Overview
Shrinking the gHAT map: identifying target regions for enhanced control in DRC

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1 Abstract

Background
Gambian human African trypanosomiasis (gHAT) is one of the neglected tropical diseases targeted to achieve elimination of transmission (EOT) by 2030. Despite the recent success in reducing the number of reported cases to less than 1,000, the Democratic Republic of the Congo (DRC) still accounts for nearly 70% of global cases, and it is unknown whether EOT can be reached within ten years. We utilised mathematical modelling to study the overall impacts of combinations of the current available intervention methods on transmission across the DRC and highlight key regions requiring intensified interventions to achieve EOT.

Methods
We used the Warwick gHAT model – previously developed and fitted to longitudinal human case data in DRC – to predict the expected numbers of active cases, passive cases, and new infections under four future strategies in 168 health zones for which sufficient data are available. The strategies comprise of medical interventions – active and passive screening – and some include vector control. In each health zone, numbers of new infections from 1,000 model realisations are used to estimate the median year of EOT and the probability of meeting this goal by 2030 under each strategy. We subsequently compute the least ambitious strategy predicted to achieve EOT by 2030 with a given confidence level.

Findings
The model predicts 42 health zones (35 are low- or or very low-risk and seven are moderate- or high-risk) are very likely to achieve EOT (>90%) using medical-only strategies continue at a previous coverage levels. An extra ten health zones will be very likely to achieve EOT (>90%) if the screening coverage can be increased to their maximum coverage during 2000–2016. In all vector control strategy simulations, health zones are predicted to meet EOT by 2030, although there are several zones where screening coverage is low and increased coverage may also be an option.

Interpretation
Limited access of medical interventions including extremely low coverage in active screening leads to pessimistic model predictions in some of the low- or very low-incidence health zones. An integrated analysis of data, model assumptions, and model predictions in moderate- and high-incidence health zones provides a priority list for consideration for supplementary vector control implementation (Bagata, Bandundu, Bolobo, Kikongo, Kwamouth, and Masi Manimba in the former Bandundu province) in conjunction with the recent coverage in active screening.

2 Introduction

In this article, we used the results of previous fitting (Crump *et al*, submitted and the preprint is available at `MedRxiv`) to now examine the strategies of active screening (AS) alone or with supplemental vector control (VC) on top of the local passive surveillance (PS) system to stop gHAT transmission by 2030 in the DRC. This was performed at the health zone level across the whole of DRC. A graphical user interface (GUI) to complement this article was set up to provide full model outputs to aid decision making (see GUI `online`). In this analysis we aim to identify regions which are likely to be successful in achieving local elimination of transmission (EOT) on their current trajectory, and ones where enhanced control may be required to meet this target.

3 Methods

We used a previously developed variant of the Warwick HAT model to predict gHAT dynamics by considering transmission among humans, tsetse, and non-reservoir animals. This model with low-risk and high-risk humans captures systematic non-participation high-risk groups in the population.

The fitted model (Crump *et al*, submitted and the preprint is available at `MedRxiv`) takes into account previous improvements in medical, diagnostic, and control systems. Based on the continuation of the current PS system, we considered four strategies, which included different coverage of AS and whether or not to implement VC from 2020 (Table 1). Forward projections from 2017 to 2050 were independently performed in each health zone with both parameter and observational uncertainty captured in the 10,000 realistations for cases and 1,000 realistations for unobservable variables such as new infections.

Table 1: Strategies considered for projections (2017–2050). VC effectiveness is determined by the proportional reduction in tsetse populations after one year of implementation. Results of sensitivity analysis on VC effectiveness are available `online`. Strategies without VC are not considered in Yasa Bonga because VC has been implemented since 2015.

Strategy name	**AS coverage from 2017**	**VC effectiveness from 2020**	**PS coverage from 2017**
MeanAS	Mean (2012–2016)	0%	Same as 2016
MaxAS	Max (2000–2016)		
MeanAS+VC	Mean	90% for Yasa Bonga 80% everywhere else	
MaxAS+VC	Max		

4 Results

Figure 1 shows results for the four strategies in two example health zones: Kwamouth and Tandala (all other health zones are available `online`). Despite very high coverage of AS in Kwamouth, achieving EOT by 2030 is predicted to only be possible when VC is added. Conversely, Tandala appears extremely likely to achieve EOT by 2030 by MaxAS strategy. In addition, EOT happens in 60% projections assuming continuation of mean AS.

Health zone maps of median year of elimination of transmission (YEOT) under four strategies are shown in figure 2. The model predicts, that under mean AS strategy, 74 health zones are on track (YEOT $\leq$ 2030), 29 health zones are slightly behind the schedule (2030 $<$ YEOT $\leq$ 2040), and 65 health zones are greatly behind schedule (YEOT $>$ 2040). A seven extra health zones become on track while 62 health zones remain greatly behind schedule under MaxAS strategy. If VC starts in 2020, all health zones are predicted to achieve EOT by 2024. MaxAS+VC could further bring down YEOT by up to one year.

Figure 3 shows probability of elimination of transmission (PEOT) by 2030 in each health zone under four strategies. The model predicts 42 health zones are very likely to meet the goal (PEOT $>$ 0.9) and 61 are almost certain to miss it (PEOT $<$ 0.1) under MeanAS strategy. High uncertainty in eliminating transmission (0.3 $<$ PEOT $<$ 0.7) is reported in 33 health zones. If VC starts in 2020, EOT by 2030 is extremely likely everywhere. Limited access to medical interventions ($<$ 40% maximum coverage) can explain why some health zones outside the former Bandundu province are predicted to be unlikely to eliminate transmission by 2030 without VC.

Finally, we rank strategies by how ambitious the use of additional interventions is and examine the minimum required to meet the 2030 EOT goal in each health zone - referred to as the "preferred strategy"(figure 4). We show maps with 90, 95, and 100% probability of meeting EOT by 2030 according to our model simulations. According to the ranking (MeanAS, MaxAS, MeanAS+VC, and MaxAS+VC), the least ambitious strategy among all that meet the PEOT criterion then becomes the preferred strategy. N.B. MaxAS+VC is absent in any of the preferred strategy maps because all health zones are expected to achieve the EOT goal by 2030 under MeanAS+VC strategy which requires less resources.

5 Conclusion

We present how modelling can be used to guide regional intervention planning across DRC depending on how confident we would like to be in achieving EOT by 2030. In this analysis we highlight how VC could be a valuable tool to meet the EOT target quickly, however it is neither necessary in some health zones, not practical to deploy at scale across the country. In particular, the model predicts six moderate- or high-risk health zones which already have good screening coverage ($>$ 40%) but $<$ 0.95 probability of meeting the goal are: Bagata, Bandundu, Bolobo, Kikongo, Kwamouth, and Masi Manimba in the former Bandundu province, and through our mathematical modelling analysis these are identified as health zones where VC could be a necessary tool for EOT (see Figure 5).

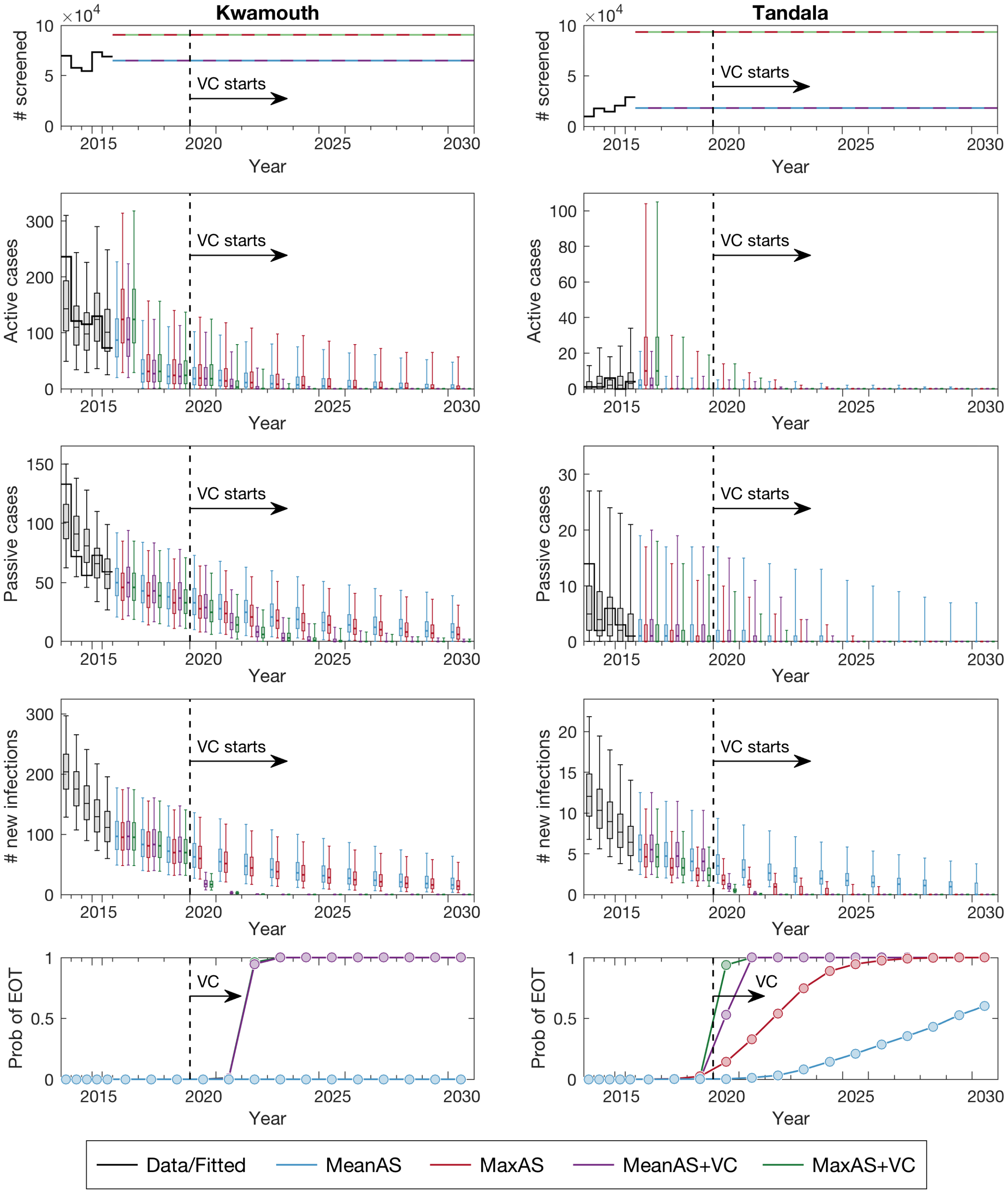

Figure 1: **Time series of key model outputs in two example health zones.** Kwamouth (left panels) in former Bandundu province and Tandala (right panels) in former Equateur province represent a high-risk and a moderate-risk health zone respectively. The top row shows the number of people actively screened, the middle rows show three direct model outputs (active cases, passive cases, and underlying new infections from top to bottom), and the bottom row shows the probability of achieving elimination of transmission (EOT) by year. Black lines and box plots indicate data and model fits in the last five years (2012-2016), coloured dashed lines denote the assumed AS starting in 2017, and colour box plots and circles present the predictions for four strategies (as defined in Table 1). Box plots with whiskers showing 95% prediction intervals summarise model uncertainty. Full model outputs (2000-2050) of all 168 analysed health zones are available `online`.

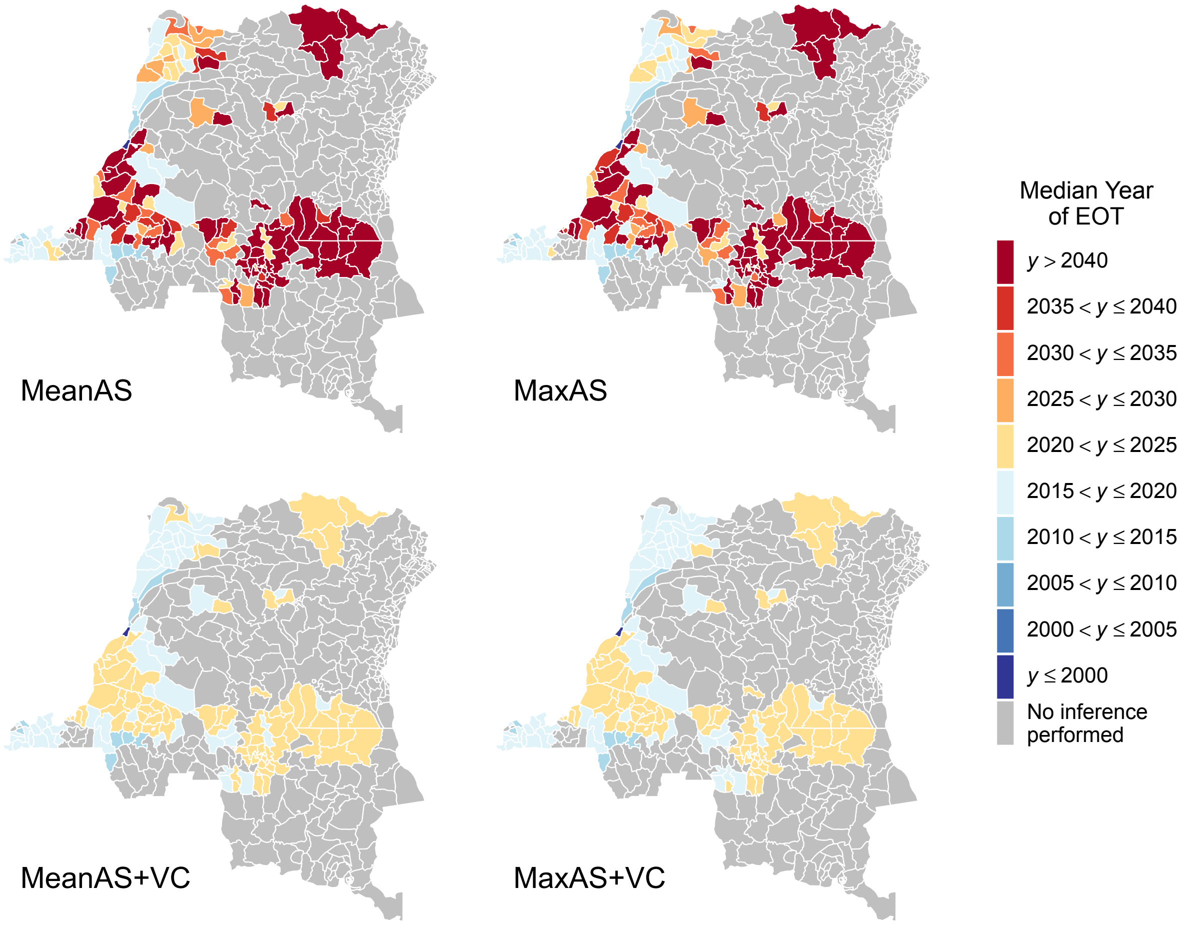

Figure 2: **Health zone median year of elimination of transmission (YEOT) maps for the DRC.** The median YEOT provides the year in which 50% of model simulations reach the EOT target in each health zone. The top two maps show strategies without VC (excluding Yasa Bonga which is shown with VC in place in all maps) and the bottom maps have VC strategies with 80% vector reduction. The left maps simulate continuation of the mean AS coverage and the right two simulate maximum AS coverage. The exact median values and 95% prediction intervals for YEOT are available `online`.

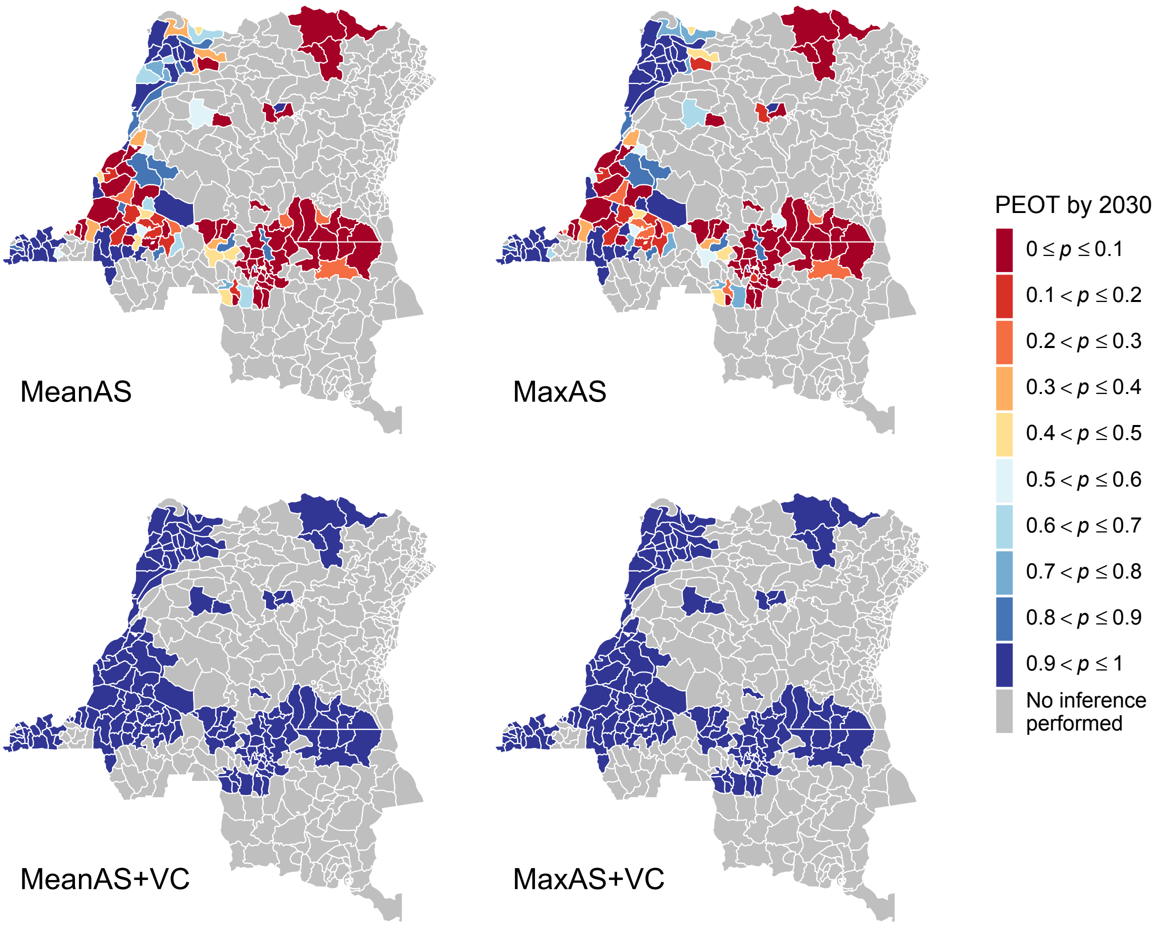

Figure 3: **Health zone probability of elimination of transmission (PEOT) by 2030 maps for the DRC.** Maps of PEOT by other years are available `online`.

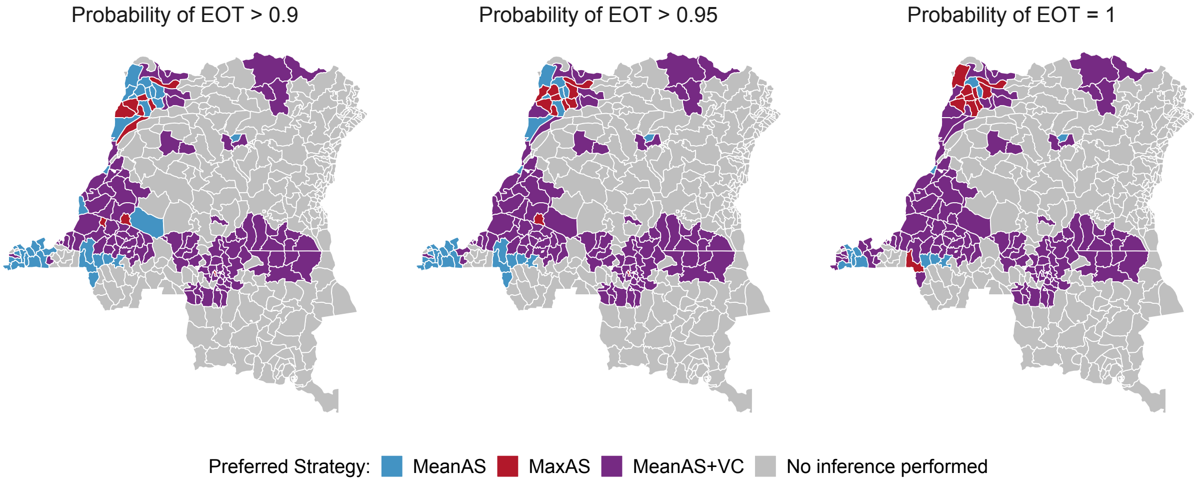

Figure 4: **Health zone preferred strategy maps for EOT by 2030 in the DRC.** The preferred strategy is defined as the least ambitious strategy which is predicted to achieve EOT by 2030 with a prescribed confidence level. The order of ambition ranking is MeanAS, MaxAS, MeanAS+VC, and MaxAS+VC. All health zones are predicted to achieve EOT by 2030 (PEOT $= 1$) under MeanAS+VC strategy so MaxAS+VC is absent in all preferred strategy maps. MeanAS and MaxAS were not considered in Yasa Bonga because VC started in mid-2015. Preferred strategy maps for smaller PEOT thresholds are available `online`.

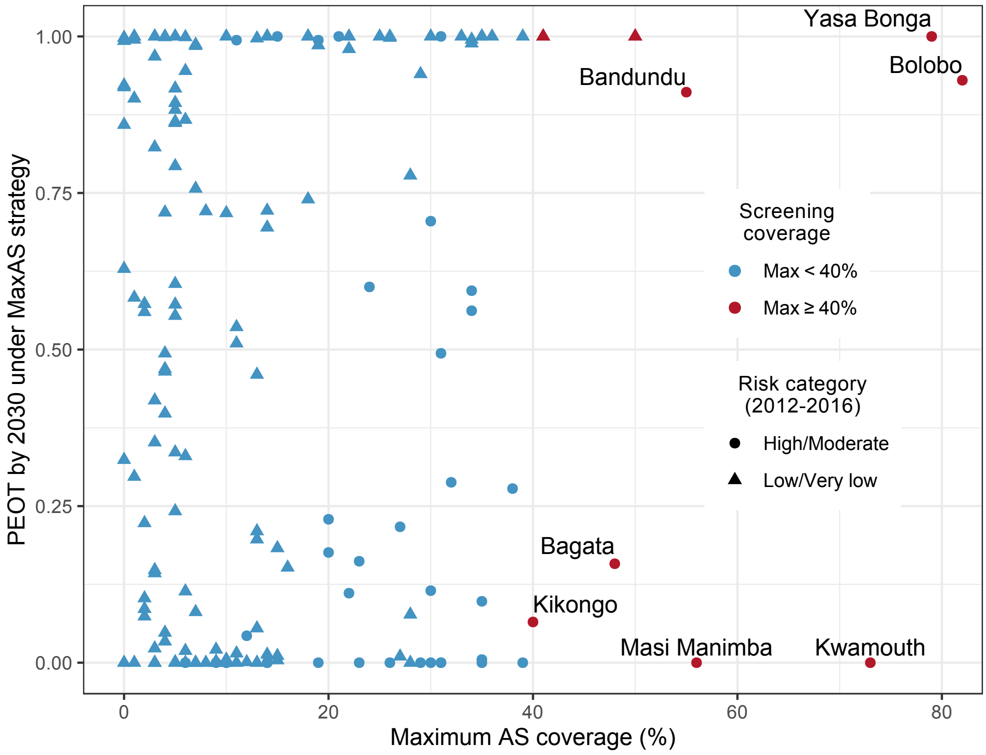

Figure 5: **Identified health zones for VC.** The risk category of each health zone is defined based on data from 2012–2016 according to the thresholds defined by the WHO. High- or moderate-risk health zones are represented by coloured circles. Low- or very low-risk health zones are represented by coloured triangles. Colours indicate the coverage of maximum AS; blue denotes health zones with low maximum AS coverage ($< 40\%$) and red denotes health zones with high maximum AS coverage ($\geq 40\%$). A cutoff of 40% on maximum AS coverage based on data analysis in YEOT and PEOT is introduced to differentiate health zones of good screening coverage from moderate-to-poor screening coverage. PEOT by 2030 under MaxAS strategy represents the maximum probability of EOT with the highest level of intervention implemented to date. Our model identifies a priority list of six health zones (highlighted by their names, Bagata, Bandundu, Bolobo, Kikongo, Kwamouth, and Masi Manimba in the former Bandundu province) for consideration for supplementary VC implementation because these health zones have less than 95% chance of achieving EOT under good AS coverage. N.B. Yasa Bonga is highlighted for VC implementation because of implementation has started in mid-2015.