Continental Spatial Non-stationarity of Fire-Human Relationship Using Geographically Weighted Regression (GWR)

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Goals, questions to be addressed

Does the relationship between fire and human vary in space?

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Adequacy of Geographically Weighted Regression (GWR)?

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Does GWR represents an improvement over OLS?
Local regression coefficients vary in sign and magnitude?
Spatial patterns of the GWR regression parameters would clarify the relationship?

Develop global empirical model to explore spatial non-stationarity in the relationship between fire and human

Assessing GWR model

$$Y = \beta_0 (\mu, v) + \beta_1 (\mu, v) X_1 + \varepsilon$$

Coordinate locations

GWR extends classical global OLS regression by allowing the spatial variation of local regression estimates, rather than global parameters.

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Different relationships between response variable and predictors are allowed to exists at different points in space and can be mapped

GWR also produces localized versions of all standard regression goodness-of-fit and diagnostics, such as R^2, standardized residuals, influential points, etc.

See Fotheringham et al., 2002 for more detail

Fotheringham AS, Brunsdon C, Charlton ME (2002) Geographically weighted regression: the analysis of spatially varying relationships. Wiley, New York

GWR modeling parameters (GWR vs 3.0*)

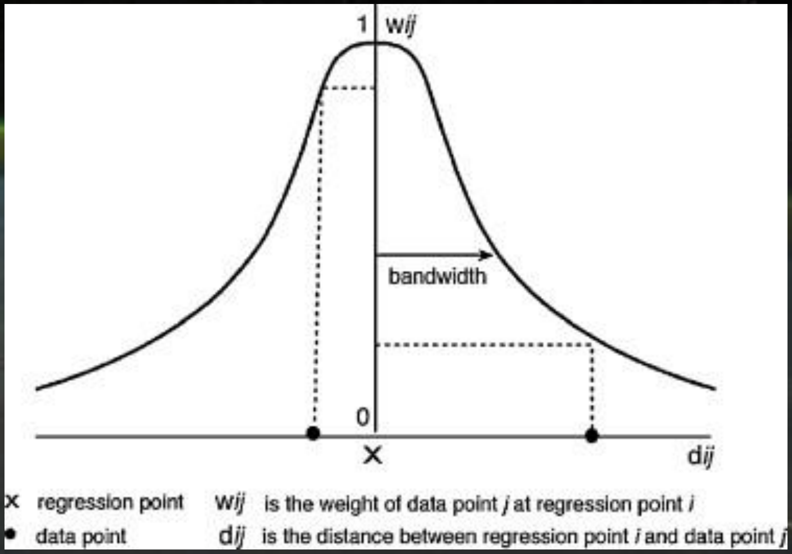
2001-2009
- *log* mean area burned
- *log* total fire MODIS counts

= *f* (*log* Population density)

- <u>Geographical weighting scheme</u>

Kernel shape – adaptative (shorter bandwidths where data are dense and longer where sparse)

Bandwidth – Optimal estimated via minimization of AIC (more sensitive)



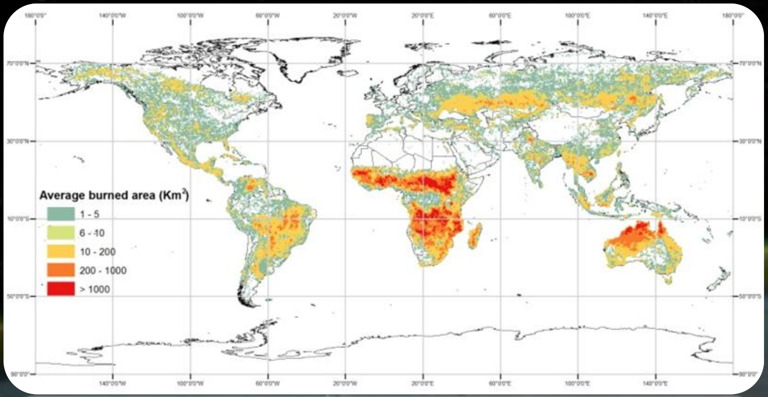
Source: **Fotheringham et al., 2002*

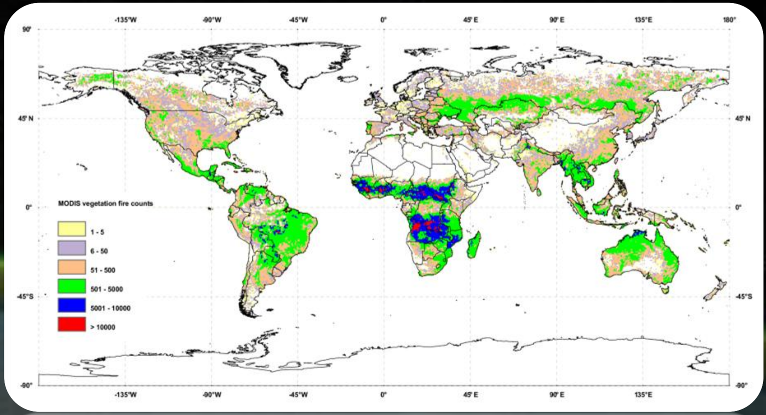
Monte Carlo statistical permutation test was used to evaluate spatial non-stationarity (variability) of local parameter estimates
The statistical significance of the local parameters estimates was done using an alpha modified (Byrne et al. 2009)

Input to the GWR/OLS models (0.5°)

Mean burned area (GFED3)* | Response variables | MODIS active fires†

2001-2009



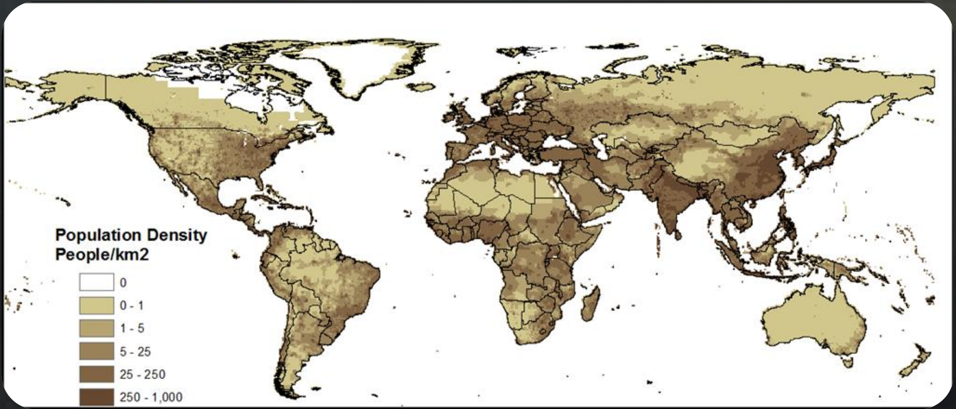


*Giglio et al., 2010

†Oom & Pereira, submitted

Population density (Gridded Population of the World, vs3)[1]

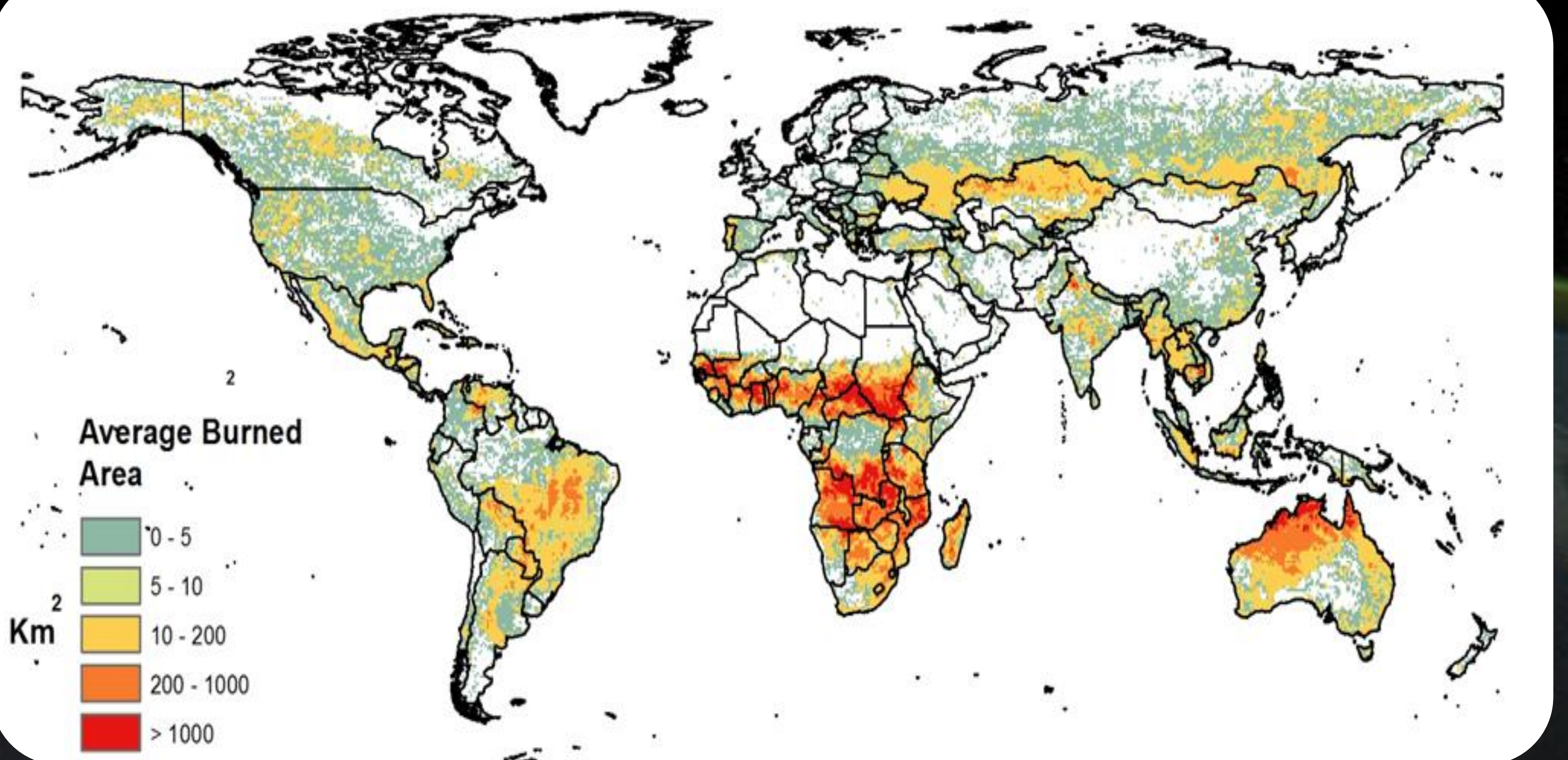
Explanatory variable



[1]CIESIN, 2005

Response variable

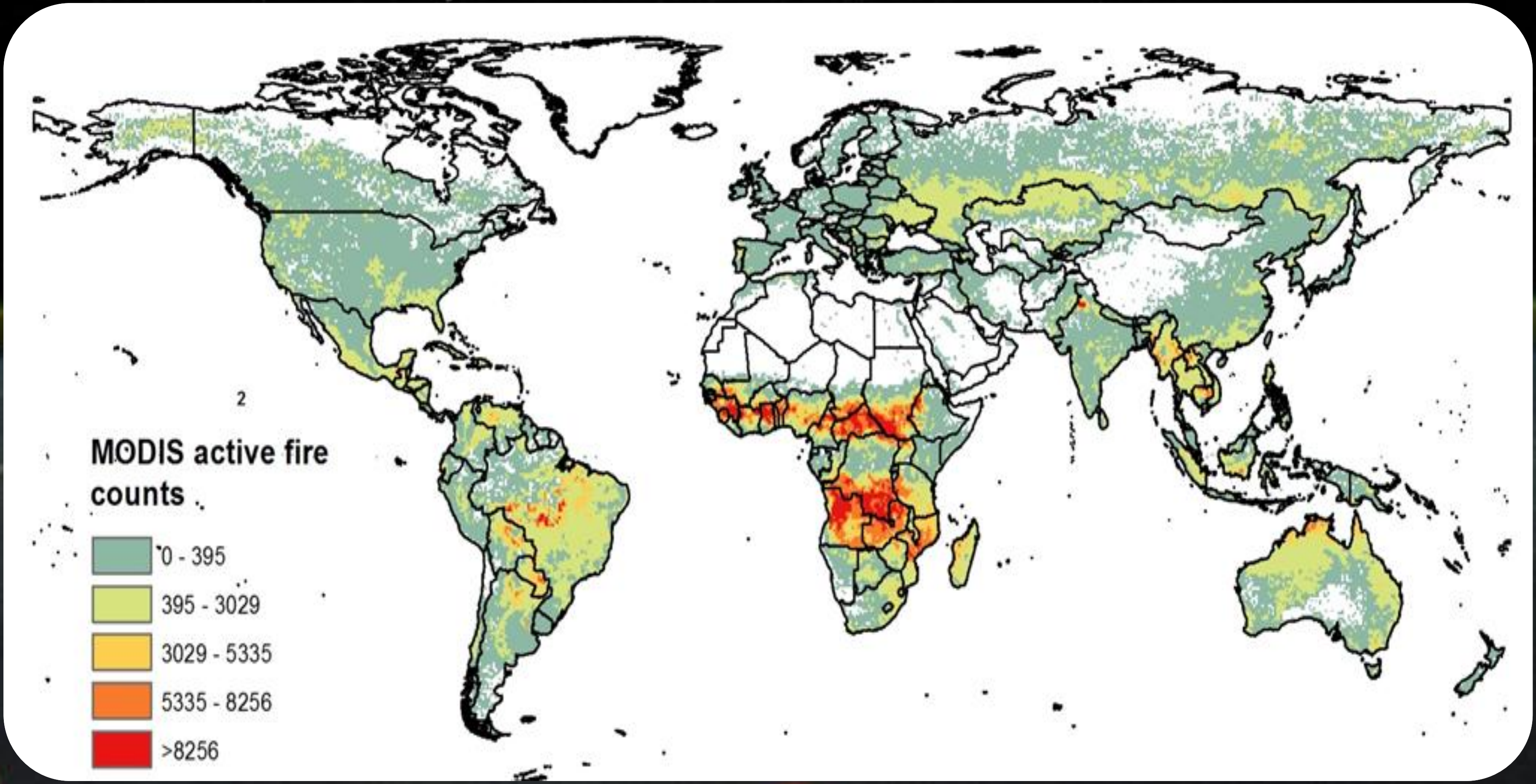
Mean burned area(Km^2)



Giglio, L. et al (2010). Assessing variability and long-term trends in burned area by merging multiple satellite fire products. *Biogeosciences*, 7, 1171-1186

Response variable

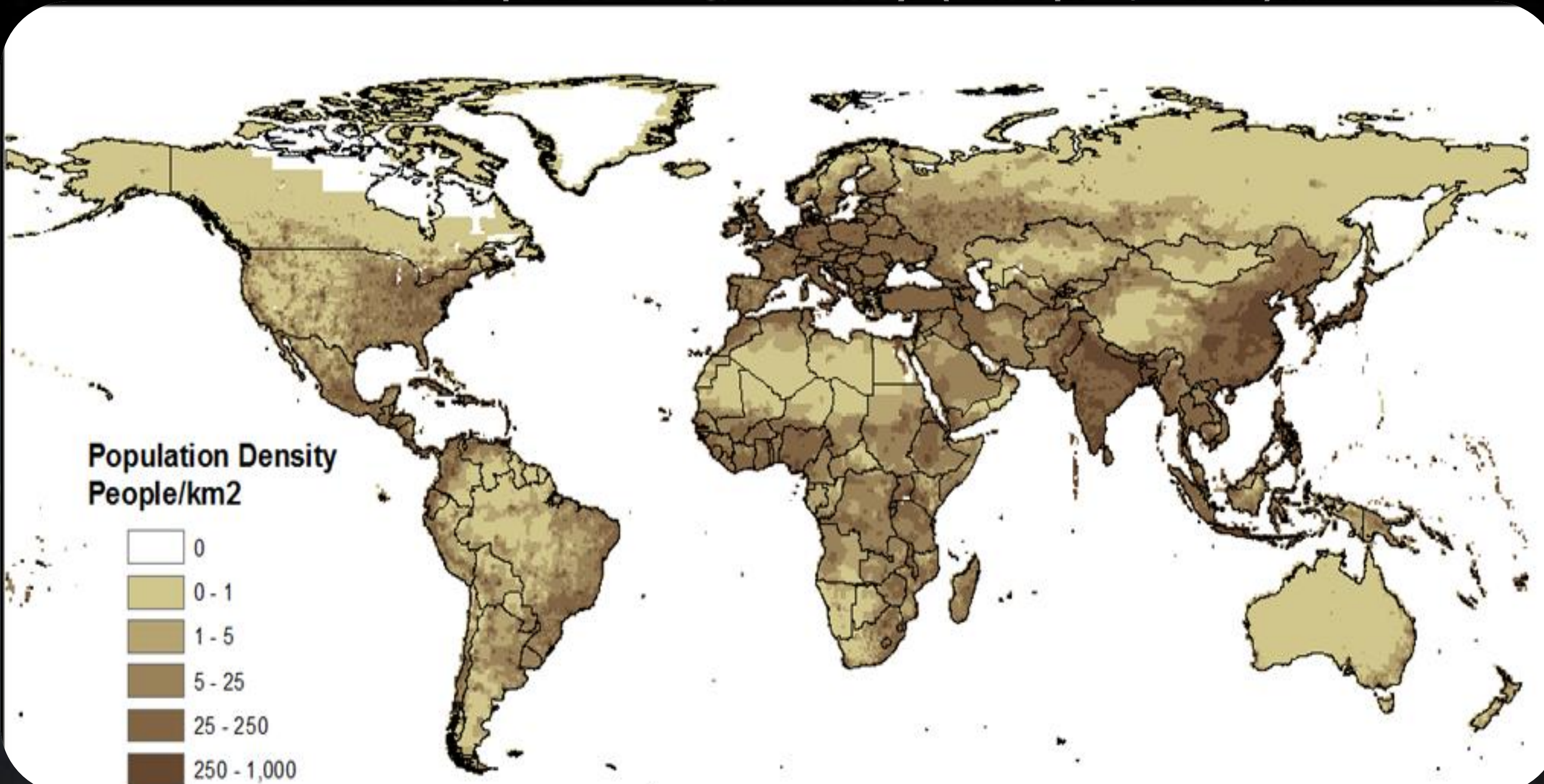
MODIS active fires



Oom, D. & J.M.C. Pereira. Exploratory spatial data analysis of global MODIS active fire data (2012). *International Journal of Applied Earth Observation And Geoinformation (submitted)*

Explanatory variable

Population density (People/Km^2)



Center for International Earth Science Information Network (CIESIN) & Centro Internacional de Agricultura Tropical (CIAT) (2005). Gridded Population of the World, Version 3 (GPWv3). Palisades, NY. Socioeconomic Data and Applications Center (SEDAC), Columbia University.

Results

OLS MODEL

	Global T value (95 % conf)	
	Burned Area	Active fires
ASIA	33.54	55.86
EUROPE	28.84	47.18
N AMERICA	75.28	83.38
S AMERICA	22.97	31.05
AFRICA	64.23	29.24
AUSTRALIA	2.77	15.79

OLS *vs* GWR MODEL

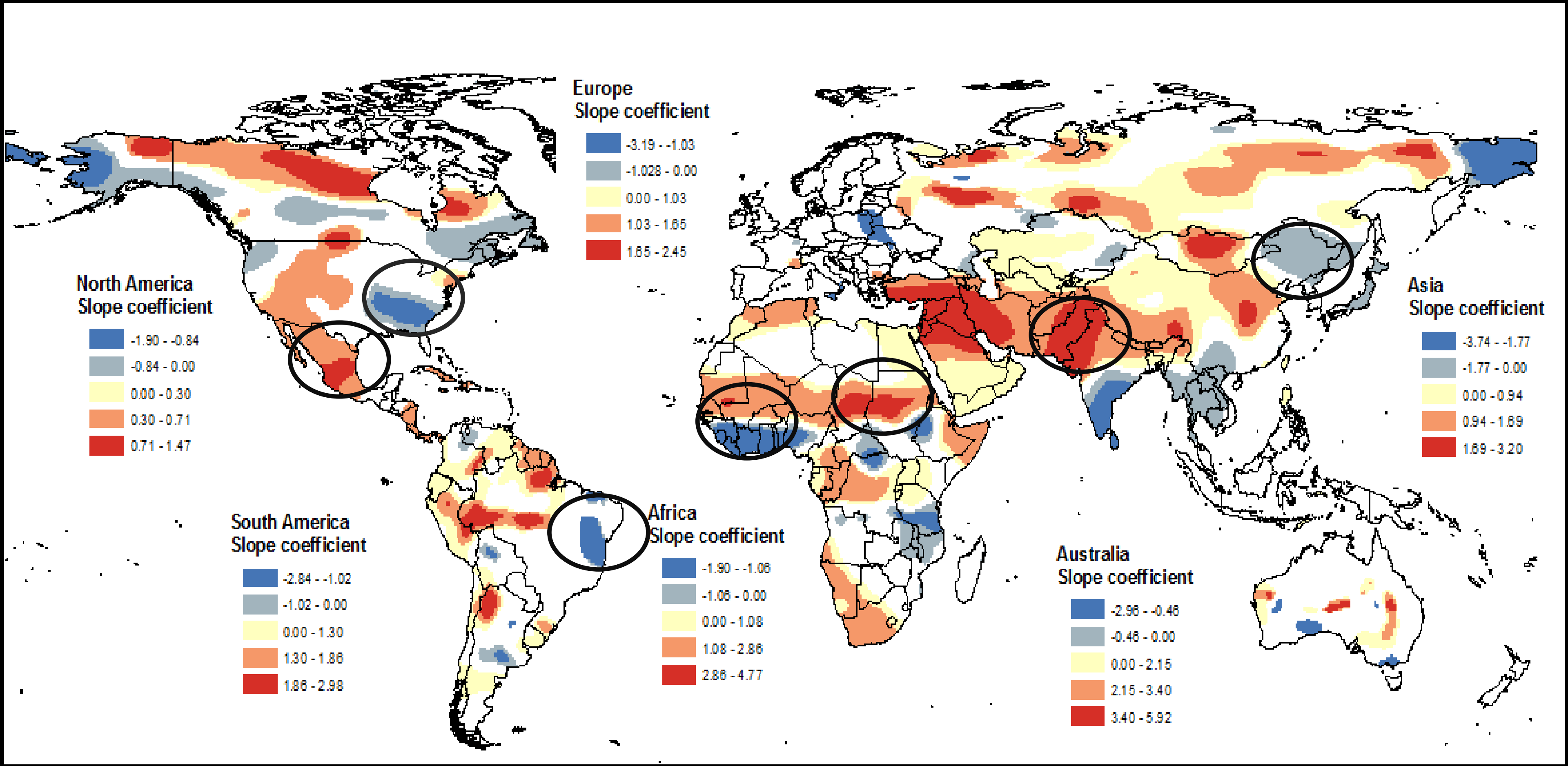
	Buned Area					Active fires				
	AIC		R^2			AIC		R^2		
	OLS	GWR	OLS	GWR	F test	OLS	GWR	OLS	GWR	F test
ASIA	115338	101721	0.04	0.46	201	116595	99565	0.13	0.61	296
EUROPE	32402	27009	0.1	0.6	89	29582	24188	0.28	0.72	96
N AMERICA	76372	67573	0.24	0.55	127	67397	59142	0.35	0.66	128
S AMERICA	31318	26494	0.07	0.056	76	31651	26713	0.13	0.62	83
AFRICA	52871	39362	0.27	0.8	309	43480	31791	0.1	0.8	306
AUSTRALIA	14508	11948	0	0.59	50	14685	10880	0.08	0.78	101

Monte Carlo test revealed that all the parameters have a spatial variability (non-stationary) with a level of significance of 0.1%; All GWR parameter estimates were tested for significance (t-test with alpha corrected)

Results

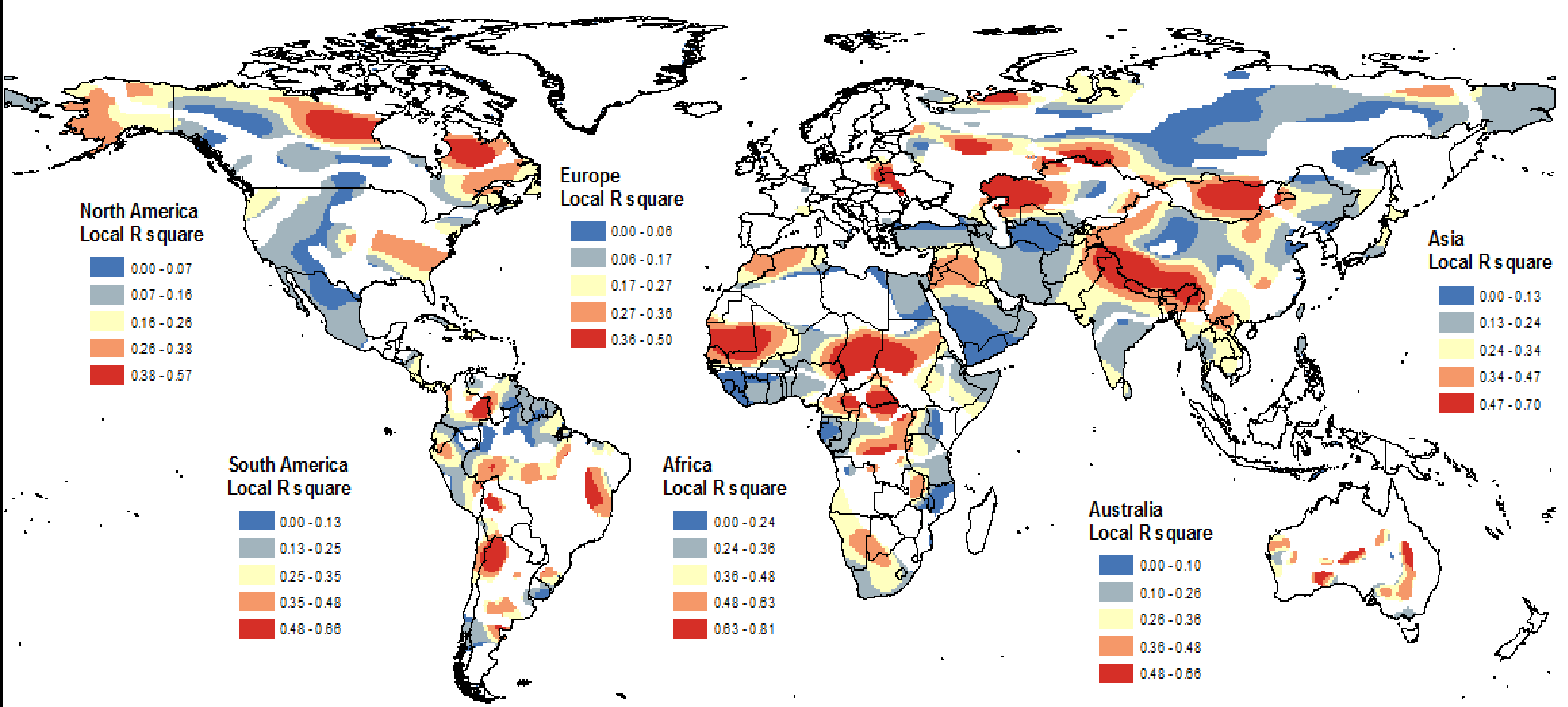
Log Mean Burned Area

Log Population Density (β_1)



Results

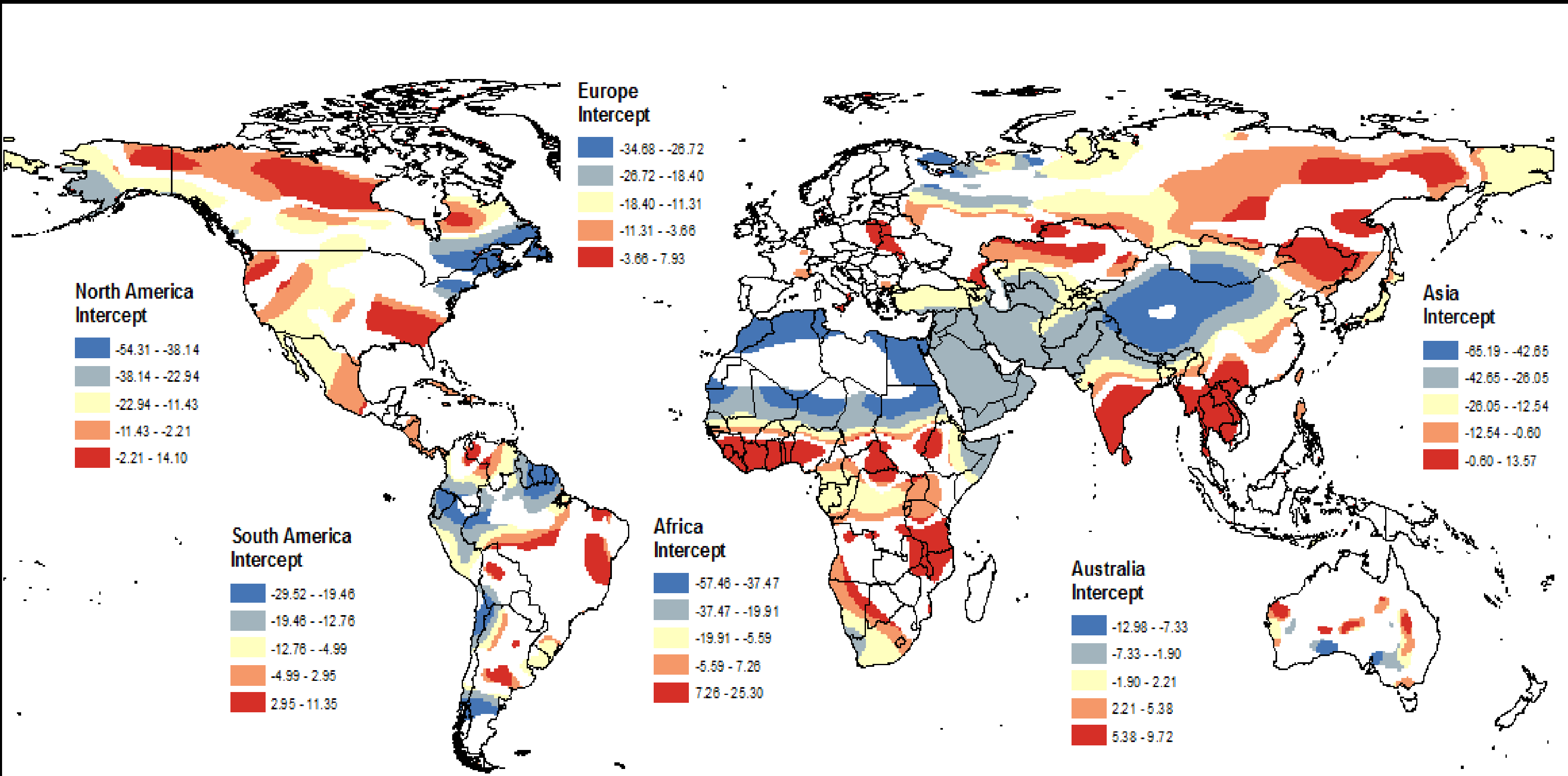
Log Mean Burned Area R^2



Results

Log Mean Burned Area

Intercept (β_0)



Results

Spatial patterns

Log Population Density (β_1)

Highest amount of statistical significant patterns can be found in Africa, Asia, north and south America

Negative slopes located mainly in "bible belt" (USA), West Africa northern , China and India

Positive slopes in Canada, Alaska, central Mexico, Amazon Central Africa ,

R^2

Higher values located in central and western Africa, NE and NW India Mongolia

In Africa 18 % of land surface has a local R square greater than 0.6

Areas of low R^2 are primarily located in very high latitudes, where fires are virtually absent

Example Africa

OLS

MBA[1]=-2.141+1.777*Pop [2]

AIC = 52871

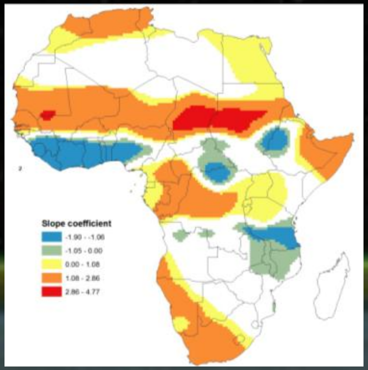
T (95% CI)=64.23

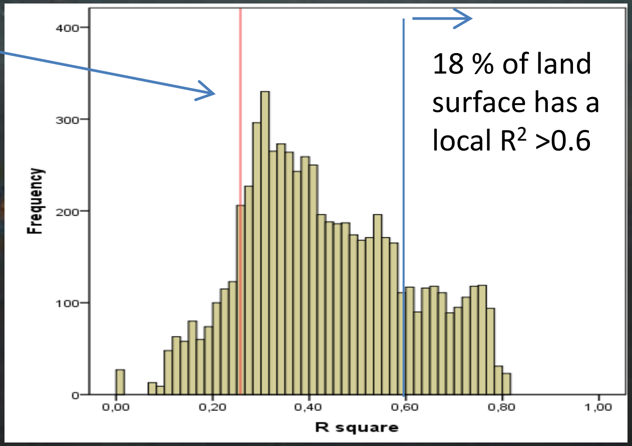
R^2 = 0.279

β_1 Lower limit of 95% CI=1.72

β_1 Upper limit of 95% CI=1.83

[1]Mean Burned Area
Populations density





GWR

AIC = 39362

	(β_1)
Mean	0.94
Minimum	-1.901
25% quartile	0.43
Median	1.13
75% quartile	1.79
Maximum	4.77

The 95% CIs of the OLS for β_1 were approximately within the median and 75% quartile – large proportion of the local parameter were smaller than OLS parameter

Conclusions (answers)

Does the relationship between fire and human vary in space?

Relation between population density and burned area / Active fires is non-stationary

Is Geographically Weighted Regression (GWR) adequate to this study?

Estimate local rather than global, allowing regression coefficients to vary in space, better describing the relationship

Is GWR better than OLS?

For all continents the null hypothesis was rejected (lower AIC's, higher R^2). Describe local relationships that were "hidden" with the OLS

Does the local regression coefficients vary in sign and magnitude? Did the spatial patterns clarify the relationship?

Maps of coefficient estimates are interpretable and vary in sign and magnitude. Maps of regression diagnostics highlight areas of higher/lower model performance, and indirectly suggest potential improvements to model specification.

Scientific question –ongoing research

ARE HUMAN DETERMINANTS OF FIRE EXTENT AND INCIDENCE?

It´s clear that we have non-monotonic relationship between human and fire

NEXT STEP

Negative and positive effects of the population density can be direct interpretations of suppression and land use practices

Get those patterns and translate the difference of signs in land use activities, exploring the anthropogenic factor , the effect on fire through land use change

I. Bistinas, D.Oom, A.C. L. Sá and J.M.C. Pereira. “Human influence on fire extent at global scale. Non-stationarity study using Geographically Weighted Regression” *(in preparation)*

Thank you