

ADDITIONAL FILE

# Additional File of Multivariate Bayesian meta-analysis: joint modelling of multiple cancers using summary measures

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## Posterior Summary of region specific mean $\log(SIR)$ and maps visualising high risk areas for Multivariate Models

The posterior means and 95% credible intervals for region specific means of  $\log(SIR)$  for each of the fitted multivariate Bayesian meta-analysis models are shown Tables S1-S3.

Using each of the 12 multivariate models, the high risk areas (SA2s) for specific groups of cancers are identified and plotted in the spatial maps (Figures S1-S9). High risk areas are defined as the SA2s having an SIR substantially larger than the Australian average using the posterior probabilities (SA2 having  $PP \geq 0.80$ , that a cancer in the SA2s has SIR more than the Australian average 1). The number of areas identified to be high risk areas under each group of cancers are also identified and mentioned in Tables S4-S6. Figure S16 shows a map of Australia with locations of states and capitals of each state in Australia. This map is intended to help the readers interpreting the spatial maps visualising high and low risk areas for groups of cancers.

Table S1: Posterior summary of region specific mean  $\log(SIR)$  for most common cancers

Model	Cancer	Region	Mean	2.5% quantile	97.5% quantile
Model 1(a): Males	Bowel	Major Cities	-0.034	-0.037	-0.026
		Regional	0.051	0.042	0.059
		Remote	-0.004	-0.042	0.034
	Lung	Major Cities	-0.057	-0.071	-0.043
		Regional	0.035	0.020	0.051
		Remote	0.171	0.111	0.230
Melanoma	Major Cities	-0.103	-0.126	-0.079	
	Regional	0.018	-0.004	0.040	
	Remote	-0.283	-0.349	-0.216	
Model1(b): Females	Bowel	Major Cities	-0.027	-0.033	-0.021
		Regional	0.044	0.036	0.053
		Remote	-0.026	-0.063	0.012
	Lung	Major Cities	-0.031	-0.043	-0.020
		Regional	0.005	-0.009	0.019
		Remote	0.060	0.004	0.118
Melanoma	Major Cities	-0.119	-0.141	-0.097	
	Regional	0.098	0.078	0.117	
	Remote	-0.107	-0.173	-0.0414	
Model 1(c): Persons	Bowel	Major Cities	-0.034	-0.042	-0.028
		Regional	0.060	0.052	0.068
		Remote	-0.014	-0.051	0.022
	Lung	Major Cities	-0.046	-0.059	-0.033
		Regional	0.040	0.026	0.054
		Remote	0.187	0.130	0.246
Melanoma	Major Cities	-0.111	-0.134	-0.087	
	Regional	0.069	0.049	0.089	
	Remote	-0.229	-0.297	-0.161	
Model 2: Males	Bowel	Major Cities	-0.034	-0.041	-0.028
		Regional	0.051	0.042	0.059
		Remote	-0.005	-0.042	0.034
	Lung	Major Cities	-0.059	-0.073	-0.045
		Regional	0.035	0.020	0.05
		Remote	0.172	0.111	0.231
Melanoma	Major Cities	-0.109	-0.132	-0.085	
	Regional	0.016	-0.006	0.038	
	Remote	-0.288	-0.356	-0.222	
Prostate	Major Cities	-0.023	-0.033	-0.014	
	Regional	-0.020	-0.033	-0.008	
	Remote	-0.256	-0.315	-0.197	
Model 3: Females	Bowel	Major Cities	-0.027	-0.033	-0.021
		Regional	0.044	0.036	0.053
		Remote	-0.025	-0.062	0.012
	Breast	Major Cities	0.007	0.002	0.013
		Regional	-0.024	-0.031	-0.018
		Remote	-0.088	-0.121	-0.055
Lung	Major Cities	-0.031	-0.043	-0.020	
	Regional	0.005	-0.009	0.019	
	Remote	0.060	0.003	0.116	
Melanoma	Major Cities	-0.122	-0.144	-0.100	
	Regional	0.097	0.078	0.117	
	Remote	-0.107	-0.174	-0.042	

Table S2: Posterior summary of region specific mean  $\log(SIR)$  for less common/rare cancers

Model	Cancer	Region	Mean	2.5% quantile	97.5% quantile
Model 4: Females	Liver	Major Cities	-0.011	-0.027	0.005
		Regional	-0.183	-0.202	-0.164
		Remote	0.039	-0.043	0.121
	Oesophageal	Major Cities	-0.050	-0.063	-0.037
		Regional	-0.016	-0.033	0.000
		Remote	-0.026	-0.089	0.038
Model 5: Males	Brain	Major Cities	-0.010	-0.016	-0.003
		Regional	-0.011	-0.020	-0.002
		Remote	-0.045	-0.083	-0.006
	Oesophageal	Major Cities	-0.098	-0.109	-0.088
		Regional	0.116	0.102	0.130
		Remote	0.242	0.191	0.294
	Thyroid	Major Cities	0.013	-0.002	0.027
		Regional	-0.144	-0.159	-0.128
		Remote	-0.181	-0.232	-0.130
Model 6: Females	Brain	Major Cities	-0.004	-0.010	0.002
		Regional	-0.009	-0.017	0.000
		Remote	-0.030	-0.066	0.007
	Cervical	Major Cities	-0.043	-0.056	-0.031
		Regional	0.005	-0.011	0.022
		Remote	0.173	0.113	0.233
	Head & Neck	Major Cities	-0.055	-0.064	-0.046
		Regional	0.055	0.043	0.068
		Remote	0.188	0.137	0.239
	Kidney	Major Cities	-0.022	-0.032	-0.012
		Regional	0.003	-0.009	0.016
		Remote	-0.047	-0.097	0.003
	Stomach	Major Cities	0.004	-0.007	0.015
		Regional	-0.094	-0.107	-0.081
		Remote	-0.139	-0.189	-0.091
Model 7: Persons	Brain	Major Cities	-0.004	-0.009	0.001
		Regional	-0.008	-0.015	0.000
		Remote	-0.060	-0.093	-0.027
	Liver	Major Cities	-0.012	-0.029	0.004
		Regional	-0.200	-0.218	-0.182
		Remote	0.093	0.005	0.181
	Oesophageal	Major Cities	-0.087	-0.097	-0.077
		Regional	0.110	0.097	0.123
		Remote	0.239	0.189	0.290
	Stomach	Major Cities	0.004	-0.006	0.015
		Regional	-0.072	-0.084	-0.060
		Remote	-0.111	-0.157	-0.066

Table S3: Posterior summary of region specific mean  $\log(SIR)$  for smoking related cancers

Model	Cancer	Region	Mean	2.5% quantile	97.5% quantile
Model 8a: Males	Head & Neck	Major Cities	-0.118	-0.131	-0.105
		Regional	0.127	0.111	0.143
		Remote	0.403	0.342	0.464
	Kidney	Major Cities	0.001	-0.007	0.009
		Regional	-0.002	-0.013	0.008
		Remote	-0.080	-0.124	-0.036
	Liver	Major Cities	-0.014	-0.031	0.003
		Regional	-0.210	-0.230	-0.191
		Remote	-0.012	-0.094	0.071
	Lung	Major Cities	-0.062	-0.076	-0.047
		Regional	0.036	0.021	0.052
		Remote	0.174	0.114	0.234
	Oesophageal	Major Cities	-0.095	-0.105	-0.084
		Regional	0.118	0.104	0.132
		Remote	0.244	0.192	0.296
	Pancreatic	Major Cities	-0.009	-0.016	-0.001
		Regional	-0.015	-0.026	-0.005
		Remote	-0.014	-0.056	0.028
	Stomach	Major Cities	0.002	-0.010	0.013
		Regional	-0.068	-0.081	-0.055
		Remote	-0.126	-0.176	-0.076

Table S3 (Continued) Posterior summary of region specific mean  $\log(SIR)$  for smoking related cancers

Model	Cancer	Region	Mean	2.5% quantile	97.5% quantile
Model 8b: Females	Head & Neck	Major Cities	-0.055	-0.064	-0.046
		Regional	0.055	0.042	0.067
		Remote	0.190	0.139	0.241
	Kidney	Major Cities	-0.022	-0.032	-0.012
		Regional	0.004	-0.009	0.016
		Remote	-0.047	-0.099	0.004
	Liver	Major Cities	-0.009	-0.025	0.007
		Regional	-0.183	-0.203	-0.164
		Remote	0.039	-0.043	0.120
	Lung	Major Cities	-0.032	-0.043	-0.020
		Regional	0.005	-0.009	0.019
		Remote	0.060	0.003	0.116
Oesophageal	Major Cities	-0.050	-0.063	-0.037	
	Regional	-0.016	-0.033	0.000	
	Remote	-0.026	-0.088	0.037	
Pancreatic	Major Cities	-0.009	-0.015	-0.003	
	Regional	-0.010	-0.018	-0.001	
	Remote	-0.025	-0.063	0.012	
Stomach	Major Cities	0.005	-0.005	0.016	
	Regional	-0.094	-0.106	-0.081	
	Remote	-0.139	-0.188	-0.091	
Model 8c: Persons	Head & Neck	Major Cities	-0.107	-0.119	-0.095
		Regional	0.129	0.114	0.145
		Remote	0.437	0.378	0.496
	Kidney	Major Cities	-0.004	-0.012	0.004
		Regional	0.010	0.000	0.021
		Remote	-0.076	-0.121	-0.030
	Liver	Major Cities	-0.011	-0.027	0.006
		Regional	-0.194	-0.212	-0.176
		Remote	0.100	0.013	0.189
	Lung	Major Cities	-0.050	-0.063	-0.037
		Regional	0.040	0.026	0.054
		Remote	0.193	0.134	0.251
Oesophageal	Major Cities	-0.084	-0.094	-0.074	
	Regional	0.112	0.098	0.125	
	Remote	0.240	0.190	0.292	
Pancreatic	Major Cities	-0.003	-0.009	0.003	
	Regional	-0.012	-0.020	-0.003	
	Remote	-0.025	-0.061	0.0112	
Stomach	Major Cities	0.005	-0.006	0.015	
	Regional	-0.072	-0.084	-0.060	
	Remote	-0.111	-0.157	-0.066	

Table S4: Number of SA2s with higher incidence for groups of cancers jointly and individually for most common cancers

Group	Cancer	No. of SA2s
Most Common Cancers (for males): Model 1(a)	Lung only	141
	Melanoma only	426
	Lung & melanoma	20
	Bowel only	265
	Lung & bowel	76
	Melanoma & bowel	69
Most Common Cancers (for females): Model 1(b)	Lung, melanoma & bowel	4976
	Lung only	17
	Melanoma only	486
	Bowel only	206
Most Common Cancers (for males): Model 2	Lung & bowel	4
	Melanoma & bowel	157
	Lung only	158
	Melanoma only	211
	Lung & Melanoma	6
	Bowel only	259
	Lung & Bowel	74
	Prostate only	59
	Lung & Prostate	50
	Lung, Melanoma & Bowel	33
	Melanoma & Prostate	216
	Lung, Melanoma & Prostate	13
	Bowel & Prostate	5
Most Common Cancers (for females): Model 3	Lung, Bowel & Prostate	4
	Melanoma, Bowel & Prostate	23
	Lung, Melanoma, Bowel & Prostate	12
	Lung only	17
	Melanoma only	335
	Bowel only	205
	Lung & Bowel	4
Breast only	68	
Lung & Breast	156	
Melanoma & Breast	159	

Table S5: Number of SA2s with higher incidence for groups of cancers jointly and individually for rare and less common cancers

Group	Cancer	No. of SA2s
Rare/ Less common Cancers (females): Model 4	Liver only	5
Rare/Less common Cancers (males): Model 5	Oesophageal only	820
	Thyroid only	261
Less Common/ Rare Cancers (for females): Model 6	Head & neck only	378
	Cervical & Head and neck	79
	Stomach only	13
Less Common/ Rare Cancers (for persons): Model 7	Oesophageal only	17
	Liver only	765
	Stomach only	38
	Oesophageal & Liver	39
	Oesophageal & Stomach	208

Table S6: Number of SA2s with higher incidence for groups of cancers jointly and individually for smoking related cancers

Group	Cancer	No. of SA2s
for females Model 8(b)	Stomach only	98
	Liver & Stomach	71
	Head and Neck only	434
	Lung & Head and Neck	14
	Liver& Head and Neck	5
	Lung, Liver & Head and Neck	5
for persons Model 8(c)	Lung only	26
	Liver only	11
	Lung & Liver	2
	Stomach only	25
	Lung & Stomach	7
	Liver & Stomach	130
	Lung, Liver & Stomach	36
	Lung, Stomach & Pancreatic	1
	Liver, Stomach & Pancreatic	12
	Lung, Liver, Stomach & Pancreatic	15
	Kidney only	24
	Lung & Kidney	47
	Stomach & Kidney	1
	Lung, Stomach & Kidney	23
	Liver, Stomach & Kidney	1
	Lung, Liver,Stomach & Kidney	18
	Lung, Pancreatic,Stomach & Kidney	2
	Lung,Liver, Pancreatic,Stomach & Kidney	5
	Oesophageal	143
	Lung & Oesophageal	11
	Oesophageal and Kidney	17
	Lung, Oesophageal and Kidney	58
	Lung,Head and Neck & Kidney	2
	Lung, Liver, Kidney & Head and Neck	15
	Lung, Liver, Pancreatic, Kidney & Head and Neck	1
	Lung, Liver & Head & Neck	1
	Lung, Stomach, Kidney & Head and Neck	9
	Lung, Liver, Stomach, Kidney & Head and Neck	8
	Lung, Pancreatic, Stomach, Kidney & Head and Neck	1
	Lung, Liver, Pancreatic, Stomach, Kidney & Head and Neck	2
	Oesophageal & Head and Neck	244
	Lung,Oesophageal & Head and Neck	298
	Liver, Oesophageal & Head and Neck	5
	Lung, Liver, Oesophageal & Head and Neck	34
	Kidney, Oesophageal & Head & Neck	9
	Lung,Kidney, Oesophageal & Head & Neck	7

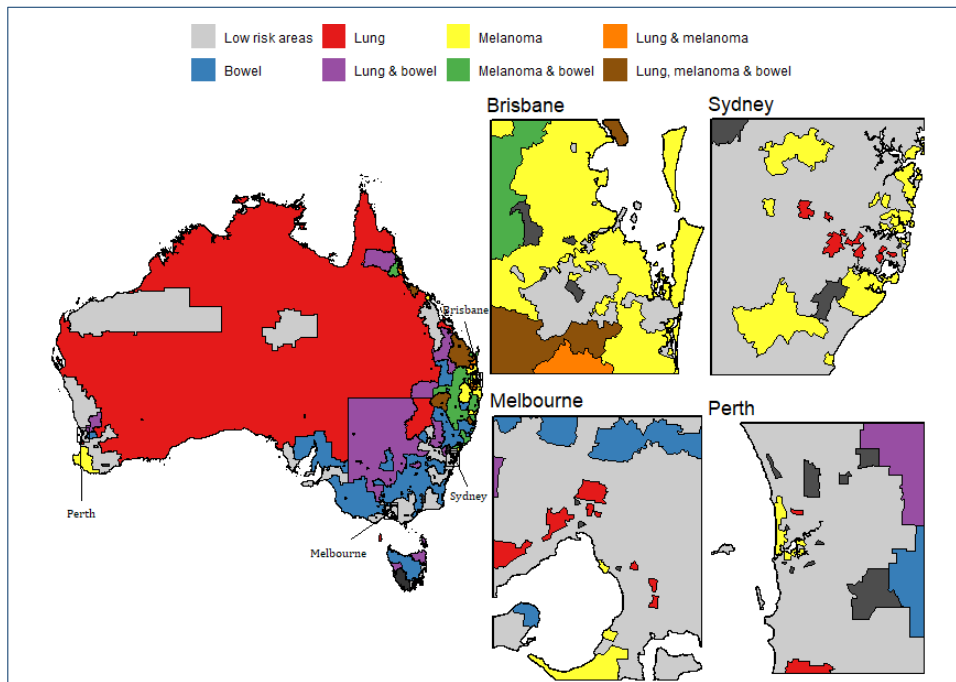


Figure S1: High and low risk areas for multiple cancers (most common cancers for males: Model 1(a))

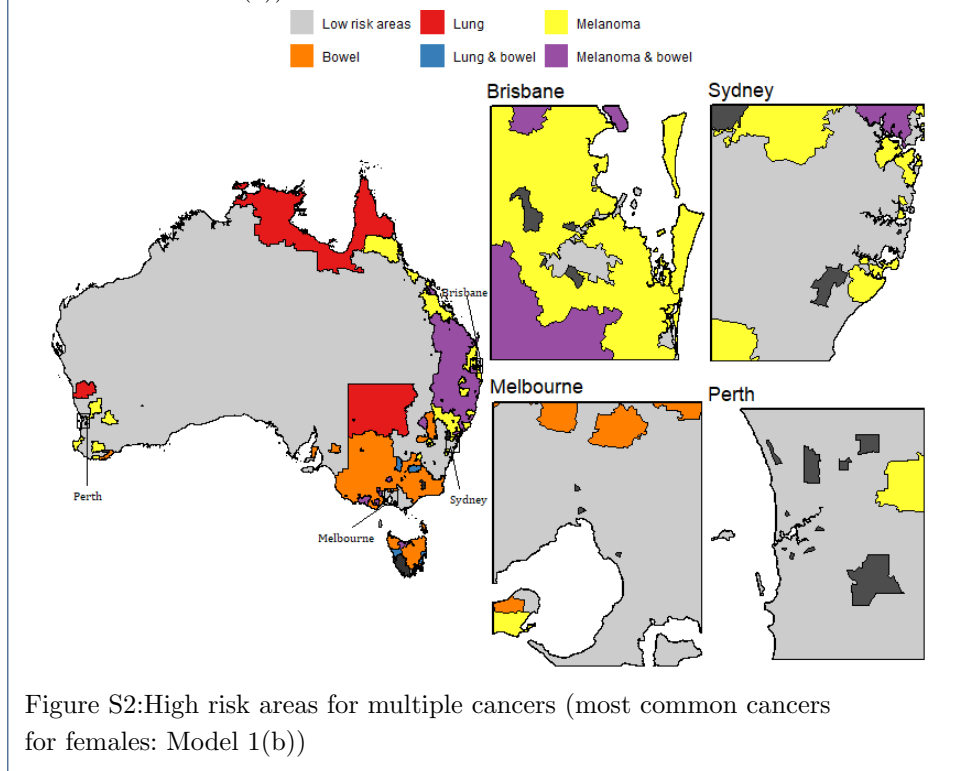


Figure S2: High risk areas for multiple cancers (most common cancers for females: Model 1(b))

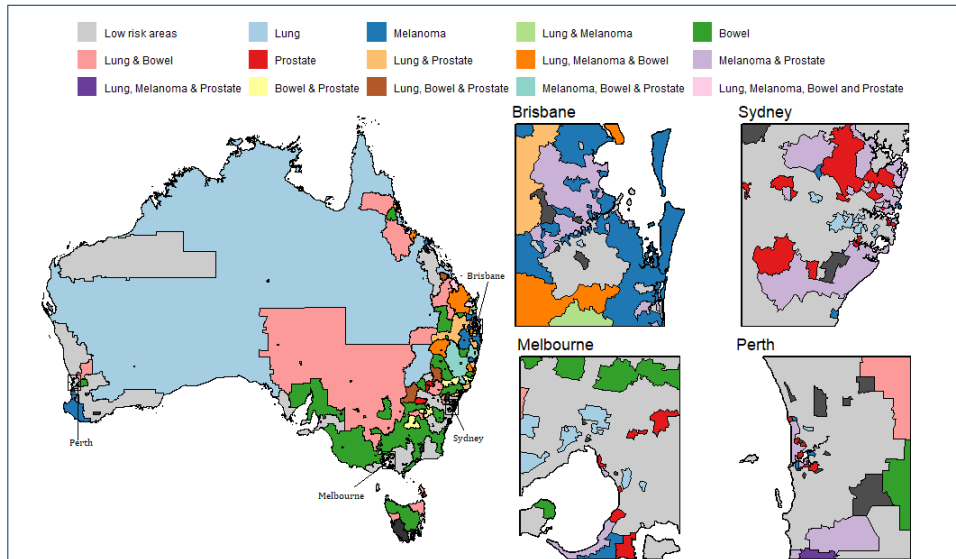


Figure S3: High and low risk areas for multiple cancers (most common cancers for males: Model 2)

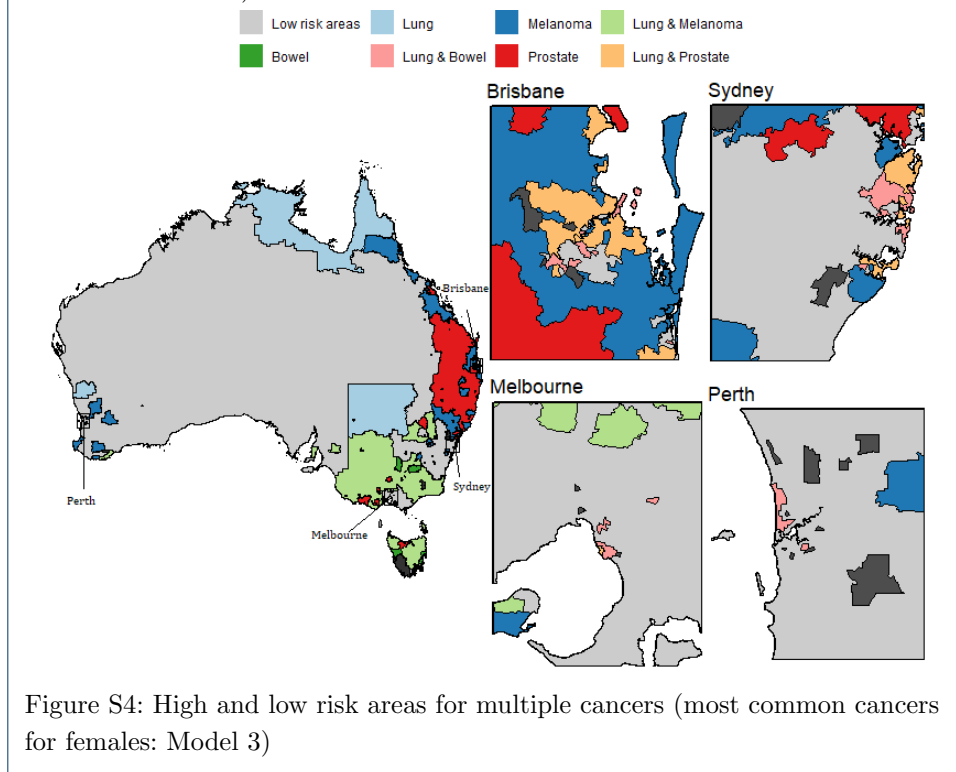


Figure S4: High and low risk areas for multiple cancers (most common cancers for females: Model 3)



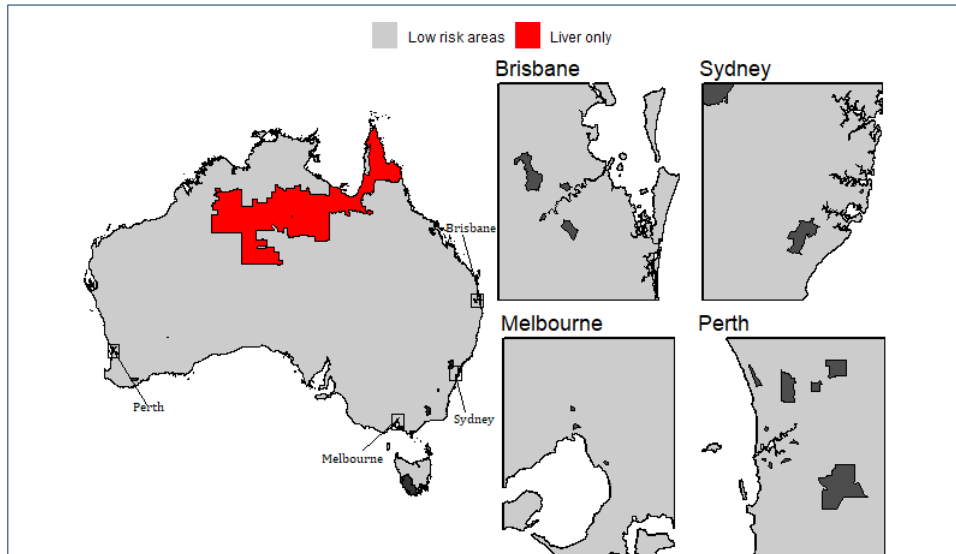


Figure S5: High and low risk areas for multiple cancers (Rare and less common cancers for females: Model 4)

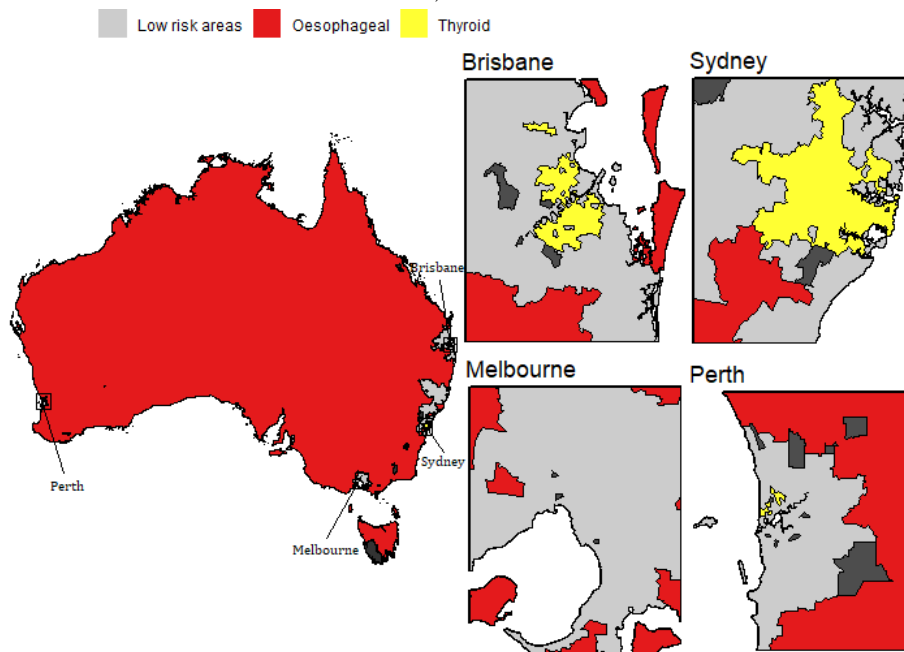


Figure S6: High and low risk areas for multiple cancers (Rare and less common cancers for males: Model 5)

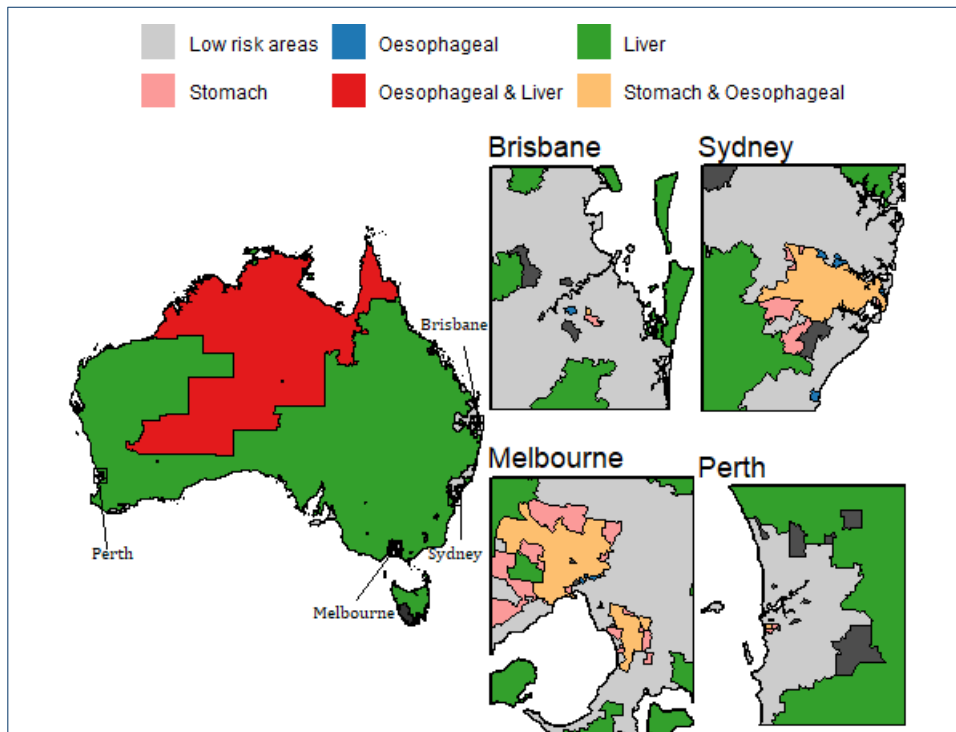


Figure S7: High and low risk areas for multiple cancers (Rare and less common cancers for females: Model 7)

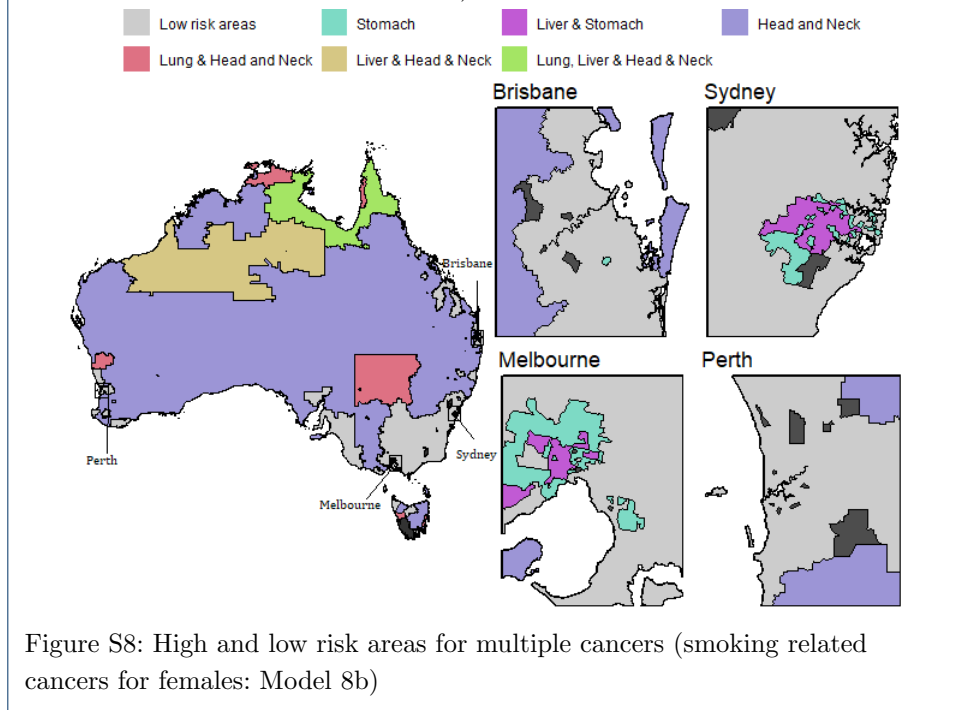


Figure S8: High and low risk areas for multiple cancers (smoking related cancers for females: Model 8b)

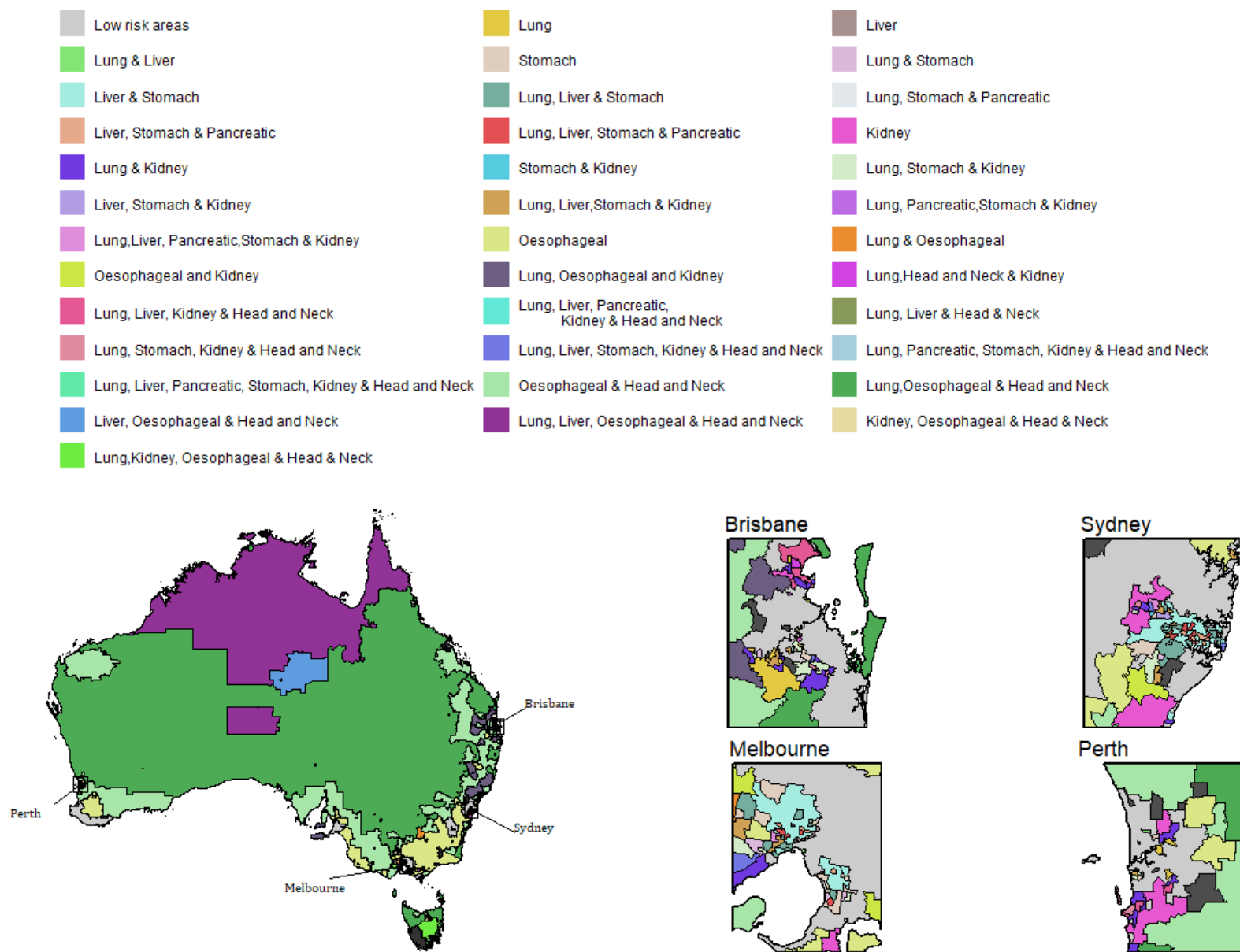


Figure S9: High and low risk areas for multiple cancers (smoking related cancers for persons: Model 8c)

## Multivariate Models for additional groups

### Hormone related cancers

Among the cancer types included in the ACA, hormone related cancers include breast, cervical, ovarian, bowel [1]. The proposed model is fitted to this group of cancers for females only (Model 9).

### Overweight and obesity related cancers

Among the cancer types included in the ACA, overweight and obesity related cancers include oesophageal, pancreatic, bowel, breast ovarian and kidney [1]. The proposed model is fitted to two sub-groups under this broad group, oesophageal, pancreatic, bowel and kidney for males (Model 10(a)) ; oesophageal, pancreatic, bowel, breast, ovarian and kidney for females (Model 10(b)).

## Results for Model 9 and 10

The posterior means and associated 95% credible intervals for SIRs for models 9 and 10 (a & b) are shown in figures S10-S11. The actual values for posterior  $\log(SIR)$  can be seen in Table S7. The posterior correlation matrices in major cities, regional and remote Australia for the cancers included in model 9 and 10 (a & b) are shown in Figure S12. The results of Jennrich’s test of equality of the correlation matrices for the remoteness regions are shown in Table S8. The number of areas with high risk of cancer incidence for both hormone related and obesity & overweight related cancers are shown in Table S9. The spatial maps visualising the high and low risk areas are presented in figures S13 - S15.

Table S7: Posterior summary of region specific mean  $\log(SIR)$  for Hormone related (Model 9) and overweight & obesity related cancers (Model 10)

Model	Cancer	Region	Mean	2.5% quantile	97.5% quantile
Model 10: Females	Bowel	Major Cities	-0.029	-0.034	-0.023
		Regional	0.044	0.035	0.052
		Remote	-0.025	-0.062	0.012
	Breast	Major Cities	0.007	0.002	0.012
		Regional	-0.024	-0.031	-0.018
		Remote	-0.088	-0.122	-0.055
	Cervical	Major Cities	-0.044	-0.056	-0.031
		Regional	0.004	-0.012	0.021
		Remote	0.173	0.114	0.233
	Ovarian	Major Cities	-0.003	-0.009	0.003
		Regional	-0.024	-0.032	-0.016
		Remote	-0.049	-0.085	-0.013
Model 10(a): Males	Bowel	Major Cities	-0.027	-0.033	-0.021
		Regional	0.044	0.036	0.053
		Remote	-0.026	-0.063	0.012
	Kidney	Major Cities	-0.031	-0.043	-0.020
		Regional	0.005	-0.009	0.019
		Remote	0.060	0.004	0.118
	Oesophageal	Major Cities	-0.119	-0.141	-0.097
		Regional	0.098	0.078	0.117
		Remote	-0.107	-0.173	-0.0414
	Pancreatic	Major Cities	-0.119	-0.141	-0.097
		Regional	0.098	0.078	0.117
		Remote	-0.107	-0.173	-0.0414
Model 10(b): Females	Bowel	Major Cities	-0.028	-0.036	-0.019
		Regional	0.045	0.032	0.058
		Remote	-0.026	-0.104	0.051
	Breast	Major Cities	0.008	0.000	0.016
		Regional	-0.024	-0.036	-0.013
		Remote	-0.088	-0.161	-0.013
	Pancreatic	Major Cities	-0.009	-0.018	0.001
		Regional	-0.011	-0.024	0.002
		Remote	-0.025	-0.104	0.053
	Kidney	Major Cities	-0.022	-0.034	-0.009
		Regional	0.005	-0.013	0.022
		Remote	-0.048	-0.137	0.040
Oesophageal	Major Cities	-0.049	-0.065	-0.033	
	Regional	-0.014	-0.036	0.007	
	Remote	-0.026	-0.126	0.078	
Ovarian	Major Cities	-0.002	-0.011	0.007	
	Regional	-0.024	-0.036	-0.011	
	Remote	-0.048	-0.128	0.030	

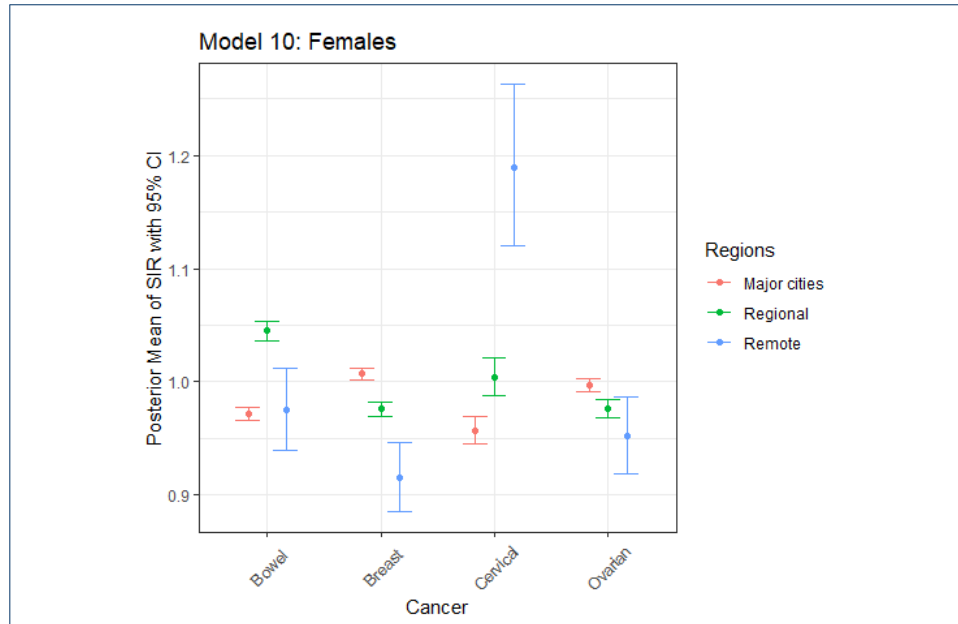


Figure S10: Posterior means with 95% credible intervals of SIR for the hormone related cancers over remoteness regions, Australia

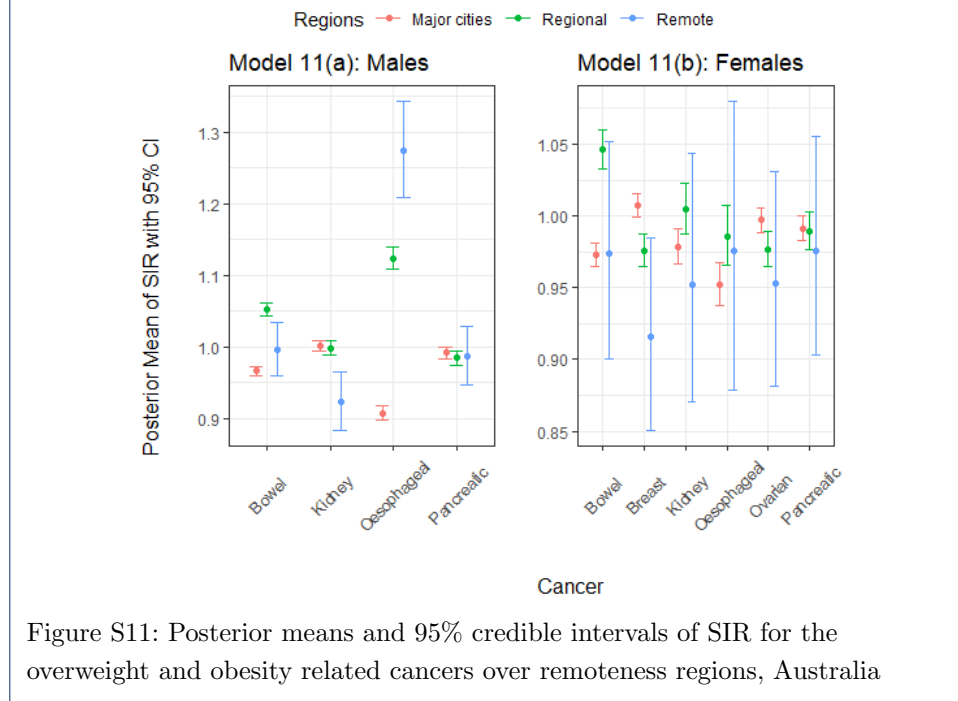


Figure S11: Posterior means and 95% credible intervals of SIR for the overweight and obesity related cancers over remoteness regions, Australia

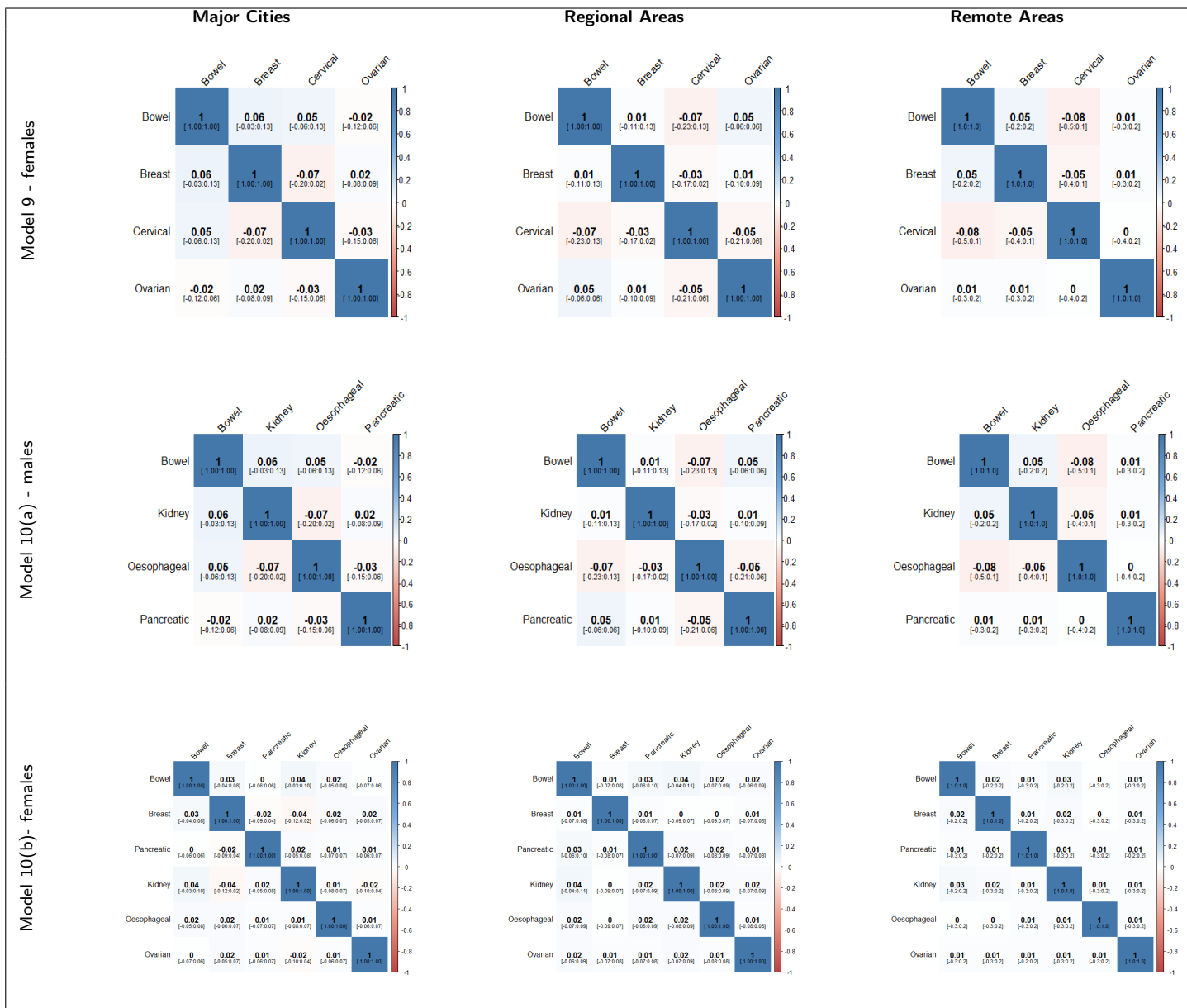


Figure S12: Posterior Correlation matrices with 95% credible intervals for hormone related cancers (Model 9) and overweight & obesity related cancers (Model 10 a & b) by region

Table S8: Results of Jennrich’s Test of differences in correlation matrices applied to hormone related and obesity & overweight related cancers in different remoteness regions

Group	Model	Test statistic <sup>a</sup>	Critical_value	P_value
Hormone related cancers	Model 10: Females	12.87	21.03	0.38
Overweight and obesity related cancers	Model 11(a): Males	23.96	21.26	0.02
	Model 11(b): Females	3.42	43.77	0.99

<sup>a</sup> Null Hypothesis: Equality of correlation matrices in major cities, regional and remote areas for each group of cancers

Table S9: Number of SA2s with higher incidence for groups of cancers jointly and individually, models 9 and 10

Model	Cancer	No. of SA2s
Model 9: females	Low risk areas	1608
	Bowel only	362
	Breast only	100
	Cervical only	78
Model 10(a): males	Low risk areas	1287
	Bowel only	279
	Kidney only	1
	Oesophageal only	395
	Bowel & Oesophageal	436
Model 10(b):females	Low risk areas	1673
	Bowel only	260
	Breast only	177
	Pancreatic only	10
	Bowel& Pancreatic	9
	Kidney only	1
	Bowel & Kidney	1
Ovarian	14	

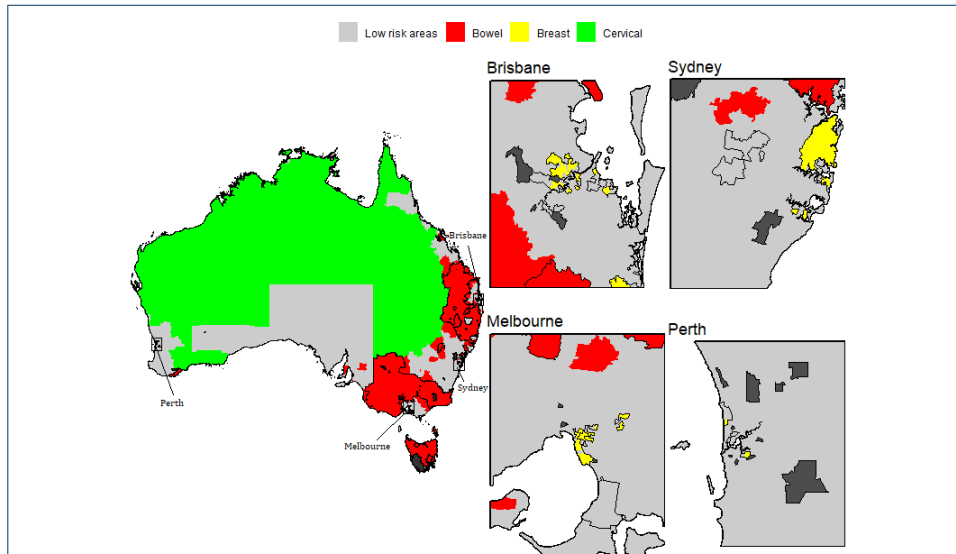


Figure S13: High and low risk areas for individuals and multiple cancers (hormone related cancers: Model 9)

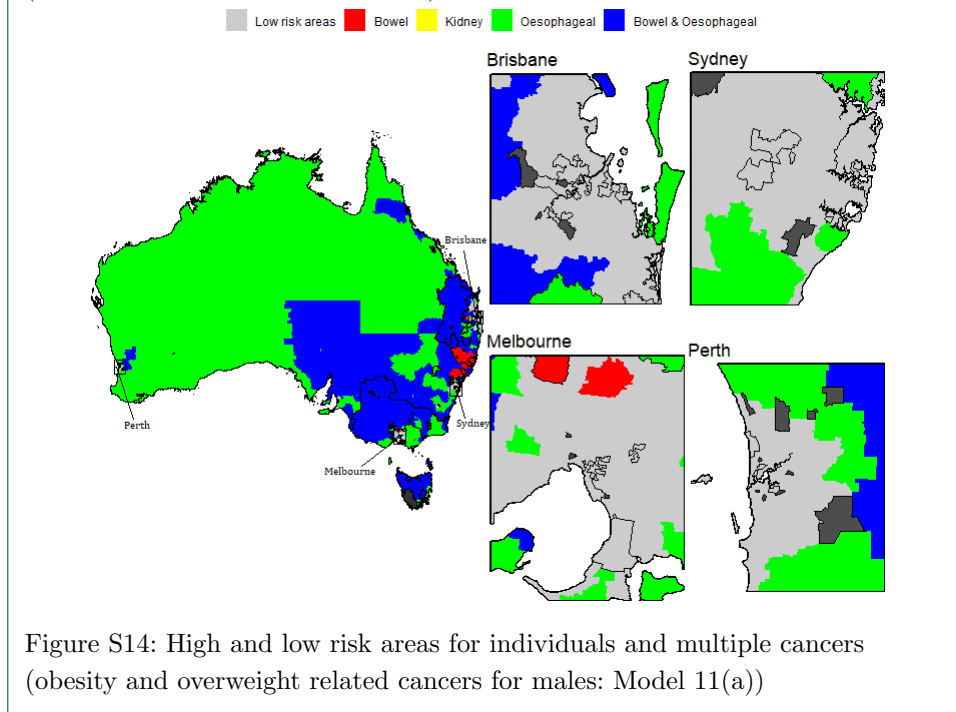


Figure S14: High and low risk areas for individuals and multiple cancers (obesity and overweight related cancers for males: Model 11(a))



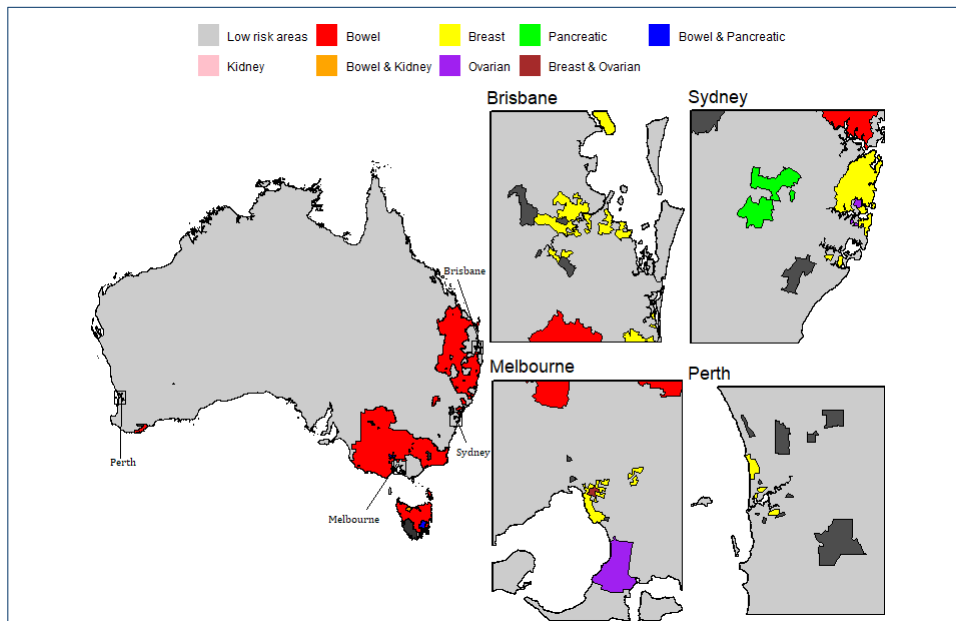


Figure S15: High and low risk areas for individuals and multiple cancers (obesity and overweight related cancers for males: Model 11(b))



Figure S16: Map of Australia showing states and capitals

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**References**

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