Towards Real-Time Spatiotemporal Monitoring and Forecasting of Meningitis Incidence in sub-Saharan Africa

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RATIONAL

Current control strategy of meningitis epidemics
- reactive vaccination strategy at a district level
- Prevents at most 60% of cases
- Numerous factors can delay its implementation (i.e. quality of surveillance, logistic constraints, limited vaccine supply, etc)

Our goal
- develop short-term forecasting to enable pre-emptive vaccination
- focus on predicting the risk of exceeding the weekly epidemic threshold (10/100,000 pop) at the district level in Niger.

METHODS

Two different approaches have been considered:

1) Discretizing the weekly incidence rates into states and modelling them (MARKOV CHAIN MODEL)

States are defined from weekly incidence rates:
- Latent if <5/100,000 pop
- Alert if >5 and <10/100,000 pop
- Epidemic if >10/100,000 pop
Model the transition probabilities between 2 consecutive weeks

Log-transformed national incidence rate (solid black line), and its discretized version (i.e. states) used in the Markov model (solid red line). The one-step ahead predictions (blue dashed line) are obtained by fitting the dynamic linear model. The epidemic threshold and the alert threshold are plotted as dotted orange and green lines respectively.

Harmonic regression terms were included in both models to account for seasonality of the disease.
We allow the incidence/state of neighbouring districts to influence future incidence/states.

The output of both models are the district-level predictive probabilities of exceeding the epidemic threshold.

RESULTS

1) MARKOV CHAIN MODEL
Spatial Dependence
- We considered the number/percentage of neighbouring districts having exceeded the alert/epidemic threshold over the last 1-4 weeks, and since the beginning of the calendar year.
- The most significant impact was the proportion of neighbours having exceeded the alert threshold over the last 2 weeks.
- Population density shows significance, but does not improve the predictions

1, 2, and 3 steps ahead predictions

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<tr>
<th>Sensitivity analysis</th>
<th>Observations</th>
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| Predicted probability > cut-off point ⇒ predicted epidemic. This cut-off is usually defined by the ROC curve BUT rarely events ⇒ high sensitivity and specificity, but very low PPV | The use of the ROC selected cut-off value (red point) results in poor PPV

Select cut-off that maximises sensitivity, specificity, PPV and NPV

Predictions considered

- 1, 2 and 3-weeks ahead predictions (these measure statistical performance)
- Predicting whether a district will exceed the threshold within a meningitis-year (these measure performance from decision maker's perspective)

CONCLUSION

- Markov chain model gives better results than the current dynamic linear model (likely to be due to inclusion of spatial dependence).
- For one-step to three steps ahead predictions the specificity and NPV are very high in both models (>90%). Therefore there is a trade-off to be made between the sensitivity and the PPV
- We can better predict epidemic years when considering longer lead time forecasts (Figure 6), but we also mistakenly predict more non-epidemic years to be epidemic.
- Preliminary results are satisfactory from a statistical modeller's point of view, but it is currently unclear how useful they might be to the policy maker for the purpose of improving the current meningitis control
- Further collaboration is therefore needed with the policy makers to fully assess the predictive abilities of our models.

NEXT STEP

- Test our results on most recent data, and possibly test it over next epidemic season (potentially at CERMES).
- Investigate whether other specifications of the spatial dependence would improve the predictions.
- Incorporate district-level meteorological variables (in collaboration with IRI) and assess whether this improves their predictive performances.
- Extend the dynamic linear model to a dynamic generalized linear model, treating case reports as Poisson counts.
- Possibly increase the predictions lead-time according to decision maker’s requirements.

BIBLIOGRAPHY


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