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Geospatial Analysis contributions to the challenge of HIV: Results from a South African National HIV Prevalence , Incidence , Behaviour Survey

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Outline

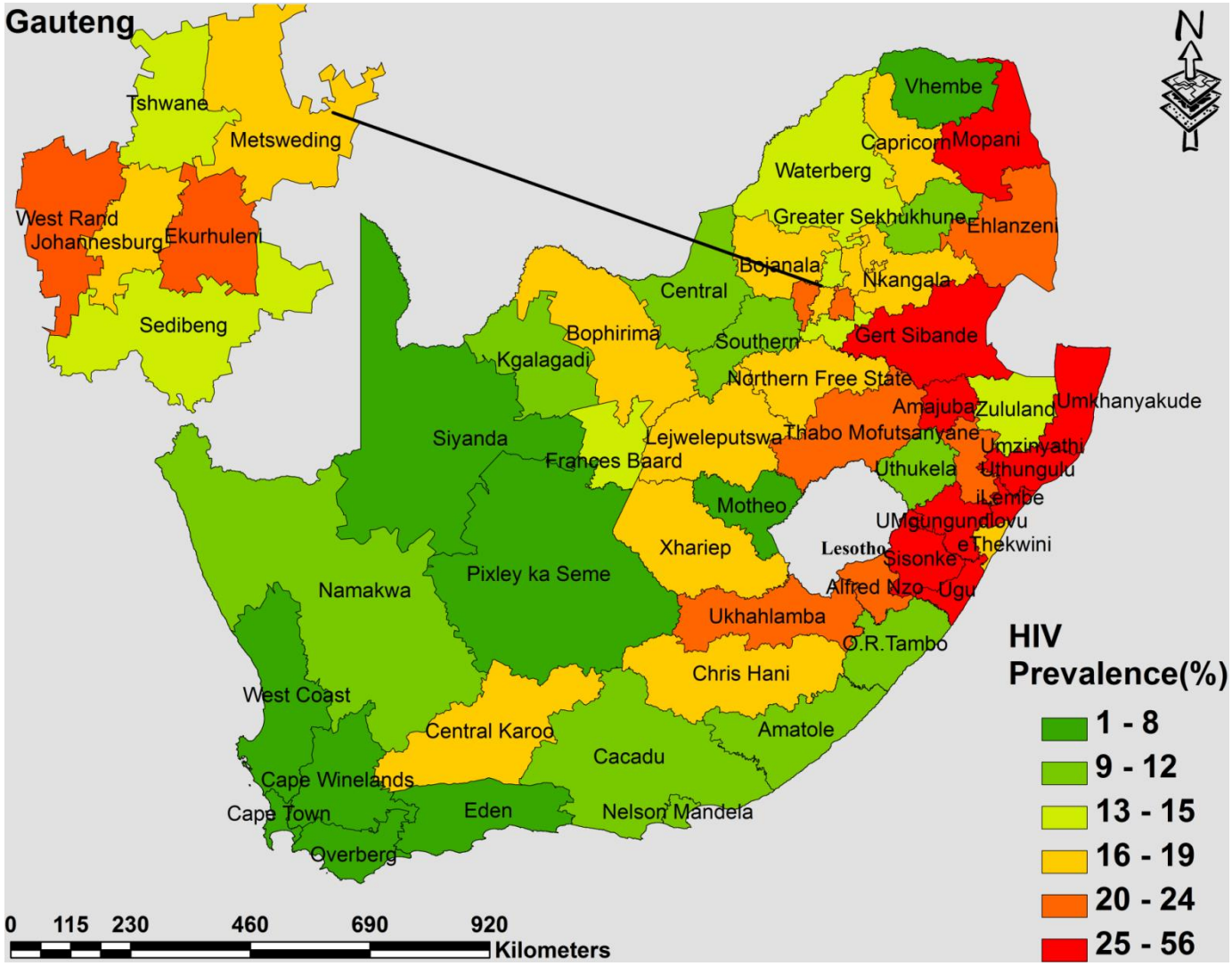
- Context and Rationale
- Data and Analytical Methods
- Results
- Conclusions

Context and rationale

- More than 6.4 million people live with HIV in South Africa.
- Distribution of HIV is heterogeneous in South Africa
- Example, based on Shisana et.al., 2008;2012 , population based HIV surveys

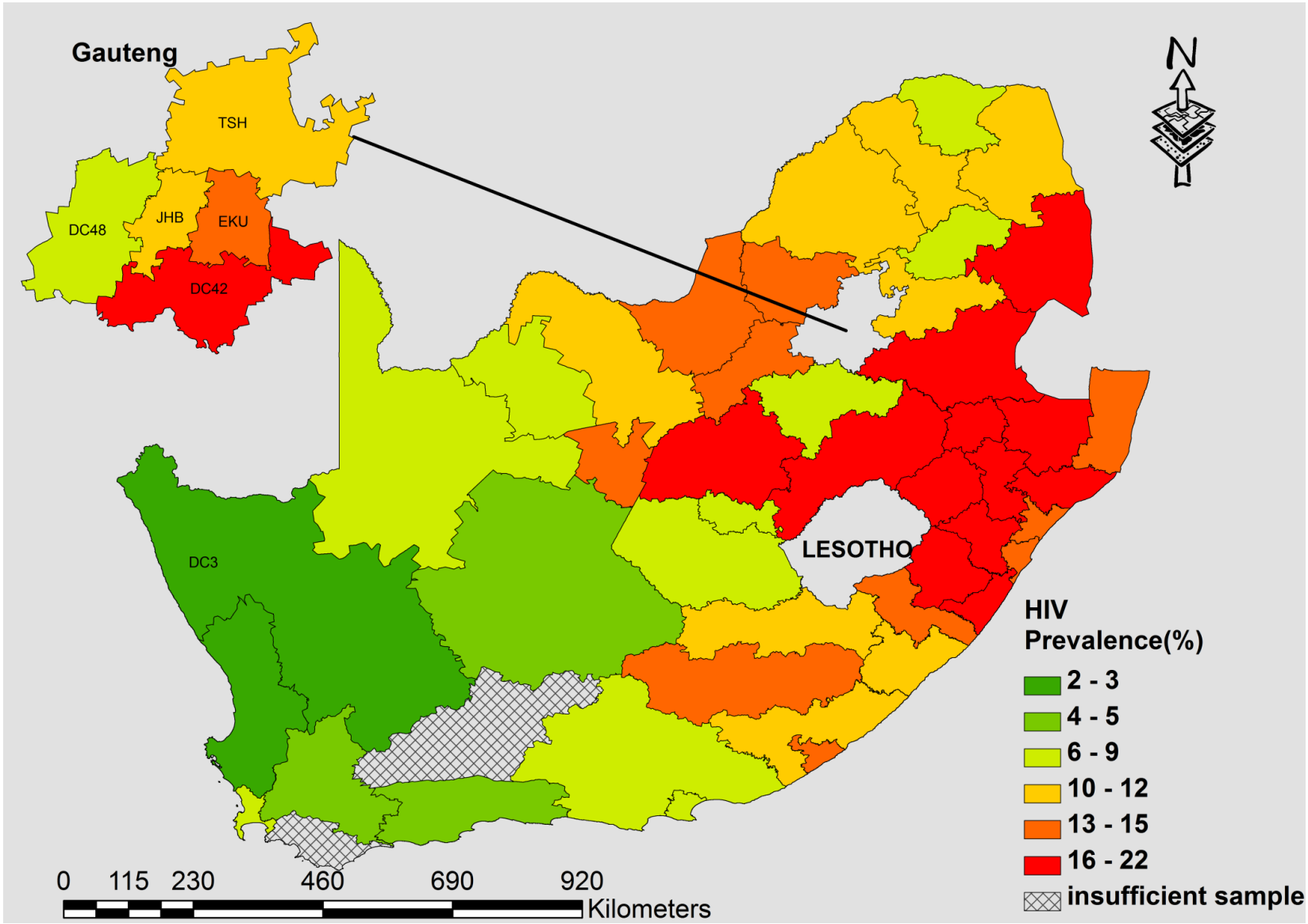
Shisana et.al 2009; 2014 South African National HIV Prevalence, Incidence and Behaviour Surveys

HIV prevalence Varies by district, SA, 2008



Wabiri, N, Shisana, O., Zuma, K., and Freeman, J. (2016) Assessing the spatial nonstationarity in relationship between local patterns of HIV infections and the covariates in South Africa: A Geographically Weighted Regression Analysis. (Spatial and Spatio-temporal Epidemiology 16 88-99 http://dx.doi.org/10.1016/ j.sste.2015.12.003); Shisana et.al 2009

…similar spatial pattern in 2012



Shisana et.al 2014 South African National HIV Prevalence, Incidence and Behaviour Survey, 2012

While there are ….

- studies* that have looked at clustering and the spatial heterogeneity of HIV e.g., among for youth, and/or selected communities

- Limited studies focusing on how relationships of HIV risk factors associates with HIV prevalence from location to location

* Bärnighausen et.al High HIV incidence in a community with high HIV prevalence in rural South Africa: findings from a prospective population-based study. AIDS 2008; 22: 139–44.; Tanser et.al Localized spatial clustering of HIV infections in a widely disseminated rural South African epidemic. Int J Epidemiol 2009; 38: 1008–16.

More essential to…

- Predicted levels of change in HIV prevalence with changes in the risk factors from location to location

- **Example:** Establish how change in percent female and / or single population significantly associates with HIV prevalence over space?

Rationale: Inform the focus of interventions to areas of particular need taking into account the risks.

Wabiri, N, Shisana, O., Zuma, K., and Freeman, J. (2016) Assessing the spatial nonstationarity in relationship between local patterns of HIV infections and the covariates in South Africa: A Geographically Weighted Regression Analysis. (Spatial and Spatio-temporal Epidemiology 16 88-99 http://dx.doi.org/10.1016/ j.sste.2015.12.003)

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Data sources

- National population-based household survey data
- Multistage cluster surveillance survey design
  - **Primary sampling unit**: 1000 EAs from 86000 EAs
  - **Secondary sampling unit**: Cluster of 15 households per EA
  - **Final sampling unit**: 4 eligible individuals per household four mutually exclusive age groups (< 2 years, 2-14 years, 15-24 years and ≥ 25 years), latest survey-all people in the household.
  - Geographic identifiers-EA's linked to external datasets
- Linked anonymous HIV testing: dried blood spot specimens with behavioural data for participants
- District health barometer- socio-economic measures

Shisana et.al 2009;2014; Day C, Barron P, Massyn N, Padarath A, Rene E. District health barometer 2010/11. Durban: Health Systems Trust; 2012

Analytic methods

- Descriptive analysis
- Non-spatial and Spatial regression models
- Spatial mapping unit (n=52):
  - The “District Municipality” in South Africa
  - District Health System- Primary Health Care delivery system*

Wabiri et al. ,Spatial and Spatio-temporal Epidemiology 2016; Shisana et.al, 2014; *Monticelli et al. 2010

Descriptive analysis

- Pearson correlations between risk factors and HIV prevalence
- Risk factors not associated with HIV prevalence not included in the models
- Only one of highly correlated risks is included in the regression models to avoid model redundancy and multicollinearity.
- Additional explanatory approach used to select risk factors
  - Thematic maps of district HIV prevalence and the covariates

Modelling

Non-spatial regression

- Fit Global model

$$y_i = a_0 + \sum_{k=1}^{n} a_k x_{ik} + \varepsilon_i$$

- a_k, the value of k^{th} parameter of independent variable k
- y_i is i^{th} observation of the dependent variable
- x_{ik} is the i^{th} observation of the k^{th} independent variable
- Explores significant relationship to explore with GWR

Spatial regression (Geographically weighted Regression)

- Localized multivariate regression
- Estimate parameters at each location

$$y_i = a_{i0} + \sum_{k=1}^{n} a_{ik} x_{ik} + \varepsilon_i$$

- a_{ik} is the value of k^{th} parameter at location i
- y_i is the HIV prevalence at location i
- x_{ik} is the i^{th} observation of the k^{th} independent variable

*Fotheringham AS, Brunsdon C, Charlton M. Geographically weighted regression: The analysis of spatially varying relationships. [Internet]. New York, USA: Wiley; 2002; Shoff C, Yang T-C, Matthews SA. What has geography got to do with it? Using GWR to explore place-specific associations with prenatal care utilization. GeoJournal 2011; 77: 331–41.

Test spatial independence of residuals

- Moran's I*

$$I = \frac{n \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} (y_i - \bar{y}) (y_j - \bar{y})}{\left(\sum_{i \neq j} \sum w_{ij} \right) \left(\sum_{i=1}^{n} (y_i - \bar{y})^2 \right)}$$

- W_{ij} is a measure of spatial proximity pairs of i and j.
- Significant (P<0.05) Moran's I -clustering of residuals not chance.
- Also confirms the models included all the key covariates

Moran PAP. Notes on continuous stochastic phenomena. Biometrika 1950;37:17–23

Analytical models used

Socio-behavioral risks GWR model

$$\text{HIV}_i(\mathbf{z}) = \beta_{0i}(\mathbf{z}) + \beta_{1i}\text{PropSingle}_i(\mathbf{z}) + \beta_{2i}\text{PropOldSexPartner}_i(\mathbf{z}) + \beta_{3i}\text{PropNonregCodm}_i(\mathbf{z}) + \varepsilon_i$$

Background/ Demographic risks GWR model

$$\text{HIV}_i(\mathbf{z}) = \beta_{0i}(\mathbf{z}) + \beta_{1i}\text{SEQ}_i(\mathbf{z}) + \beta_{2i}\text{PropFemale}_i(\mathbf{z}) + \beta_{3i}\text{PropAfrican}_i(\mathbf{z}) + \beta_{4i}\text{Prop25-49}_i(\mathbf{z}) + \varepsilon_i$$

- ($\mathbf{z}$) indicate the parameters, β, estimated at each District
- vector $\mathbf{z}$ is the centroid coordinates for each district, (i=1,2,…,52) districts
- ε_i residual at district i.
- Fixed kernel to calibrate the model- spatial structure.

Wabiri et al. ,Spatial and Spatio-temporal Epidemiology 2016

Model fitness

- A difference of greater than 3 in the AIC between the non-spatial (OLS) and spatial (GWR) model signifies better model fit.
- The variance inflation factor VIF >10 indicate multicollinearity.
- -1.96 ≤ ***Pseudo-t*** ≤ 1·96 to test significance of the local parameters
- Overlay smooth map of *Pseudo-t* values on map of local parameter to visualize significant parameters.

Descriptive Results

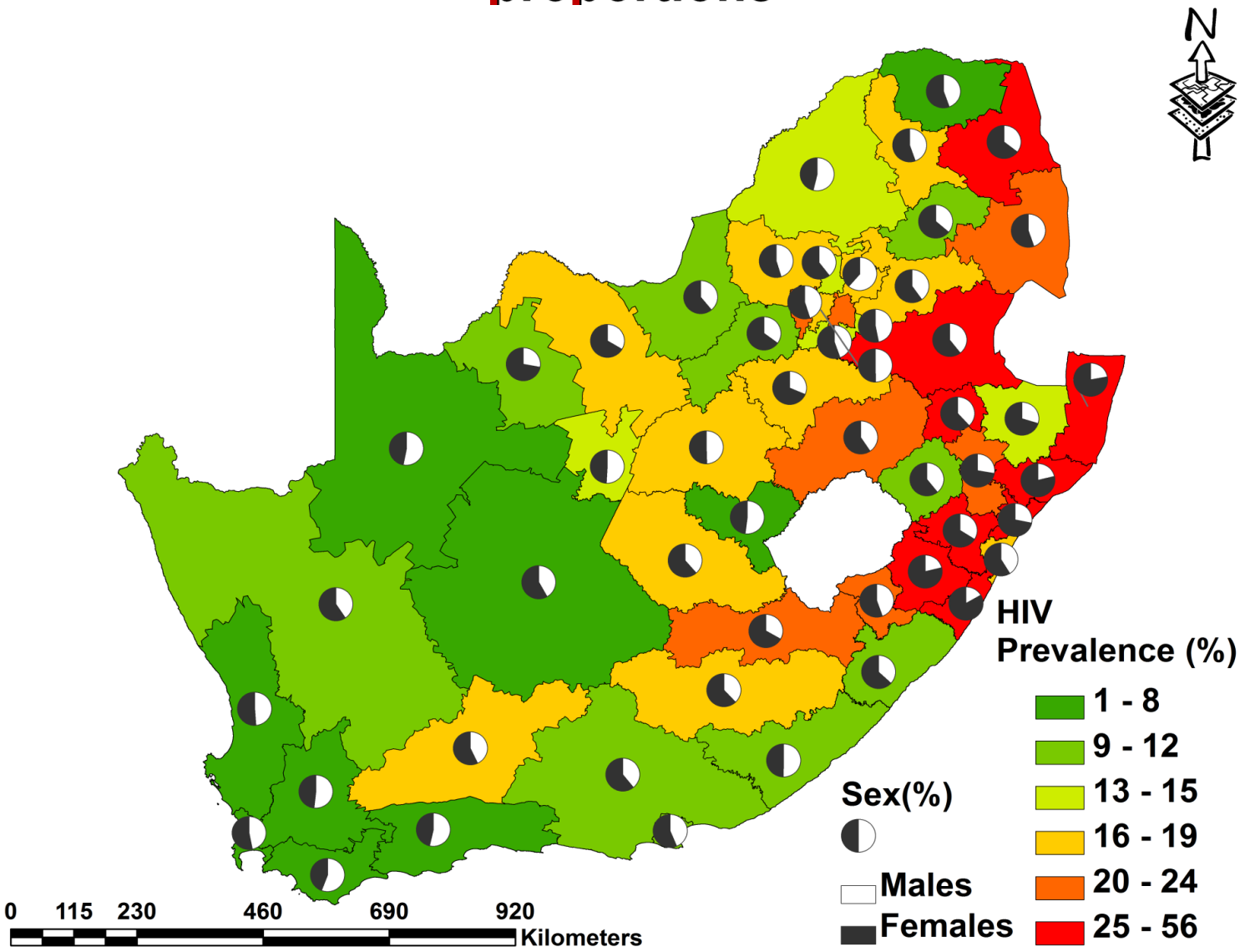
Correlations: HIV and associated risks

	HIV prevalence	Rural informal	Urban formal	Female	African	25–49 yrs.	Single	Older partner > 5yrs	Young partner < 5yrs	Condom
Rural Informal	0.34*									
Urban Formal	−0.36*	−0.92*								
Female	0.55*	0.56*	−0.49*							
African	0.49*	0.64*	−0.55*	0.43*						
25–49 years	0.30*	−0.22	0.09	0.07	−0.22					
Single	0.25	0.19	−0.16	0.15	0.41*	−0.15				
Older partner > 5 yrs.	0.28*	0.50*	−0.51*	0.62*	0.15	0.15	−0.13			
Young partner < 5 yrs	−0.33*	−0.20	0.18	−0.56*	−0.07	−0.20	−0.21	−0.31*		
Condom	0.29*	0.36*	−0.27	0.15	0.67*	−0.34*	0.41*	−0.05	0.21	
SEQ	−0.44*	−0.86*	0.86*	−0.56*	−0.73*	0.14	−0.32*	−0.45*	0.21	0.44*

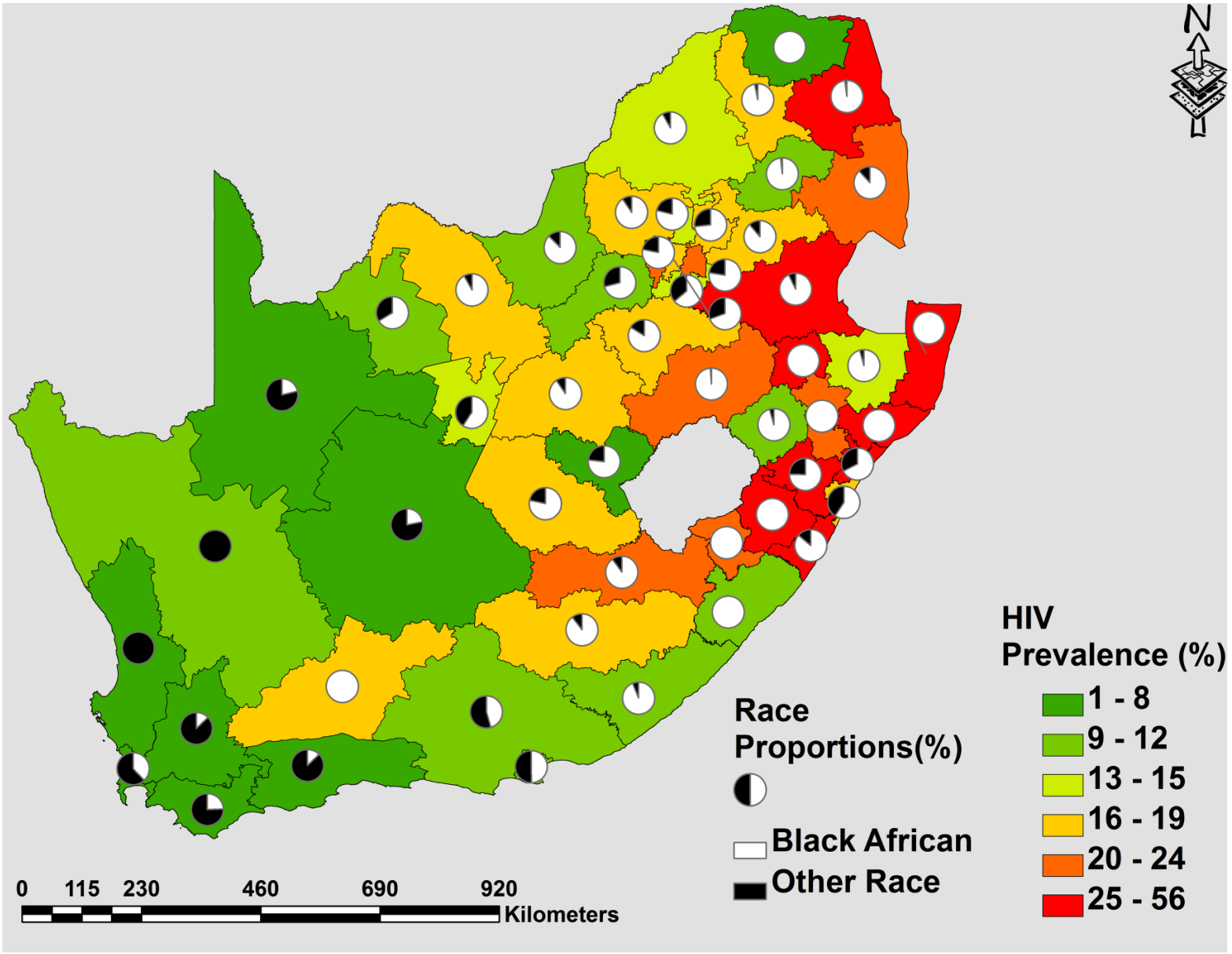
* significant at 5%; $n = 52$.

Wabiri et al. ,Spatial and Spatio-temporal Epidemiology 2016; cases : 20 826 Interviewed; 15 031 tested

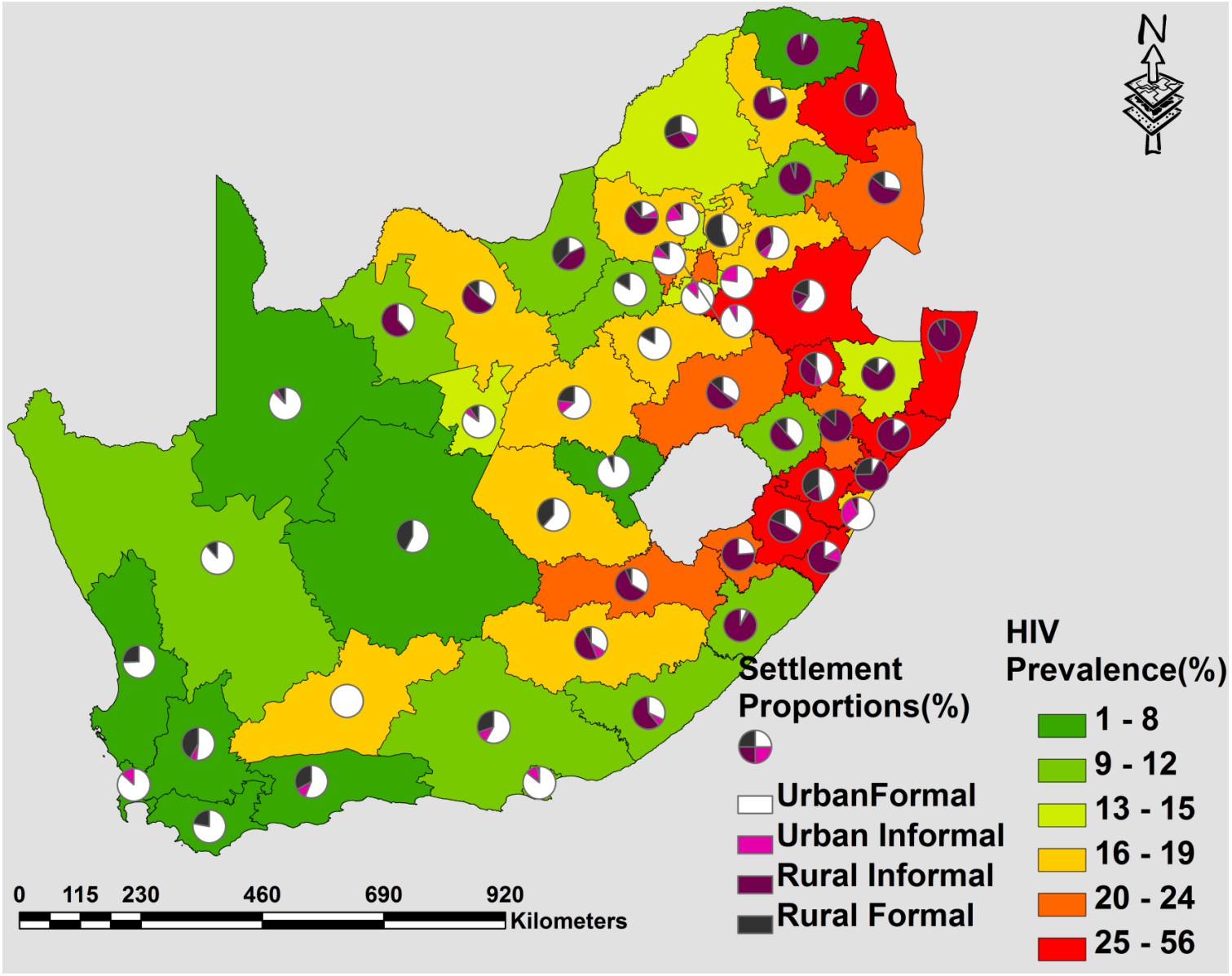
HIV prevalence associates with regions with high females proportions



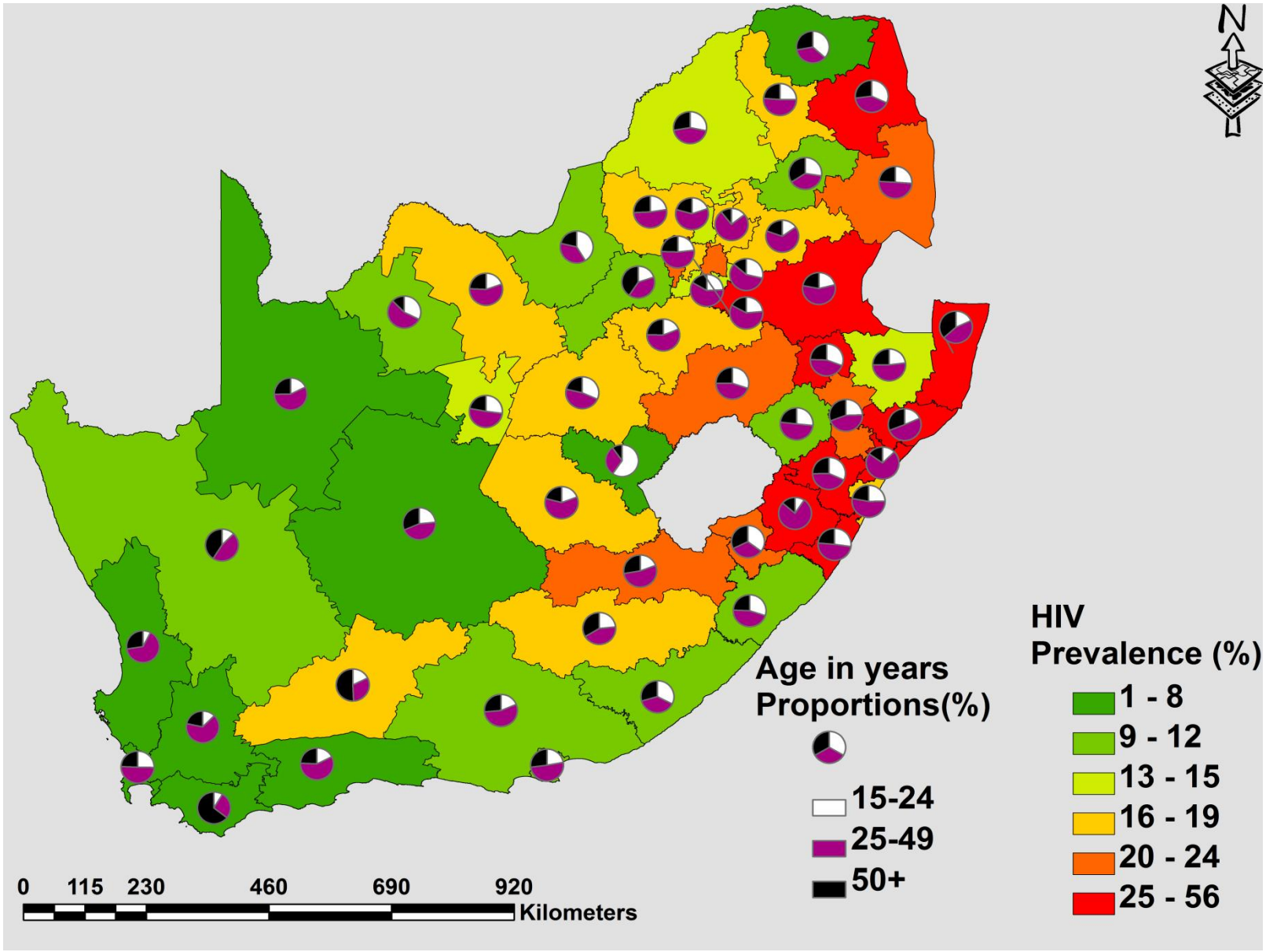
High HIV prevalence in Black African dominated districts



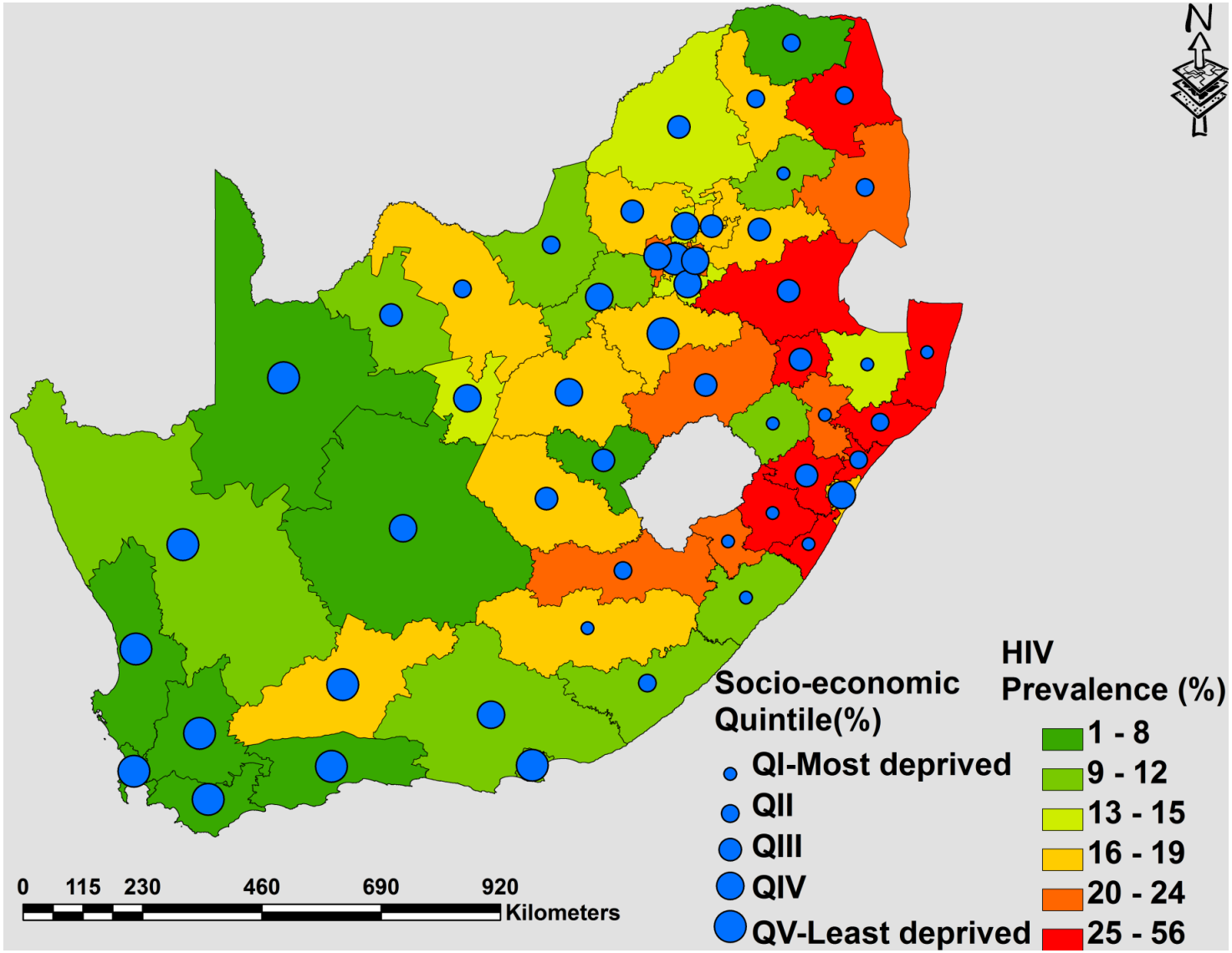
HIV prevalence geographically associates with Ruralness



High Proportions of 25+ in high prevalence districts

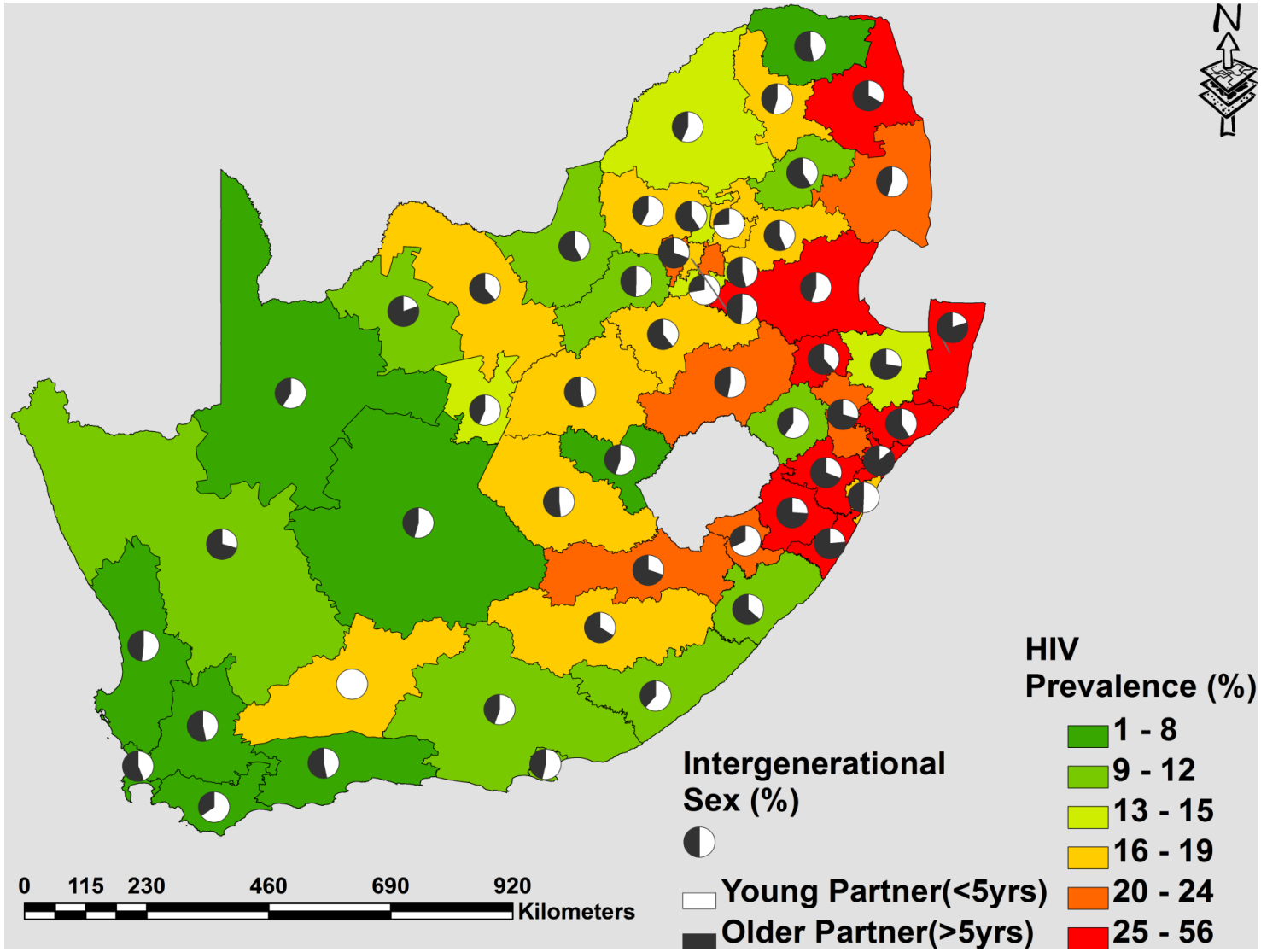


Deprivation associated with HIV prevalence

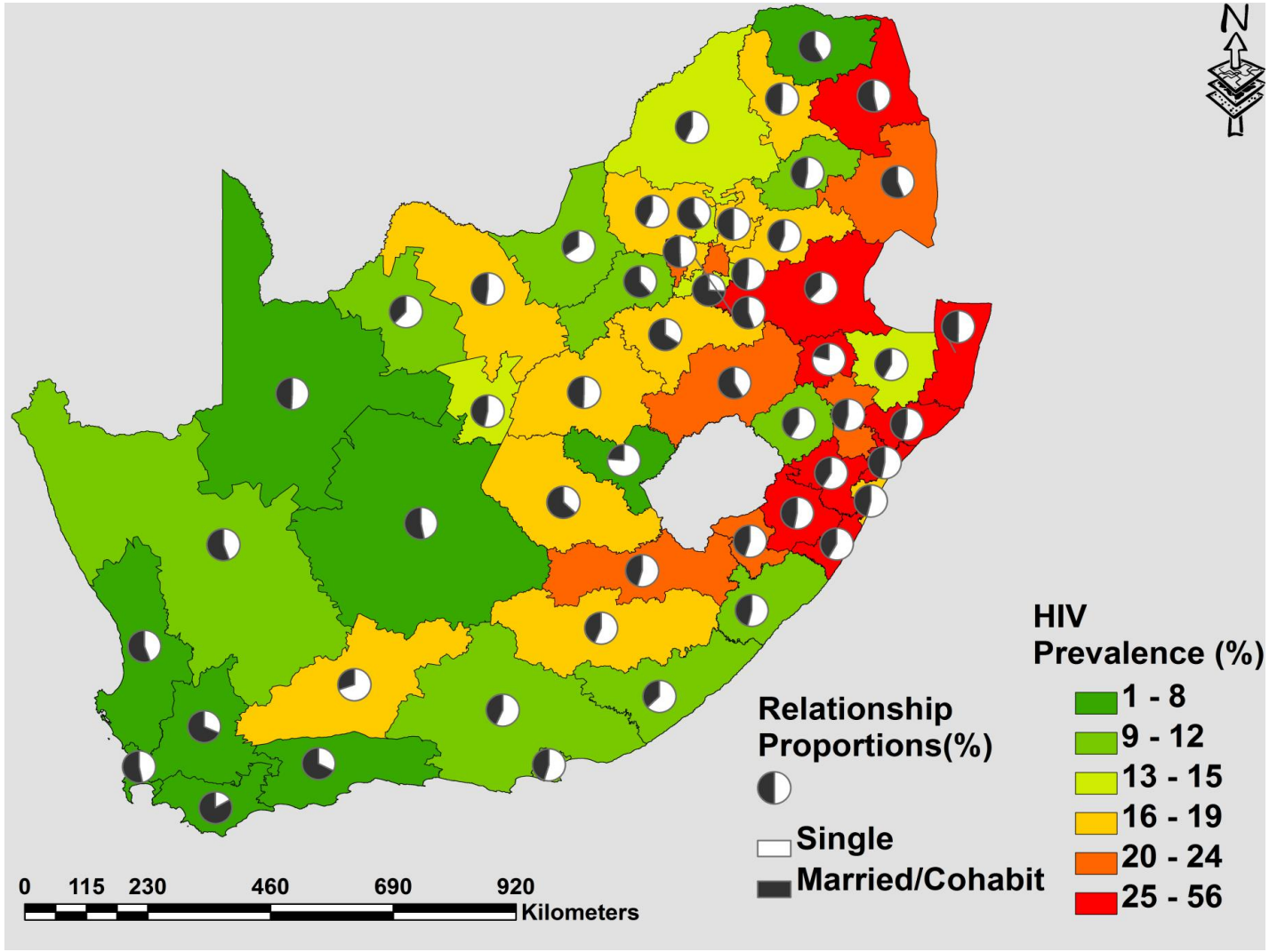


Social-Behaviour risk factors

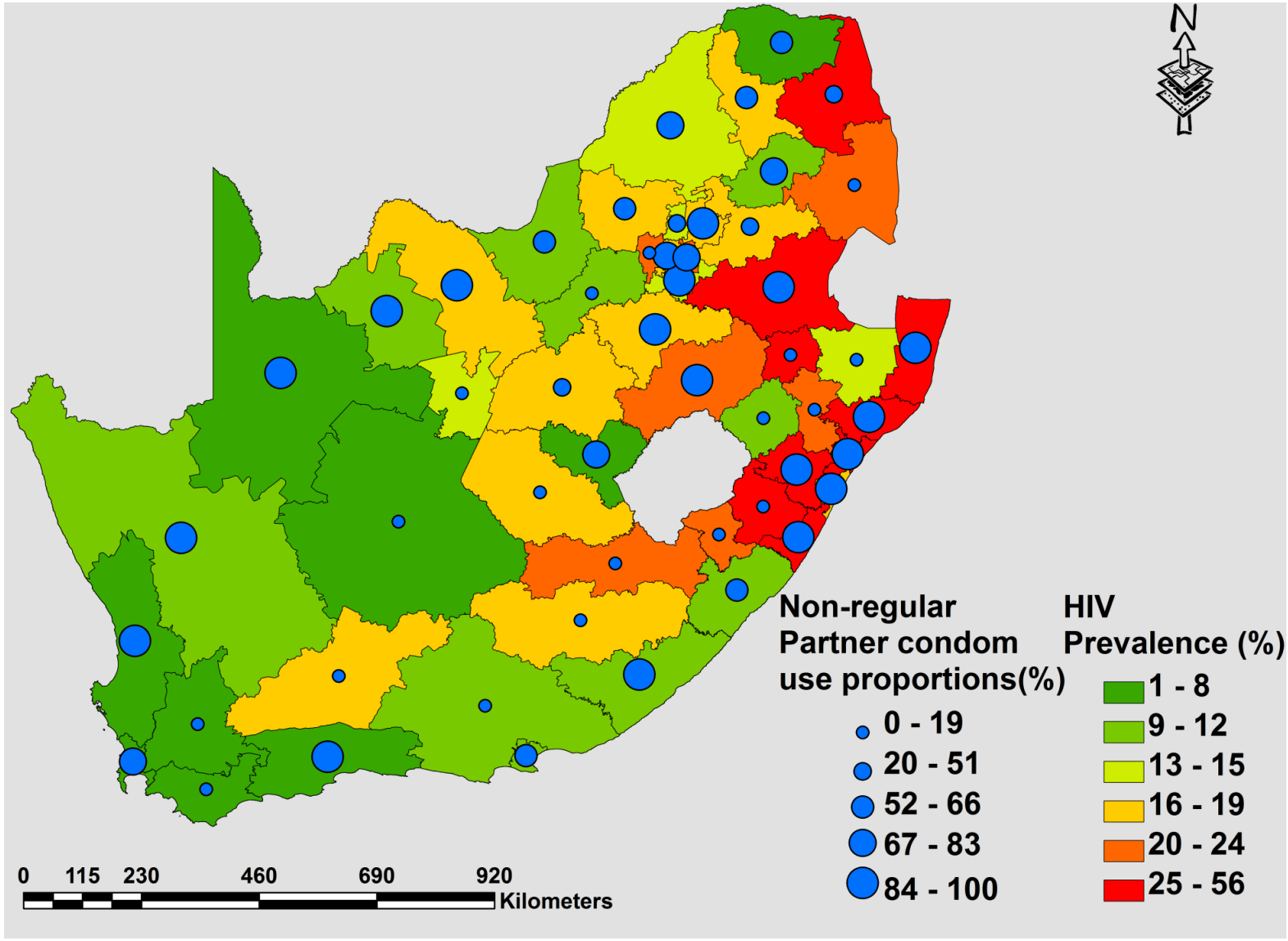
High HIV prevalence spatially associates with intergeneration sex



Spatial association of HIV prevalence with singlehood



High HIV prevalence ; mixed levels of condom use



Analytical Results

Non-spatial model results

Risk factors	Parameter	Std. Error	R^2	Adjusted R^2	AICc	Moran's I
Rural Informal	0.10*	0.04	11.44	9.67	383.8	0.23*
Urban Formal	-0.12*	0.04	12.90	11.50	382.9	0.22*
Female	0.56***	0.12	30.27	28.85	371.0	0.07
Black African	0.17***	0.04	23.90	22.46	375.9	0.20*
25-49 Years	0.27*	0.12	8.91	7.09	385.3	0.34*
Single	0.22	0.12	6.28	4.41	386.8	0.26*
Older Sexual Partner	0.32*	0.16	7.73	5.89	385.9	0.26*
Non-regular Partner Condom Use	0.01	0.03	0.1	-1.80	384.0	
Younger Sexual Partners	-0.40*	0.16	11.08	9.31	383.0	0.24*
Social Economic Quintile(SEQ)	-2.98**	0.87	19.01	17.40	379.2	0.16*

*significant at 5% level; **significant at 1%; ***significant at 0.1%

Demographic : Spatial vs. non-spatial

	Non-spatial regression (OLS)			Spatial Regression(GWR)
Demographics Risks	Estimate	Standard Error	VIF	
Intercept	-32.15***	7.88		
Female	0.40**	0.13	1.63	
Black African	0.15**	0.05	2.32	
25- 49 years	0.33**	0.09	1.09	
Social-Economic Quintile	0.21	1.11	2.53	
Adjusted R^2	46.5			52.3
Condition Number	11.0			6.75
AICc	360.7			357.4
Moran's I	0.007			-0.05

*significant at 5% level; **significant at 1%; ***significant at 0.1%

A condition number less than 30 suggests lack of multicollinearity

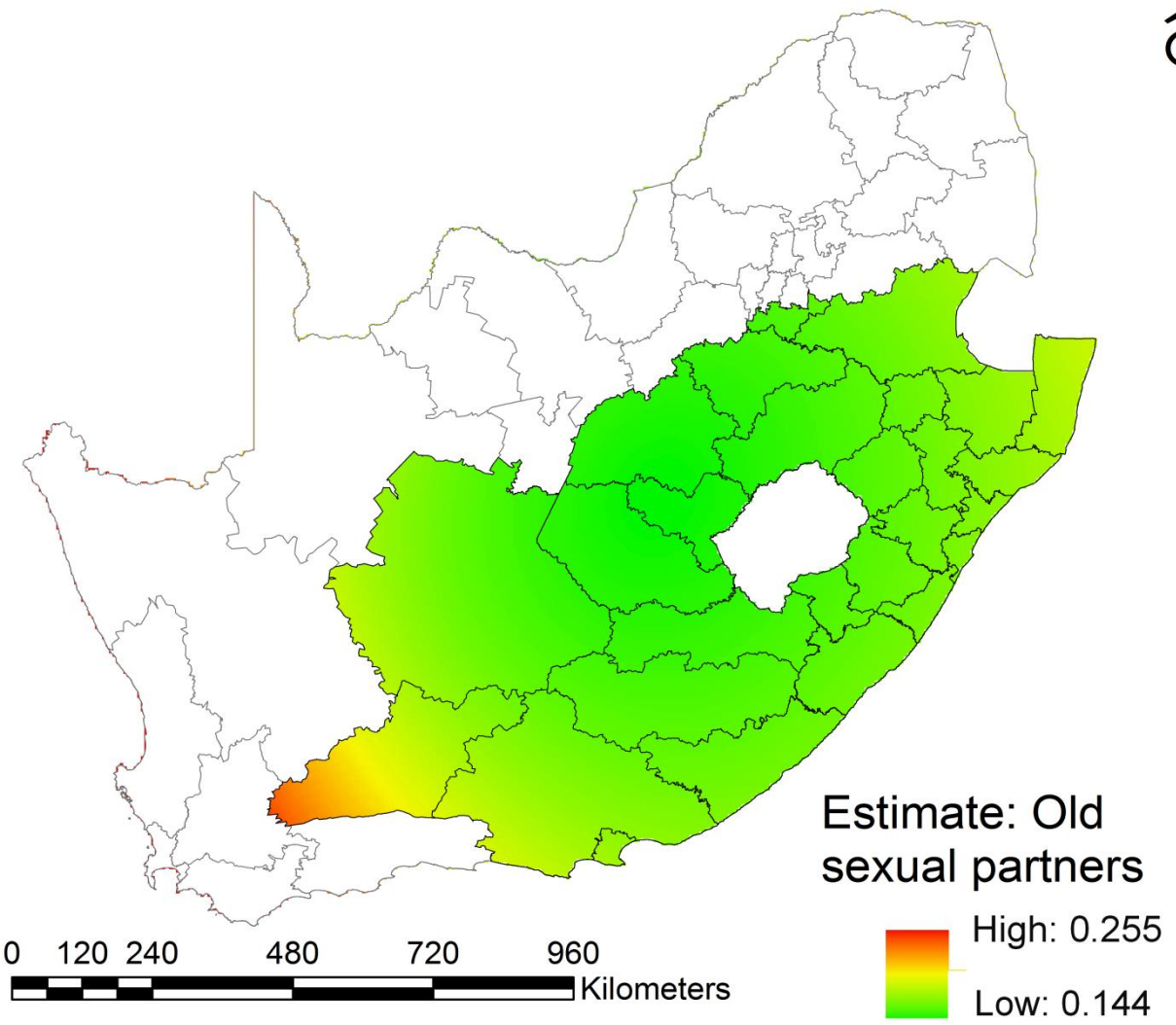
Socio-behavior risks: Spatial vs. non-spatial

	Non-spatial regression (OLS)			Spatial Regression(GWR)
Socio-behavior risks	Estimate	Standard Error	VIF	
Intercept	-3.64	7.07		
			1.0	
Single	0.26*	0.11	2	
			1.0	
Older Sex partner	0.36*	0.15	2	
			1.0	
Non-Regular partner and Condom	0.01	0.03	0	
Adjusted R^2	10.88			28.10
Condition Number	1.24			8.28
AICc	385.80			378.6
Moran's I	0.22*			0.05

*significant at 5% level; **significant at 1%; ***significant at 0.1%

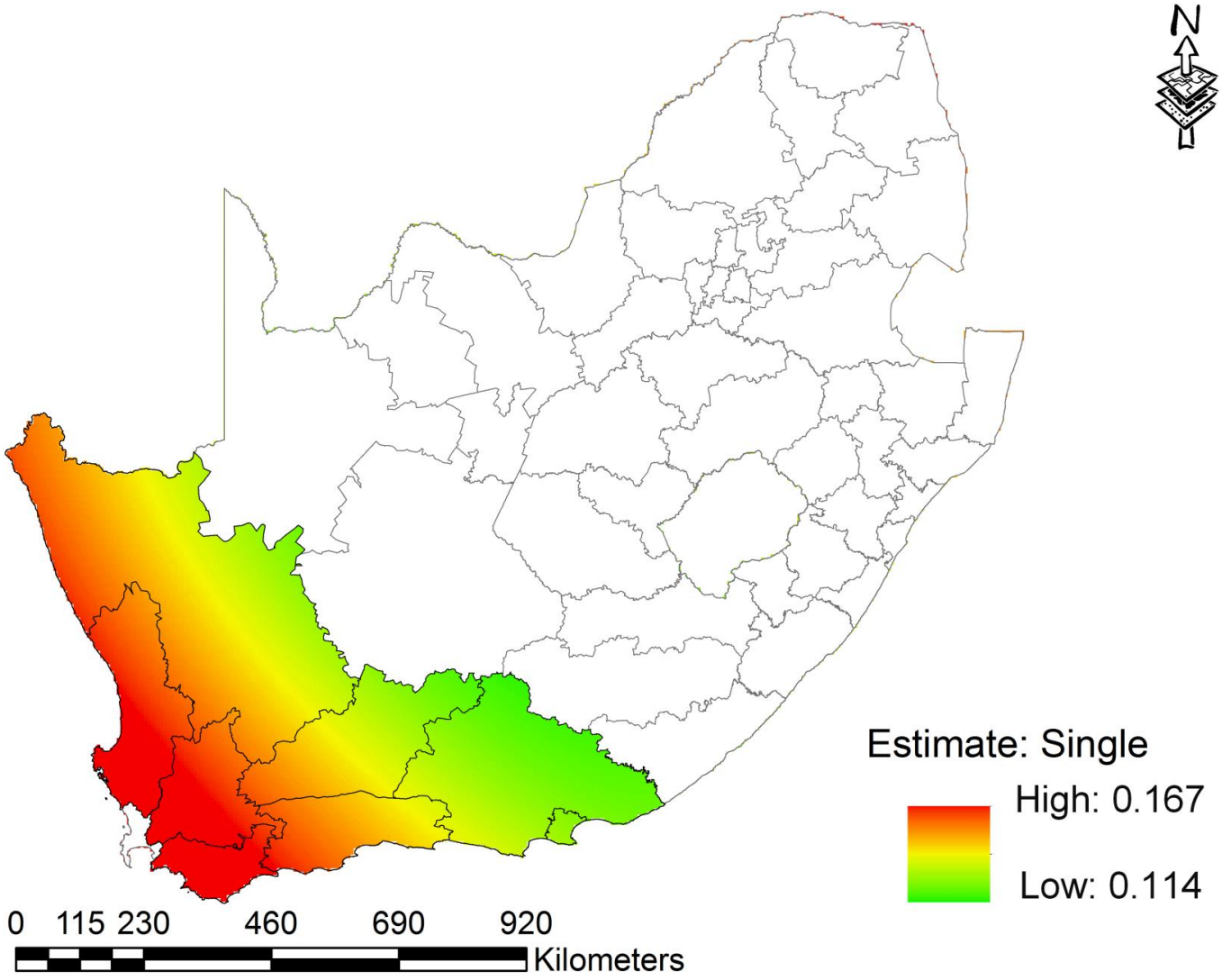
A condition number less than 30 suggests lack of multicollinearity

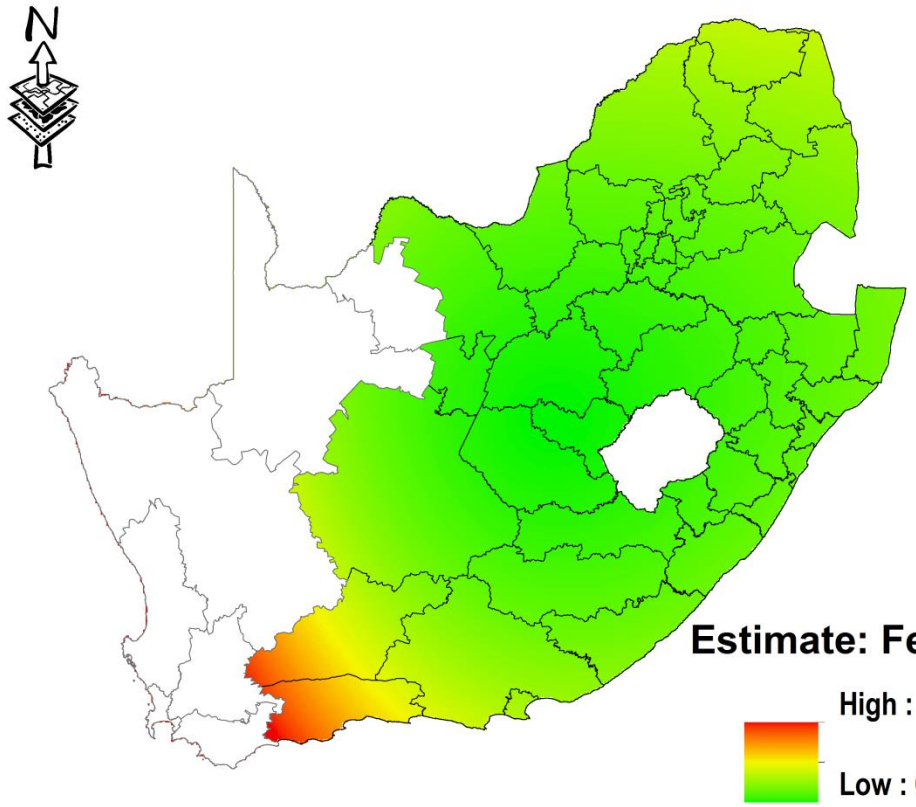
Message: A percent increase in old sexual partnership is associated with (0·14-0·30) average increase in HIV Prevalence



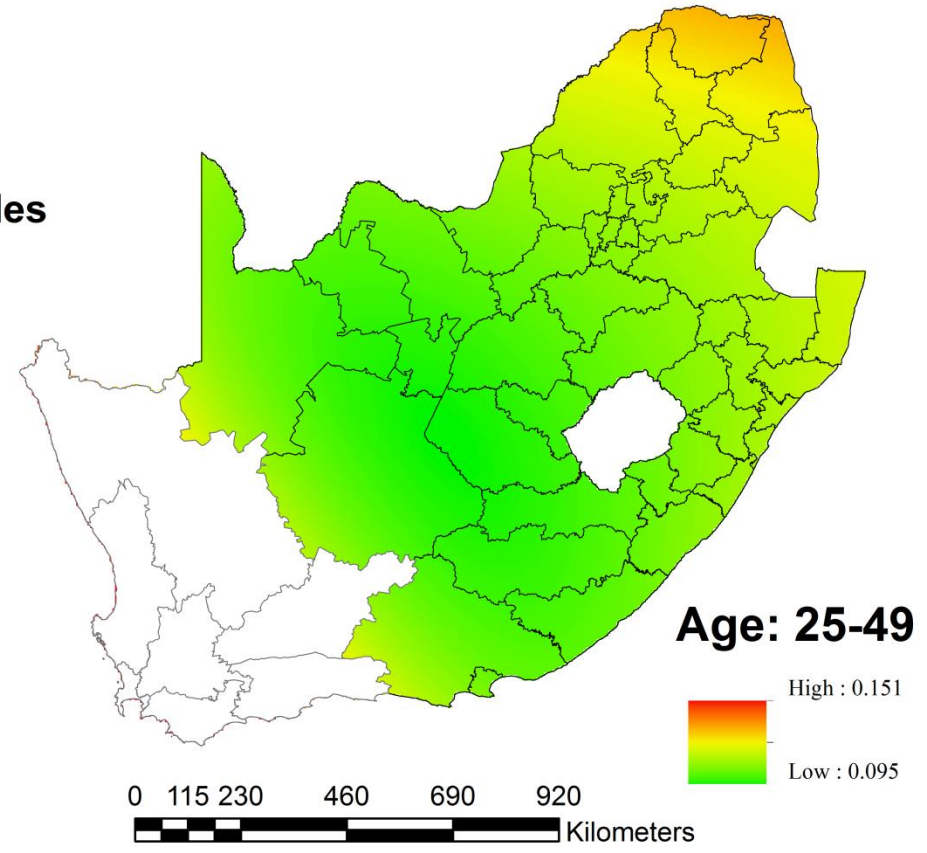
Message: A percent increase in single population is associated with (0·11-0·17) average increase in HIV Prevalence

Marriage rates high in Western cape province, know to have low HIV prevalence



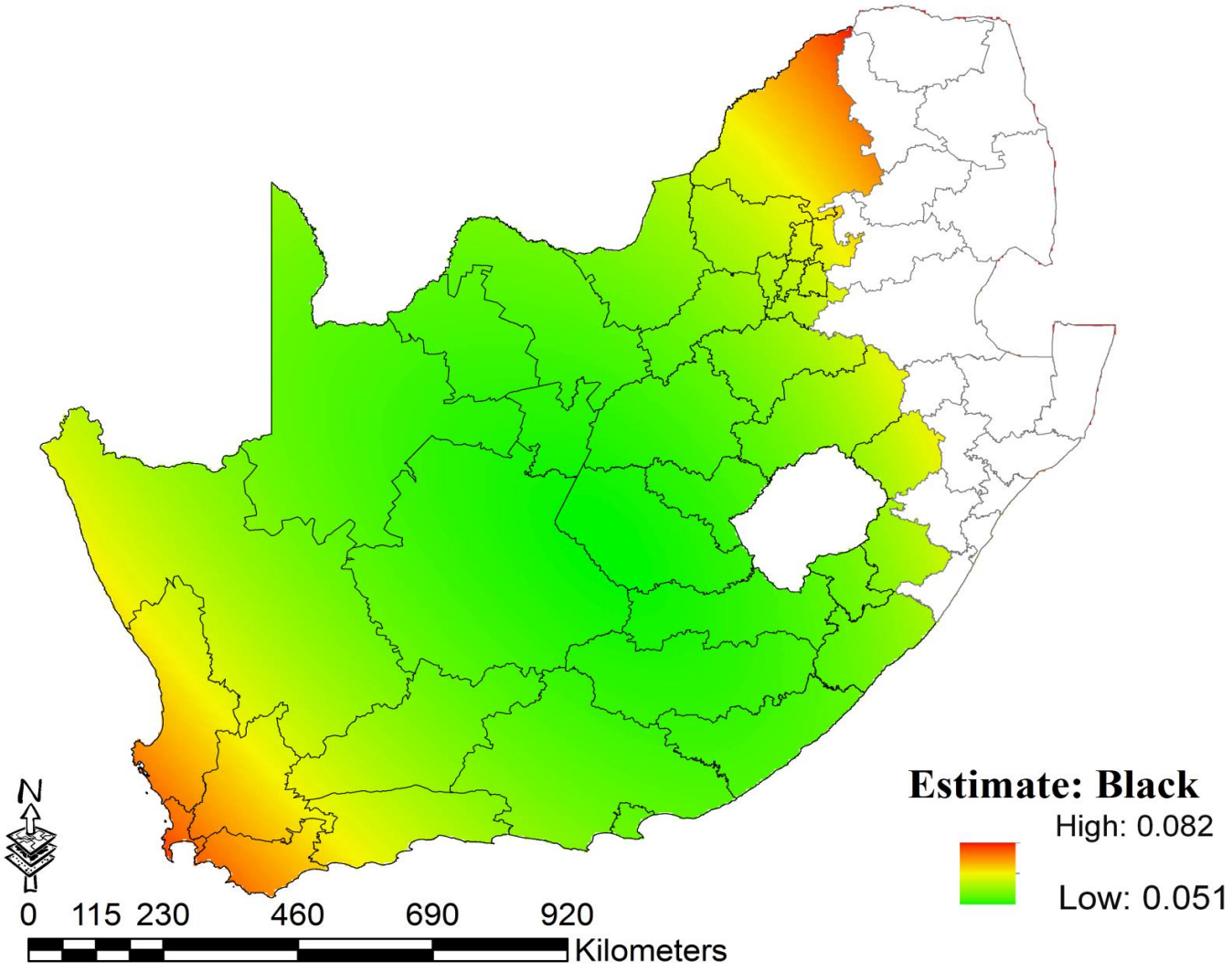


Message: A percent increase in female population is associated with 0.21 average increase in HIV Prevalence

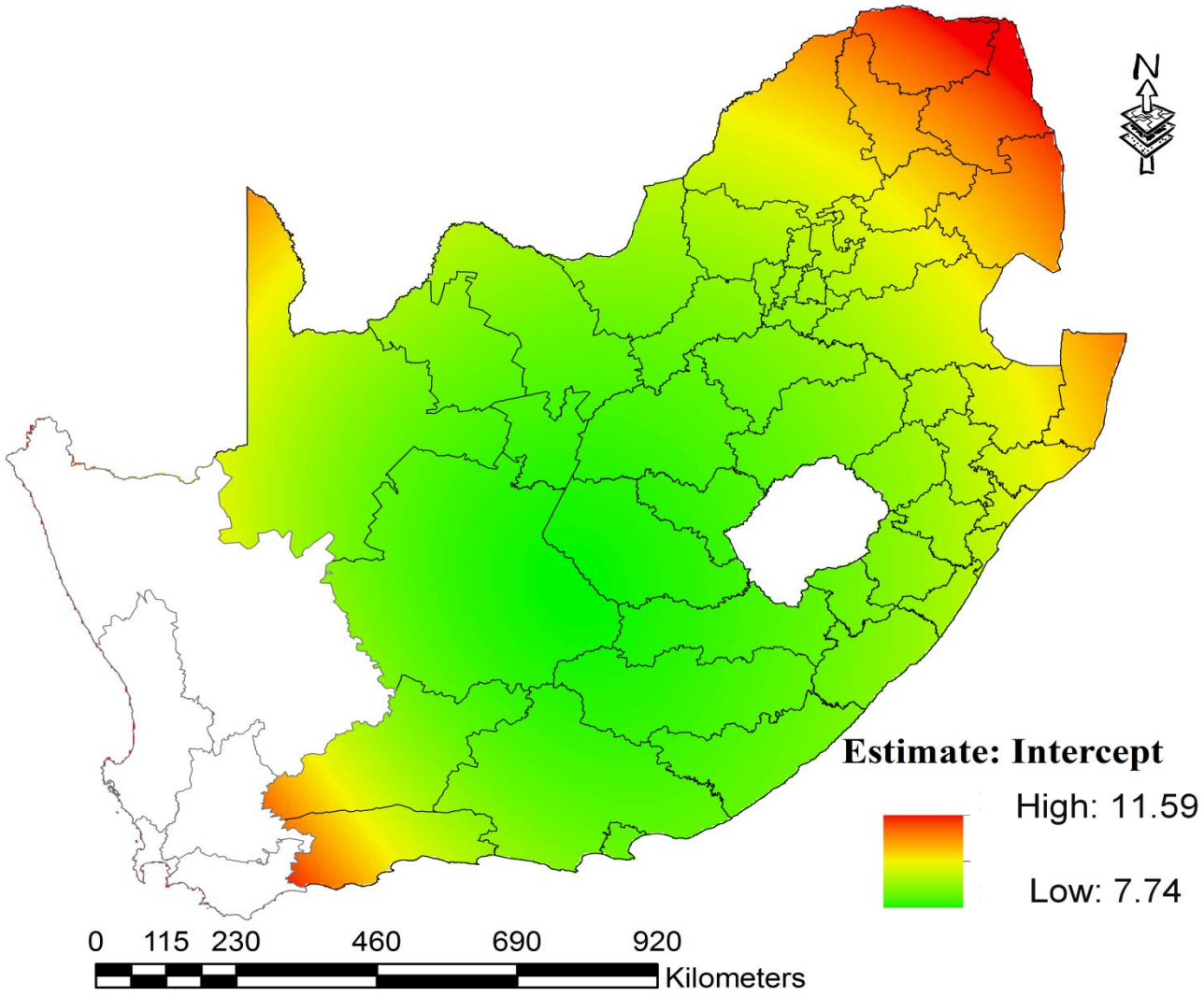


Message: A percent increase in those aged 25-49 years population is associated with 0.15 average increase in HIV Prevalence

Marginal average increase of (0·05-0·08) in HIV prevalence associated Black African population



Message: High intercept estimates: residual variation explained by location

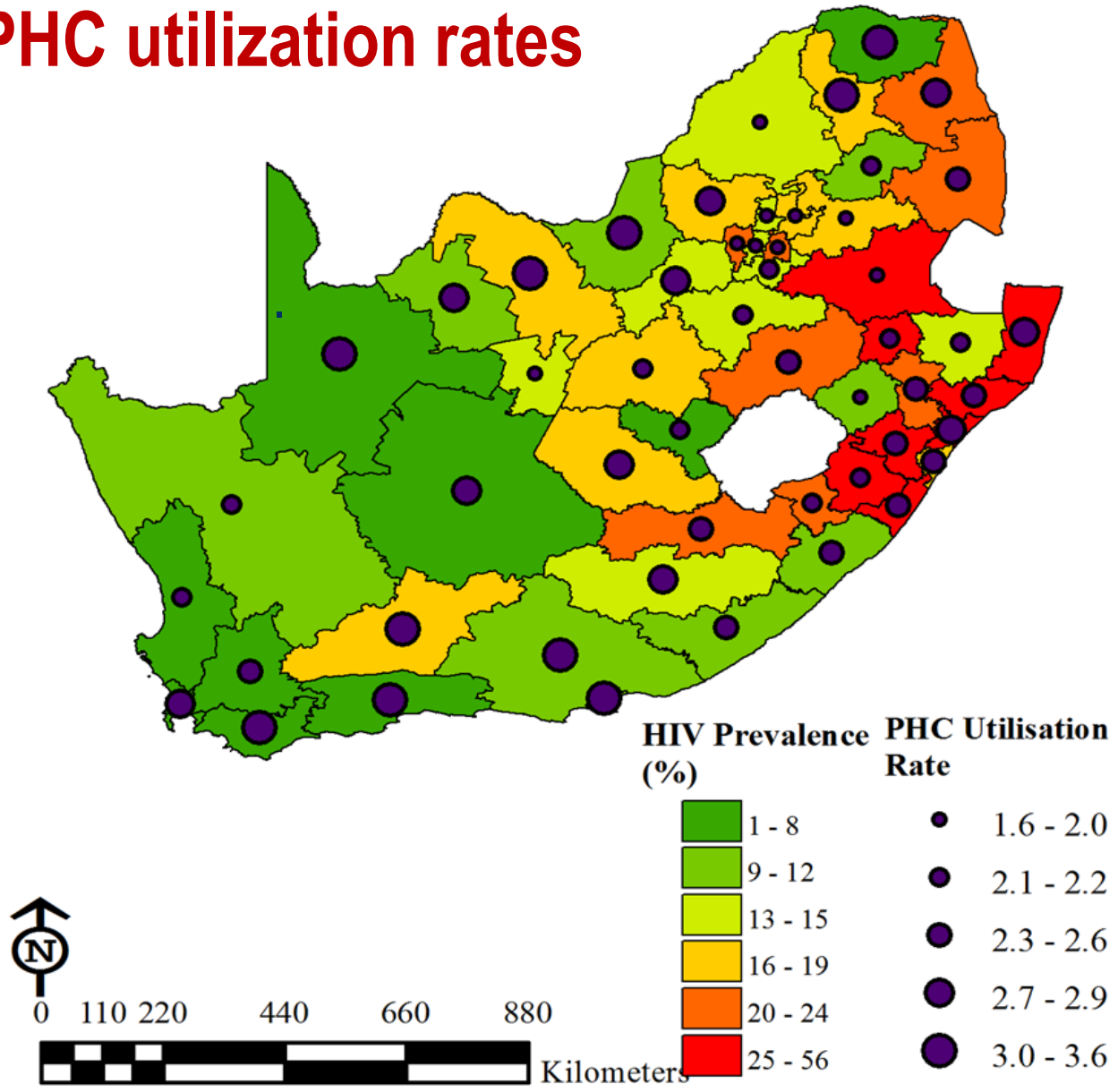


Alignment of public health care utilisation and local patterns of HIV

Note: High HIV Prevalence spatially associates with PHC utilization rates

The PHC utilization rate* PHC total annual headcount / total catchment population

Measure of average number of primary health care visits per person per year to a public PHC facility



* District health barometer/; District Health information systems

Conclusions

- Relationship between HIV risks and HIV prevalence is non-stationary with covariates causing different levels of prevalence in different districts.

- Targeting the who and where with a good understanding of variation in HIV risks will make every rand count.

Conclusions

- High HIV prevalence spatially associates with
  - Black African origin,
  - unfavourable sex ratio (high proportion of females),
  - being single or low marriage rates
  - Intergenerational sex
  - Deprivation

- Intergenerational sex compounds the risk of acquiring HIV infection for females in deprived districts

Conclusions

- Need for additional research to ascertain other HIV infection risks
  - How ARV rates at the district level relate to changes in prevalence rates?
  - What are the major differences in behaviour patterns in rural and informal settlements in areas where HIV prevalence remains low in spite of high numbers of settlements?

Declarations

- Observed geographical patterns of HIV prevalence parallels that observed using the National Antenatal Sentinel HIV & Herpes Simplex Type-2 Prevalence Survey in South Africa (Department of Health 2011, 2013)
- Distribution of the covariates: race, sex, SEQ, and inter-generational sex have predominantly remained the same over the years
- The district Health System is basic channel through which the delivery of Primary Health Care is undertaken in South Africa

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HSRC survey team

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