small area estimation model	Steve Gutreuter
12:30	60	Lunch	
13:30	60	LBD geospatial HIV prevalence model	Laura Dwyer-Lindgren
14:30	60	Joint model for district prevalence, ART coverage, and incidence	Jeff Eaton
15:30	30	Coffee	
16:00	15	Socio-behavioural covariates for predicting HIV	Olivia Keiser
16:15	15	HIV incidence trends at admin 2 level with EPP and population movement	John Vander-Heide
16:30	15	Spatio-temporal model for HIV incidence at admin 2	Tim Wolock
16:45	15	Spatial estimates of HIV testing and linkage to care from programme data	Ray Shiraishi
17:00	15	Facility-level ART attendance	Matt Thomas
17:15	15	Summary / roundup	Tim Hallett
17:30	–	Meeting close	

DAY 2

Time	Duration (mins)	Topic	Presenter(s)/ Lead Discussant
Session 3: Discussant panel (chaired by Ray Shiraishi) Consider: • Strengths and weaknesses of models to estimate prevalence, incidence, ART/service coverage • Similarities and complementary features • Opportunities to draw together model elements			
09:00	30	Discussant 1 – Health statistics	Leontine Alkema
09:30	30	Discussant 2 – HIV surveillance	Wolfgang Hladik
10:00	30	Discussant 3 – Spatial statistics	Jon Wakefield
10:30	30	Discussion 4 – HIV dynamics	Adam Akullian
11:00	15	Summary	Ray Shiraishi
11:15	30	Coffee	
Session 4: Platforms for HIV data (chaired by Olivia Keiser)			
11:45	10	HIV data reporting and curation in Mozambique	Roxanne Hoek
11:55	10	PEPFAR MER reporting, DATIM, and geospatial data	Nate Heard
12:05	10	UNAIDS AIDS Data Exchange	Jonathan Berry
Session 5: Working groups and recommendations (chaired by Josh Salomon)			
12:15	15	Introduction to working groups	Josh Salomon
12:30	60	Lunch	
13:30	60	Working groups	
14:30	45	Working groups report back	
15:15	60	Discussion – short and long priorities for geospatial tool development	
16:15	30	Coffee	
16:45	15	Recommendation summary	Josh Salomon
17:00	45	Workplanning & next steps	
17:45	–	Meeting close	

DAY 3

Time	Duration (mins)	Topic	Presenter(s)/ Lead Discussant
Session 1: Novel data for paediatric HIV estimation (chaired by John Stover)			
9:00	15	Spectrum paediatric model, calibration and triangulation with data sources	Mary Mahy
9:15	25	Paediatric HIV testing and mortality in South Africa	Leigh Johnson
9:40	20	CEPAC paediatric model calibration and validation	Andrea Ciaranello
10:00	25	Paediatric programme data and analysis in PEPFAR	Katie O'Connor
10:25	20	Discussion	
10:45	15	Coffee break	
Session 2: Estimating population viral load suppression (chaired by Mary Mahy)			
11:00	20	Viral load monitoring guidelines, country implementation, and estimation needs	Kim Marsh
11:20	25	Programmatic viral load data reported to PEPFAR PEPFAR data and insights	John Aberle-Grasse
11:45	20	Estimating population VLS in South Africa from routine VL testing	Leigh Johnson
12:05	20	Discussion	
12:25	15	Meeting summary	Jeff Eaton
12:40		Meeting close	

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Inverse distance weighting

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