Appendix

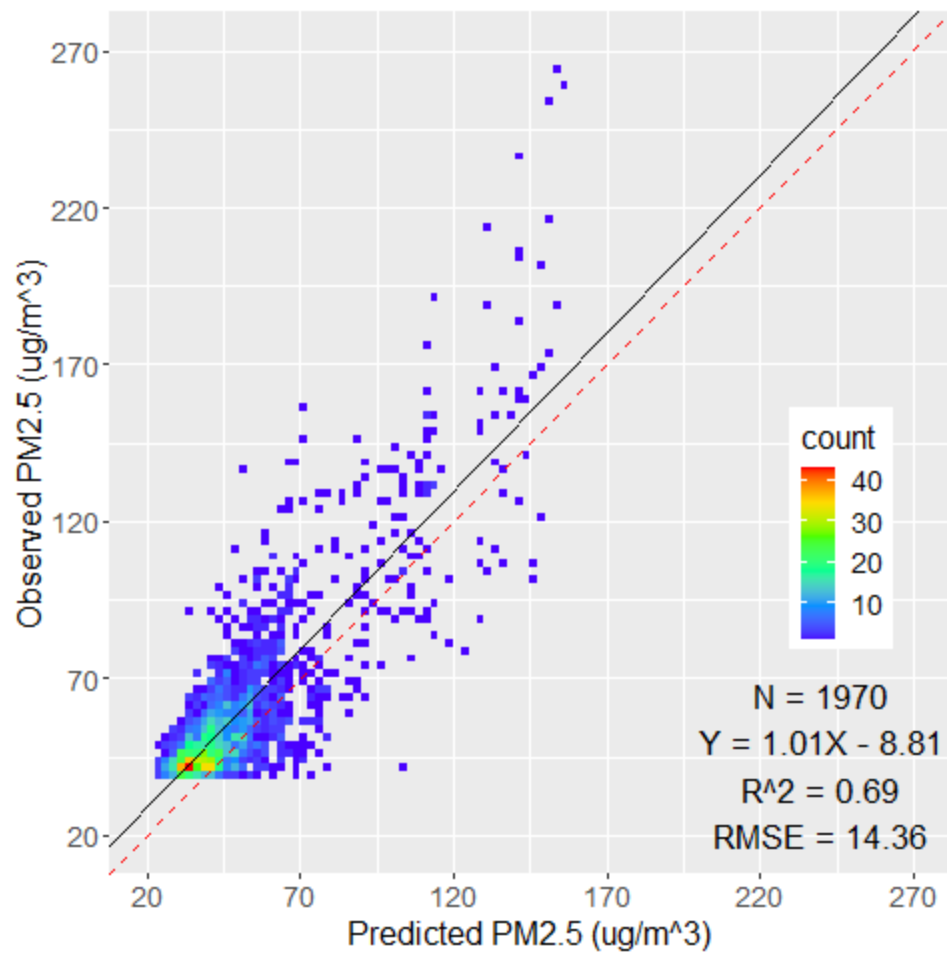**Figure S1.** Scatter Plot for 10-fold CV of the top 20% of daily $PM_{2.5}$ concentration measurements. Red dashed line is the 1:1 line.
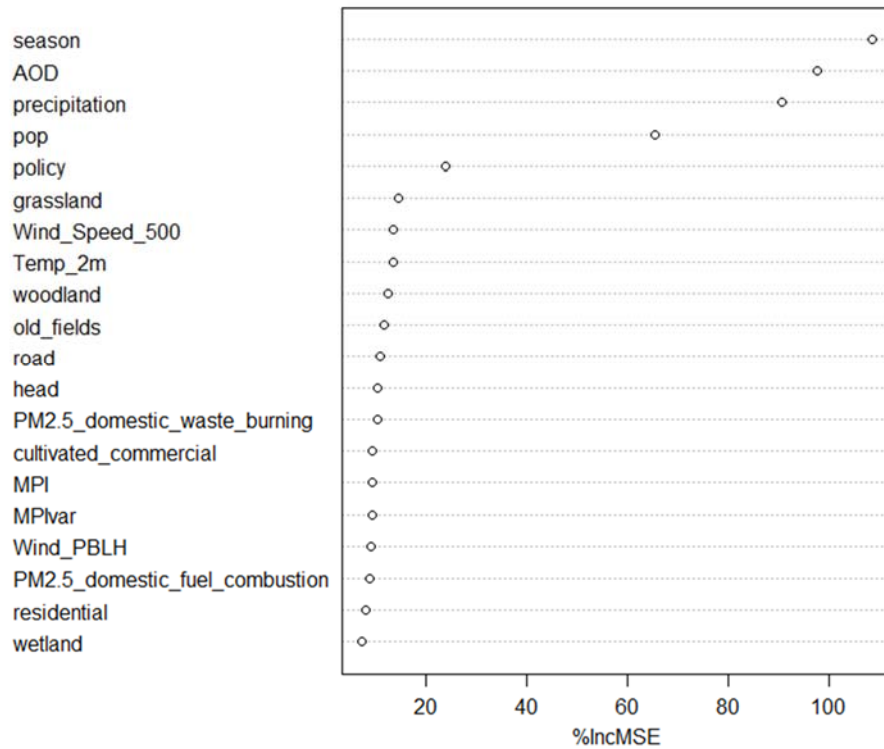
Figure S2. Importance Rank Plot.

Season is the indicator of season including summer, winter, fall and spring. AOD is daily aerosol optical depth. Precipitation is total daily precipitation. Pop is annual population. Policy is an indicator of whether the new PM$_{2.5}$ standard is implemented. Temp_2m is daily temperature at 2-meter. Woodland, cultivated commercial, wetland are land use types collected in 2018. CLDTOT is total daily cloud fraction. Head is income poverty collected in 2011. ALBEDO is daily surface albedo. PM2.5_domestic_waste_burning and PM2.5_domestic_fuel_combustion are estimated PM$_{2.5}$ caused by domestic waste burning and fuel combustion collected in 2016. Wind_PBLH is daily planetary boundary layer height of wind. MPIvar and MPI are the variance of weighted deprivation scores and multidimensional poverty index collected in 2011. Road is total main road length.
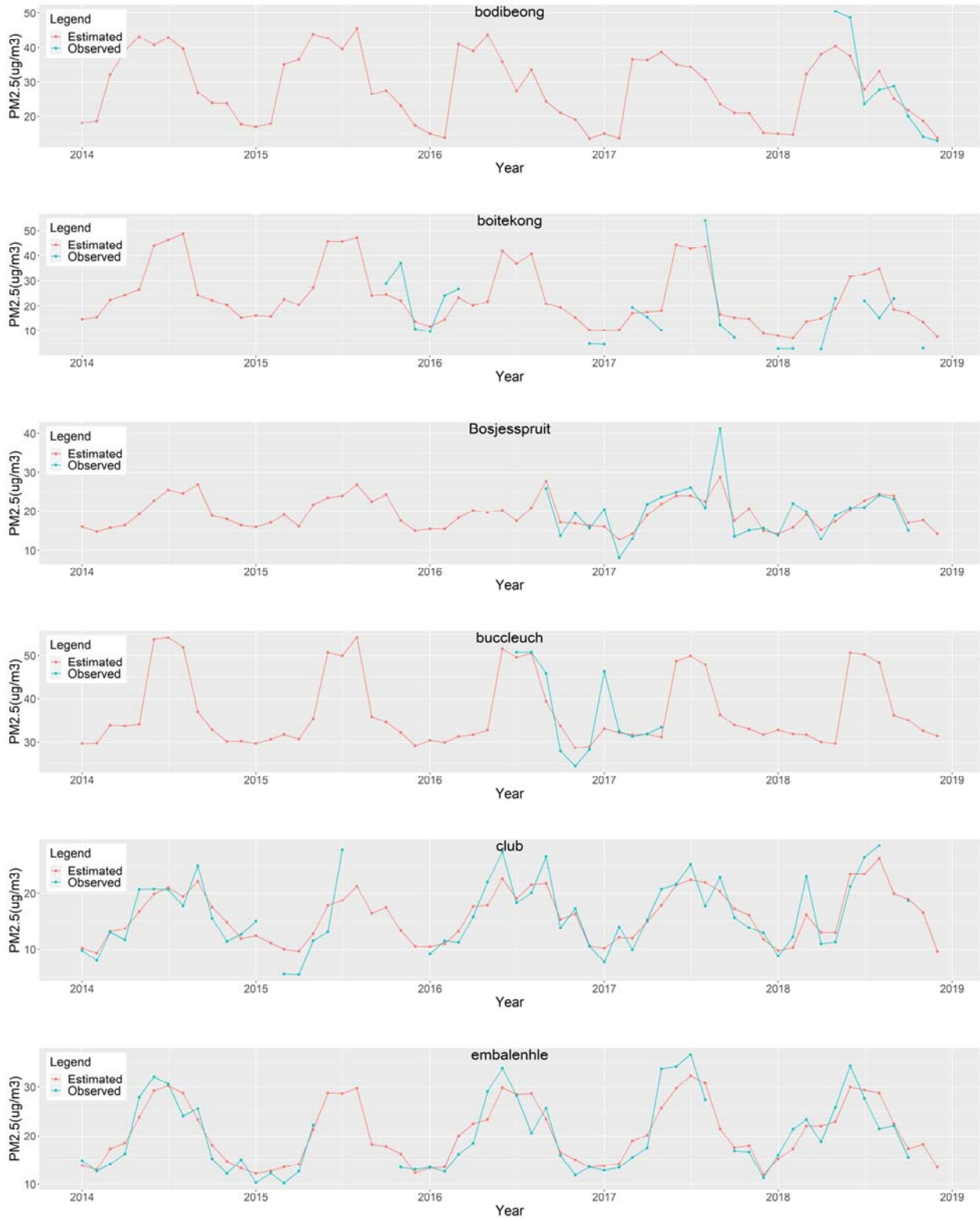
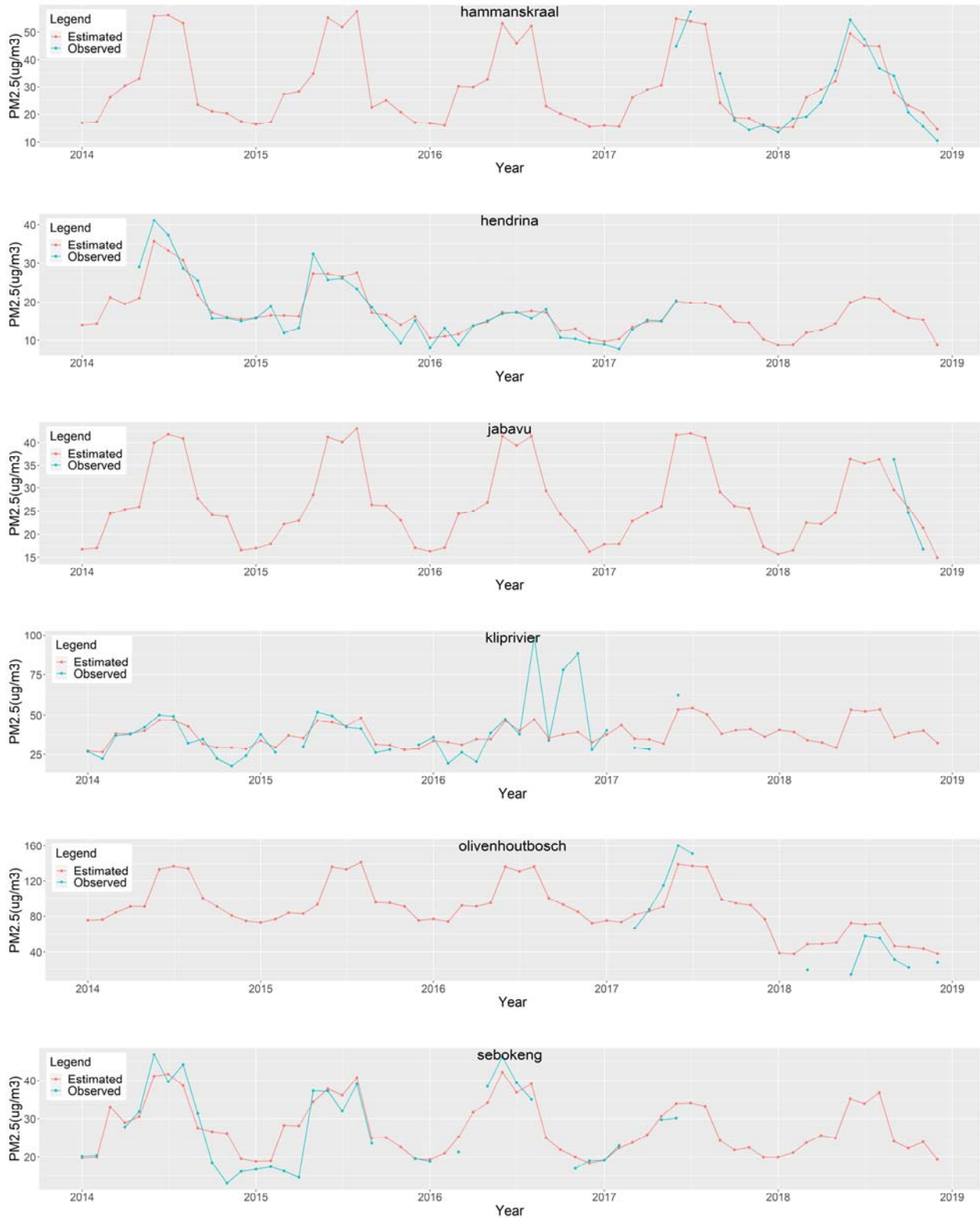**Figure S3.** Observed and Estimated Monthly PM$_{2.5}$ Concentration for Each Station.
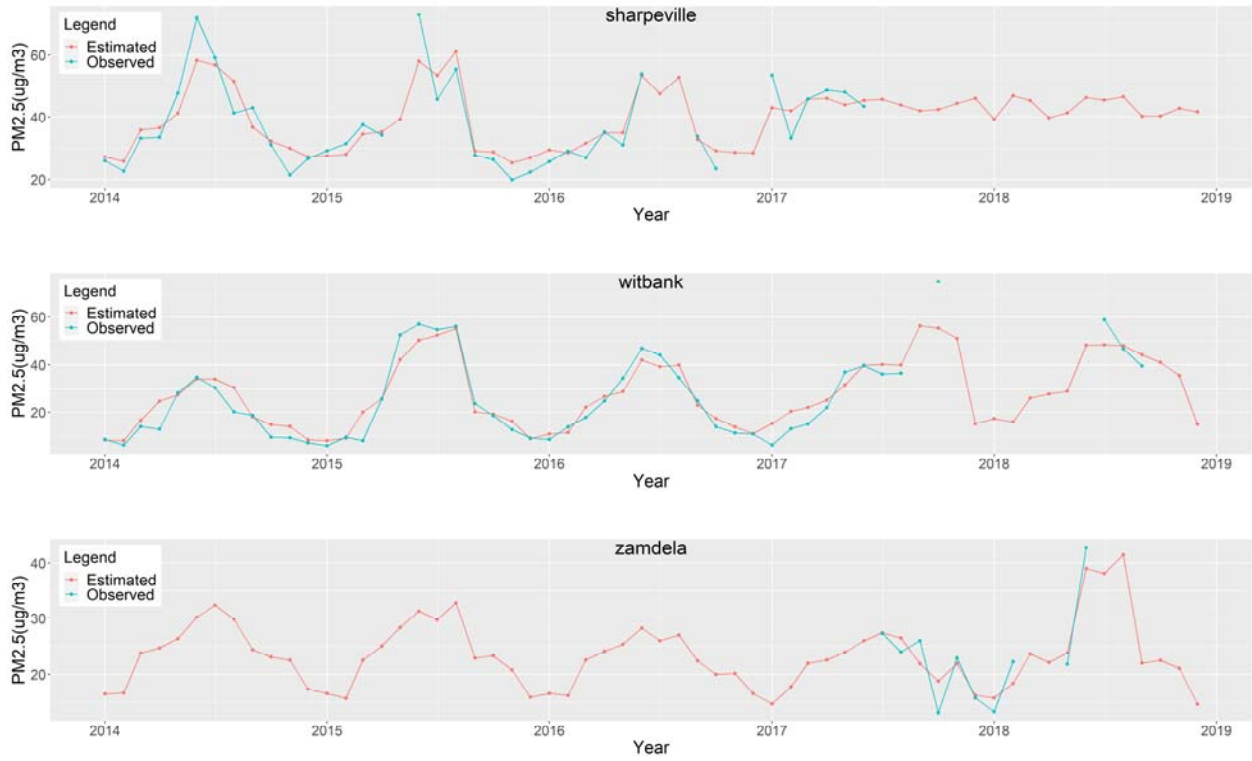
Figure S3. Continued.

Figure S3. Continued.
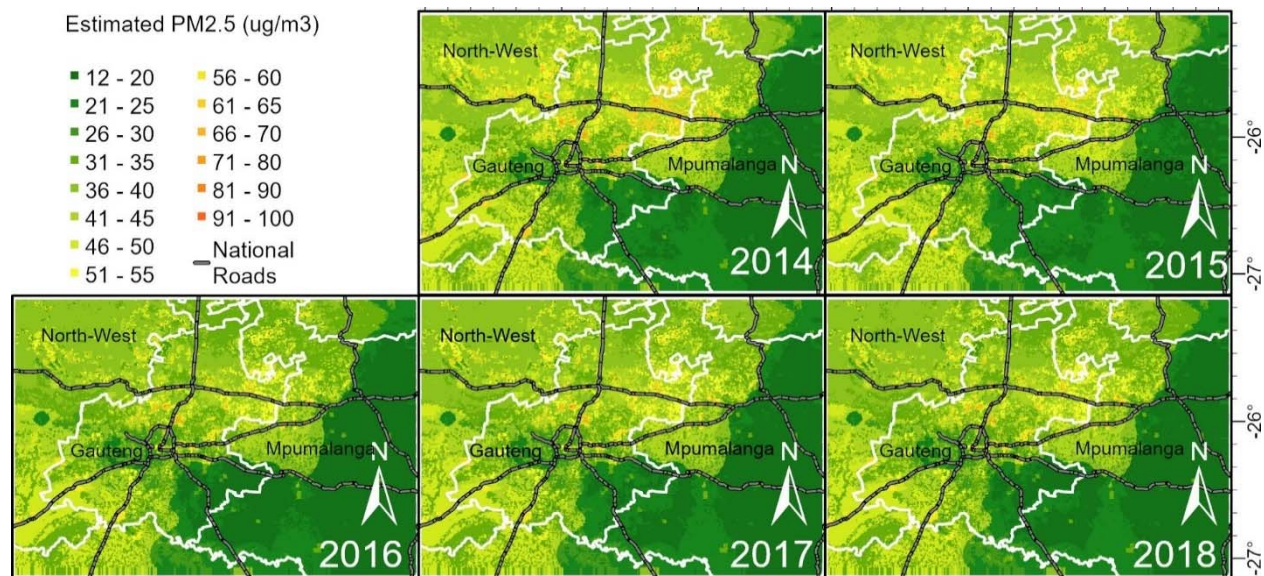
Figure S4. Annual Average Estimated PM$_{2.5}$ Concentration Map.

Table S1: South African National Ambient Air Quality Standards for $PM_{2.5}$ (Department of Environmental Affairs, 2012a)

Averaging period	Concentration	Frequency of Exceedance	Compliance date
24 hours	65 µg/m^3	4	Immediate – 31 December 2015
24 hours	40 µg/m^3	4	1 January 2016 – 31 December 2029
24 hours	25 µg/m^3	4	1 January 2030
1 year	25 µg/m^3	0	Immediate – 31 December 2015
1 year	20 µg/m^3	0	1 January 2016 – 31 December 2029
1 year	15 µg/m^3	0	1 January 2030

Table S2. Information of Ground Stations

Station name	Abbreviation in Figure 1	Latitude	Longitude	Network	Station Type	# of raw hourly measurements	# of hourly measurements after quality control
Hammanskraal	HAM	-25.3875	28.2581	CoT	Low-income residential, urban	10452	9366
Bodibeng	BOD	-25.4958	28.0896	CoT	Low-income residential, urban	5243	4984
Boitekong	BOI	-25.6125	27.313	Rust	Low-income residential	20501	17575
Xanadu	XAN	-25.7458	27.9264	SAWS	High-income residential, peri-urban background	25501	19605
Middelburg	MID	-25.7958	29.4654	HPA	Middle-income residential, peri-urban, industrial	31146	20825
Witbank	WIT	-25.8792	29.1897	HPA	Low-income residential, peri-urban, industry	29914	28362
Olivenhoutbosch	OLI	-25.9125	28.0955	CoT	Low-income residential, urban	8526	3094
Buccleuch	BUC	-26.0458	28.0995	CoJ	Traffic, urban	6052	5227
Hendrina	HEN	-26.1542	29.7131	HPA	Middle-income residential, power station	24931	24346
Jabavu	JAB	-26.2542	27.871	CoJ	Low-income, urban	1869	1869

Diepkloof	DIE	-26.2542	27.9546	VTAPA	Middle-income residential, urban	26726	22553
Kliprivier	KLI	-26.4208	28.088	VTAPA	Peri-urban, small industry, traffic	21382	18145
Ermelo	ERM	-26.4958	29.9685	HPA	Low-income residential	28978	27599
Club	CLU	-26.5208	29.1927	Sasol	Middle-income residential, industry	33568	30977
Embalenhle	EMB	-26.5542	29.108	Sasol	Low-income residential, industry	43380	39836
Sebokeng	SEB	-26.5875	27.8398	VTAPA	Low-income residential, industry	23975	18461
Bosjesspruit	BOS	-26.6042	29.214	Sasol	Industry, mining	17193	14631
Three rivers	THR	-26.6542	27.9959	VTAPA	Middle-income residential, power station	24593	23237
Sharpeville	SHA	-26.6875	27.8642	VTAPA	Low-income residential, industry	23605	22385
Zamdela	ZAM	-26.8458	27.8564	VTAPA	Low-income residential, industry	7244	2812

Abbreviations in Network

SAWS: South African Weather Service

CoT: City of Tshwane

CoJ: City of Johannesburg

VTAPA: Vaal Triangle Airshed Priority Area

HPA: Highveld Priority Area

Rust: Rustenburg

Table S3. Predictor Variables Used in Random Forest Model

MAIAC AOD	Gap-filled AOD, Type: continuous, Unit: dimensionless
	Fire spot data, Type: categorical, 0 = no fire, 1 = fire
	Smoke/dust mask, Type: categorical, 0 = no mask, 1 = smoke mask
Meteorological Data	Surface albedo, Type: continuous, Unit: dimensionless
	Surface incident shortwave flux, Type: continuous, Unit: W m-2
	Evaporation from turbulence, Type: continuous, Unit: kg m-2 s-1
	Total Cloud fraction, Type: continuous, Unit: %
	Total precipitation, Type: continuous, Unit: kg m-2 s-1
	Specific humidity at 2 m above the displacement height, Type: continuous, Unit: kg kg-1
	Temperature at 2 m above displacement height, Type: continuous, Unit: K
	Mean wind speed, Type: continuous, Unit: m s-1
	Mean wind direction, Type: continuous, Unit: degree
	Surface pressure, Type: continuous, Unit: Pa
	Planetary boundary layer (PBL) height, Type: continuous, Unit: m
	Mean wind speed in PBL, Type: continuous, Unit: m s-1
	Mean wind direction in PBL, Type: continuous, Unit: degree
	Air temperature in PBL, Type: continuous, Unit: K
	Specific humidity in PBL, Type: continuous; Unit: kg kg-1
	Relative humidity at PBL, Type: continuous, Unit: %
Land cover data	Woodland fraction, Type: continuous, Unit: dimensionless
	Grassland fraction, Type: continuous, Unit: dimensionless
	Wetland fraction, Type: continuous, Unit: dimensionless
	Residential area fraction, Type: continuous, Unit: dimensionless
	Rock surface fraction, Type: continuous, Unit: dimensionless
	Water surface fraction, Type: continuous, Unit: dimensionless
	Old fields fraction, Type: continuous, Unit: dimensionless
	Commercial land fraction, Type: continuous, Unit: dimensionless
	Industrial land fraction, Type: continuous, Unit: dimensionless
	Main road length, Type: continuous, Unit: km
	Railway length, Type: continuous, Unit: km
	Population, Type: continuous, Unit: dimensionless
Emission data	Emissions from domestic waste burning, Type: continuous. Unit: tonnes per year
	Emissions from domestic fuel combustion, Type: continuous. Unit: tonnes per year
Economic data	Income inequality, Type: continuous, Unit: dimensionless
	Income poverty, Type: continuous, Unit: %
	Multidimensional poverty index, Type: continuous, Unit: dimensionless
	Variance of weighted deprivation scores, Type: continuous, Unit: dimensionless
Seasonal data	Season, Type: category, 1 = winter, 2 = summer, 3 = fall and 0 = spring
Elevation	Elevation, Type: continuous, Unit: m
Policy	Annual PM2.5 National Ambient Air Quality Standard Type: categorical 0 = old Air Quality Standard, 1 = new Air Quality Standard