



LUND UNIVERSITY

Spatio-temporal patterns of intentional fires, social stress and socio-economic determinants: A case study of Malmö, Sweden

Guldåker, Nicklas; Hallin, Per-Olof

Published in:
Fire Safety Journal

DOI:
[10.1016/j.firesaf.2014.08.015](https://doi.org/10.1016/j.firesaf.2014.08.015)

2014

[Link to publication](#)

Citation for published version (APA):
Guldåker, N., & Hallin, P.-O. (2014). Spatio-temporal patterns of intentional fires, social stress and socio-economic determinants: A case study of Malmö, Sweden. *Fire Safety Journal*, 70, 71-80.
<https://doi.org/10.1016/j.firesaf.2014.08.015>

Total number of authors:
2

General rights

Unless other specific re-use rights are stated the following general rights apply:
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

Read more about Creative commons licenses: <https://creativecommons.org/licenses/>

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

LUND UNIVERSITY

PO Box 117
221 00 Lund
+46 46-222 00 00



ELSEVIER

Contents lists available at ScienceDirect

Fire Safety Journal

journal homepage: www.elsevier.com/locate/firesaf

Review

Spatio-temporal patterns of intentional fires, social stress and socio-economic determinants: A case study of Malmö, Sweden

Nicklas Guldåker ^{a,*}, Per-Olof Hallin ^b^a Department of Human Geography, Faculty of Social Sciences, Lund University, Sölvegatan 12, 223 62 Lund, Sweden^b Department of Urban studies, Faculty of Culture and Society, Malmö University, Östra Varvsgatan 11 A, 205 06 Malmö, Sweden

ARTICLE INFO

Article history:

Received 9 August 2013

Received in revised form

23 August 2014

Accepted 31 August 2014

Available online 7 October 2014

Keywords:

Intentional fires

Social stress

Spatio-temporal analysis

Living conditions

Malmö

ABSTRACT

Since the end of the 1990s, the number of fires has increased dramatically in Malmö, a city in the southernmost part of Sweden. Between 1998 and 2009, the increase was 215%, and a large number of the fires were intentional. The aim of this paper is to deepen our understanding of the underlying causes of the spatial and spatio-temporal distribution of intentional fires in Malmö, and to analyse how different living conditions in Malmö sub-areas may determine the frequency of intentional fires. This paper's main contributions to the field is to operationalize theories of social stress into measurable variables and an index of living conditions (ILC), and to statistically and spatially analyse the underlying relationship between living conditions and intentional fires. One key conclusion is that the spatio-temporal patterns of intentional fires can be determined by different living conditions and different levels of exposure to socio-economic stressors. Another important finding is to emphasize the importance of analysing specific and local patterns of fire incidents and living conditions in order to utilize them in locally-adapted fire safety policy formulations and in implementing preventative measures.

© 2014 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/3.0/>).

Contents

1. Introduction	71
2. Previous research and theoretical points of departure	72
3. Study area and data	73
4. Methods	73
5. Analysis and results	75
5.1. Spatial and spatio-temporal analysis	75
5.2. Living conditions and intentional fires	76
5.3. Clusters of sub-areas	76
5.4. Spatio-temporal distribution of intentional fires and Clusters of sub-areas	78
6. Conclusions and discussion	78
Acknowledgments	79
References	79

1. Introduction

Since the end of the 1990s, the number of fires has increased dramatically in Malmö, a city in the southernmost part of Sweden. Between 1998 and 2009, the increase was 215%, and 60% of the

fires 2009 were started deliberately, compared to 38% 1998 (Fig. 1). Furthermore, many of them took place outdoors in bins, containers and other places where paper or other combustible materials were available. Most of the fires were concentrated in a limited number of sub-areas which had poorer living conditions than the average in the city. Many schools were also affected. Between 2000 and 2011, nearly 360 intentional fires occurred in schools predominantly located in, or in close proximity to, disadvantaged neighbourhoods. In addition, major conflicts between groups of

* Corresponding author. Tel.: +46 462223279; fax: +46 462228401.

E-mail address: Nicklas.Guldaker@keg.lu.se (P.-O. Hallin).

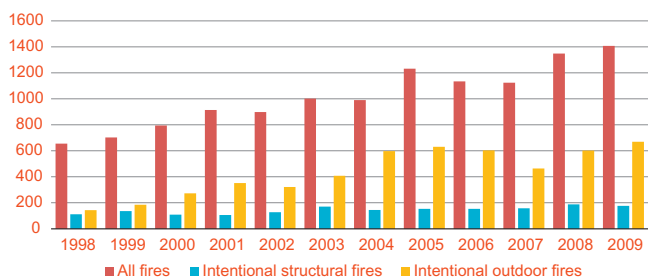


Fig. 1. Total number of fires and two categories of intentional fires in Malmö, 1998–2009.

Data source: Emergency Services South, Sweden.

teenage boys and young men on the one hand, and the police and the emergency services on the other hand, took place in December of 2008 and continued in spring of 2009. In these conflicts, fire-setting was extensively used as an instrument of conflict.

The overall aim of this paper is to deepen our understanding of the underlying causes of the spatial and the spatio-temporal distribution of intentional fires in Malmö, and more specifically, to analyse how different living conditions in Malmö sub-areas may determine the frequency of intentional fires. The concept of social stress, defined as the large part of circumstances that directly affect an individual's or family's emotions, beliefs, and behaviors, will be central in the analysis. The spatio-temporal patterns of intentional fires, social stress and socio-economic determinants will be analysed in order to develop strategies to better prevent and respond to intentional fires. The strategic and operational benefits of this paper's analysis and methods lie in showing how the emergency services and local authorities in Sweden can better understand and interpret the different spatio-temporal patterns of intentional fires and underlying living conditions, respond to specific fire risk behaviors and mitigate the effects of intentional fires in exposed neighbourhoods.

2. Previous research and theoretical points of departure

Previous studies have emphasized the importance of socio-economic determinants of building fires [1], the vulnerability of disadvantaged households [2], and the impact of household factors such as family composition on fires [2]. Furthermore, a number of studies have shown associations between socio-economic conditions and fire incidence [3,4]. In recent years, both spatial and statistical methods were used to analyse potential associations of fire incidence with socio-economic data [5,6], and to identify communities at risk [7].

There is a need for research into associations between socio-economic factors and intentional fires [8]. In one of the few studies within the field, Bohman [9] found statistically significant correlations between the number of intentional fires (dependent variable), and specifically two independent variables: number of young people (16–18 years), and level of education. However, she concluded that even though the number of young people and level of education are the strongest predictors, they must still be combined with other socio-economic variables to fully explain why some areas are more affected by intentional fires than others. This paper has the same research focus and research area as Bohman's study, i.e. intentional fires and socio-economic factors in Malmö. However, our paper differs in several ways, e.g. by combining more variables in the analysis, by applying complementary statistical methods such as a non-parametric testing based on Spearman's rank correlation coefficient, indexing variables, and in particular by considering the spatial dependence of the key variables.

Much of the related research focuses on fire setting and characteristics of the perpetrators [10]. Jennings [11] reviewed the socio-economic modeling of fire incidence with an emphasis on urban residential fires and predominantly from a U.S. perspective. Much of the social-oriented research consisted of analysing differences in fire risk between geographical areas at different scales of analysis. Most of them also involved intra-city studies. Jennings concluded that fourteen different variables have, to varying degrees, identified significant correlations between socio-spatial characteristics and different types of fires. These characteristics are: age of structure, average rent/property value, percent units occupied, percent units owner occupied, percent commercial properties, percent black population, percent population over 65, poverty rate substandard, residential structure, education, average number of persons per room, property or population density, family stability, and percentage of foreign population [11].

There is also a need for more studies that focus on arson or intentional fires from a spatio-statistical and socio-economic perspective. However, some important contributions have been made in this field. The studies that Jennings [11] identifies emphasize factors such as dilapidated housing units, non-white population, general community climate, population density, children living with both parents, and income structure. An interesting result in one of the earlier studies was the presence of an "arson culture" in some Boston areas where landlords systematically burned buildings in order to remove tenants [12]. Jennings [11] concluded that there is a lack of a well-defined theory for differential fire risk: "Without an understanding of the causes of fires and the various contributions of the social, behavioral, environmental, and economic realms, specifying the most effective policies to reduce the fire problem is nearly impossible" (p. 28 [11]).

Jennings' call for a theory for differentiating fire risks is still unheard, but in recent years, some studies have deepened the understanding of the association between fire incidence and disadvantaged areas. Using a combination of spatial statistical techniques and regression analysis Corcoran et al. [5,6] demonstrated correlations between fire incidence and socio-economic deprivation, and they also employed analytical mapping techniques to identify communities at risk (see also [13]). Furthermore, Corcoran et al. Analyzed intra-urban trends between Brisbane (Australia) and Cardiff (United Kingdom) [6]. They also called for a common deprivation index to determine differences between urban contexts [6]. However, the research described above generally includes all types of fires and does not focus specifically on arson or intentional fires.

Most of the above mentioned studies have focused on urban areas in English-speaking countries. However, major differences can be found between urban areas in different cultural contexts, not least, between many North American and European cities. One of the more significant disparities involves the different urban structures, for instance, in many American cities deprived areas with large numbers of abandoned buildings can be found close to the city centre. From a European perspective, most disadvantaged neighbourhoods are located in the outskirts of the cities, and less often, with numerous abandoned apartments or buildings that are vulnerable to fire setting.

From this brief review of previous research, the following conclusions can be drawn: there is a need for complementary case studies and comparative interurban studies from different cultural and urban contexts; and, even if many studies demonstrate statistically significant correlations between specific urban socio-economic factors and different types of fires such as intentional fires, there is still a lack of more comprehensive theories that can explain the causal mechanisms underlying the

relationship between living conditions in neighbourhoods and fire-setting. This is particularly so when explaining intentional fires, and why some types of neighbourhoods are more affected than others.

One field of research that can bridge the gap between research on intentional fires from a more structural socio-economic and spatial perspective on one hand, and research focusing more on the characteristics of fire setters, on the other, relates to theories on social stress. The association between adverse neighbourhoods, social stress, and negative outcomes such as depression, drug use, health, mental health and well-being has been extensively researched [14–20]. One of the basic assumptions in all theories on social stress is that social and economic circumstances directly influence individual has been extensively researched people's and family's emotions, beliefs, and behaviors [21,22]. Disadvantage and economic hardship affect the functioning of parents and impair their children's physical, intellectual, social, and emotional health [21]. Besides family stress factors, social stressors in the neighbourhood such as fear of crime, loitering, public drunkenness, litter, and vandalism can be embedded in the conditions of people's everyday life. This becomes even more severe when neighbourhoods are characterized by high levels of social disorganization and the absence of adequate social control [18,23–25]. Furthermore, individuals have different personality dispositions and social support, and consequently they have varying capacities to cope with social stress. Meager financial resources, limited social support and personality characteristics can lead to ineffective coping and increased vulnerability to different cataclysmic incidents in the neighbourhood or to dramatic life-events [17,26]. The findings in research on social stress can clearly be related to research on adolescent fire setting. A comprehensive number of studies show that young, predominantly male, fire setters grow up in problematic family circumstances such as large and financially impoverished families, neglectful parenting styles, physical or sexual abuse, and low parental monitoring [27,28].

The above reasoning can be summarized as follows: (a) economic and ethnic segregation leads to socially and spatially differentiated neighbourhoods in urban areas; (b) families with limited resources are forced to live in more impoverished areas which are replete with more social stressors; (c) high exposure to social stressors can lead to disrupted family relations and adolescents who grow up in problematic family circumstances with inadequate social support; (d) more young people, especially males, living in these types of areas are at greater risk to develop deviant behavior and will, under certain circumstances, be more inclined to set fire in their neighbourhoods or nearby areas. Consequently, it can be hypothesized that disadvantaged neighbourhoods that are exposed to severe social stressors and with a large group of teenage boys and young men, will be more affected by intentional fires than in other more prosperous residential areas.

3. Study area and data

Malmö is the third largest city in Sweden with more than 300,000 inhabitants in 2012. Since the mid-1970s, Malmö has gone through several crises which initially led to decreased population, de-industrialisation, and economic decline. However, since the beginning of the 1990s, the population has increased dramatically with a growing proportion of immigrants. In 2012, nearly 45% of the population was born abroad or at least had one parent per family who had. Most people live in apartments. Of the city's 147,000 dwellings, only 26,500 are single-family homes. Even though the city has gone through an economic revitalisation, approximately 14% of the workforce was listed as unemployed in the year 2012. The city has developed into an attractive place for

various types of economic and cultural activities, but at the same time, is becoming increasingly more economically, socially and spatially divided.

The city is normally divided into 136 statistical sub-areas. For this analysis, 38 non-residential areas were excluded. Consequently, 98 sub-areas are included in the analysis. Socio-economic data related to the sub-area level have been collected on a yearly basis from 2000 to 2008, from Malmö City's web-site and from the longitudinal dataset known as the city's *Area facts*, which covers the years 1995–2008 [29]. This dataset is based on both local and national sources such as *Malmö Urban Planning Office* and *Statistics Sweden*. All variables were examined in order to increase the reliability of the analysis. Corrections to the dataset were made for obviously incorrect and missing data, new sub-area divisions, and changes in variables during the period.

The socio-economic variables used in the study are population, unemployment rate, overcrowding (average number of family members per room), descent (proportion of inhabitants born abroad), education (proportion of the population who has only attended lower secondary school), and proportion of young males, 6–18 years old. All proportions have been calculated based on the number of inhabitants per sub-area. The average number of family members per room (overcrowding) was calculated by dividing the population with the number of rooms of all dwellings in each sub-area.

Fire incident records were provided by the Emergency Services South in Sweden. Fire statistics cover two time periods at two different geographical scales; the 2000–2008 dataset is based on fire statistics on the sub-area level; the 2007–2008 dataset consists of geocoded coordinates of fires. Intentional fire is defined as a fire that is started deliberately and is distinguished from unintentional fires such as fires caused by electrical and mechanical deficiencies [7]. Intentional fires are divided into two main categories: intentional fires in buildings (intentional structural fires) and intentional outdoor fires. The rise of intentional fires in Malmö during the 2000s consists mainly of intentional outdoor fires (Fig. 1). In the statistical analysis, both types of intentional fires are merged and normalized to the number of fires per 1000 inhabitants and at the sub-area level.

Before commencing the statistical and spatial analysis, the fire incidents and socio-economic data were geocoded and added to a comprehensive geodatabase at Malmö University and Lund University [30]. In addition, the geodatabase was connected to, and processed in, both SPSS and ArcGIS.

4. Methods

In the study, spatio-statistical methods were employed for spatial and spatio-temporal analysis. The Kernel Density Estimation (KDE) method was applied to create a smooth density surface of point events (intentional fires) over space. KDE is one of several methods for analysis of point event distribution, also known as point pattern analysis (PPT) [31]. One main advantage of KDE in this analysis opposed to other statistical hot spot and clustering methods lies in the estimation of an increased likelihood of an event (fire) to occur in a defined cluster [32]. The method is commonly used in the analysis of crime clusters [33–35]. The KDE-model aims to highlight local patterns of intentional fires. The parameters are adjusted accordingly to obtain these patterns. To minimize the risk of suppressing the spatial variation and obtain local patterns, the cell size was set at 30 m, and the bandwidth, at 300 m. Identified problems with KDE-models consist of smoothing between the areas and a focusing on the most concentrated areas. Therefore, it is important to test whether the hot spots are statistically significant. The Average Nearest Neighbor tool in

ArcGIS was employed to perform a Nearest Neighbor (NN) analysis in order to determine whether these calculated fire patterns are statistically significant and whether they are likely explained by causes other than random chance (see Section 5). Furthermore, significance lines (black and red polylines in Fig. 2) were created to visualize the location of significant hot spots of intentional fires in the city. In order to emphasize areas with higher risk of intentional fires, the polylines were set at cluster values of two standard deviations from zero. The spatial analysis tool that was used for this purpose is Contour List [33]. Spatio-temporal analysis was performed by dividing the day into three periods: daytime, evening and night (Fig. 3).

In the analysis of the relation between living conditions and intentional fires, different quantitative statistical methods were employed. By compiling five variables, an additive index measuring living conditions through social stress factors was constructed (Index of Living Conditions, ILC). The reliability of the index was tested by calculating Cronbach Alpha. Mean values were calculated for each variable and for each sub-area for the period 2000–2008, and then, each variable was standardized to a minimum of 0 and a maximum of 1. Each of the five variables was given equal weighting, and the additive index can range between 0 and 5. The variables chosen are unemployment rate, overcrowding – number of persons per room, proportion of inhabitants born abroad, proportion of the population that only had lower secondary school education, and proportion of young males, 6–18 years (group of potential perpetrators). In Table 1, the relations between social stress factors (stressors) and used variables (indicators) are presented. The reliability of the index was tested by calculating Cronbach Alpha. The Index of Living Conditions (ILC) can be compared with other types of social indices that have been employed in analysing incidences of fires, such as the Index of Relative Socio-Economic Disadvantage [1] or Advantage Disadvantage Index [6]. All indexes try to capture conditions in different

social settings, but ILC differs primarily because it is designed to explain only intentional fires and not unintentional fires such as accidental and natural fires.

Based on the assumption of a rejected 0-hypothesis of normality for the variables *Index of Living Conditions* and *Intentional fires per 1000 inhabitants*, Spearman's (nonparametric) Rank Correlation Coefficient (r_s) was calculated [36,37]. Since both variables are derived from spatial locations and the spatial dependency may influence the statistical outcome, a spatial autocorrelation test – Moran's I – was carried out at the sub-area level. The spatial autocorrelation was tested for distances between 500–6000 m. Based on the fact that the data set is not large, the selected conceptual model of spatial relationships was *Zone of indifference*. It is important here to emphasize that other geographic units (grids, smaller or larger zones) were not used in this study and may yield different results [36].

SPSS Two Step Cluster Analysis was employed in order to reveal clusters among the analysed sub-areas, i.e. to identify sub-areas with similar characteristics. The main reason for grouping sub-areas into clusters is to identify different socio-economic environments in order to develop specific, and for each group of sub-areas, adapted proactive measures and strategies. Cluster analysis is an exploratory technique that has been widely used in different disciplines for its partitioning ability. The SPSS Two Step Cluster Analysis consists of two steps [38].

Step 1: Pre-clustering of cases where a sequential method is used to pre-cluster the cases. A new data matrix with fewer cases for the following step is calculated.

Step 2: Clustering of cases where a model-based hierarchical technique is applied. Pre-clusters are merged stepwise using the standard agglomerative clustering algorithm, where a range of solutions is produced, which is then reduced to the best number of clusters based on Schwarz's Bayesian inference criterion (BIC) [39,40].

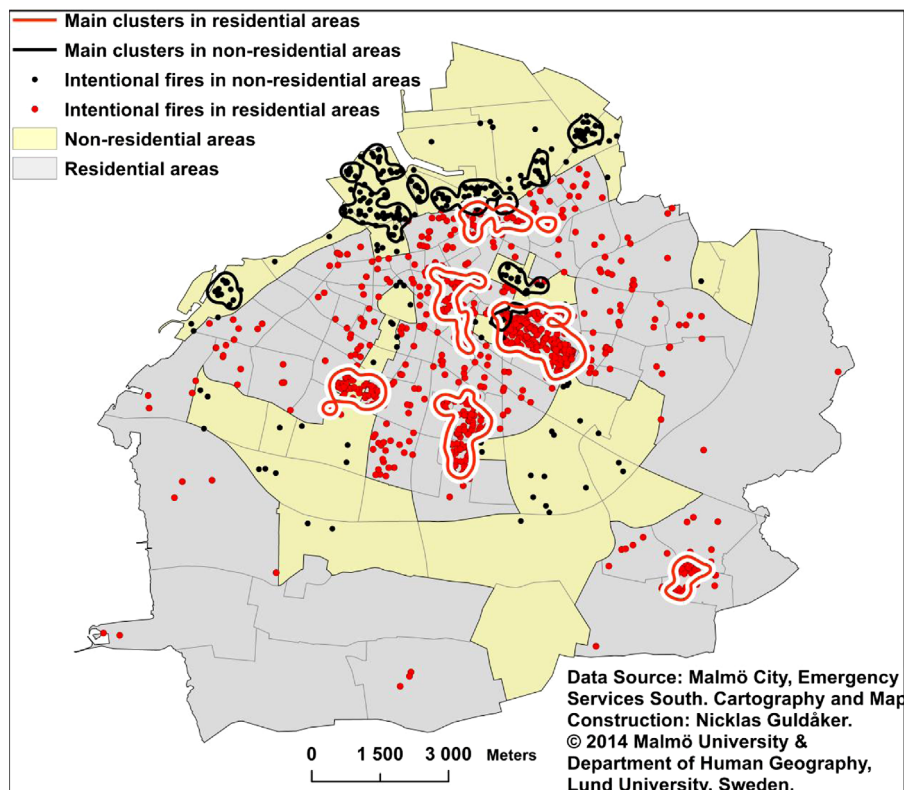


Fig. 2. Main clusters of Intentional fires in residential and non-residential sub-areas, 2007–2008.

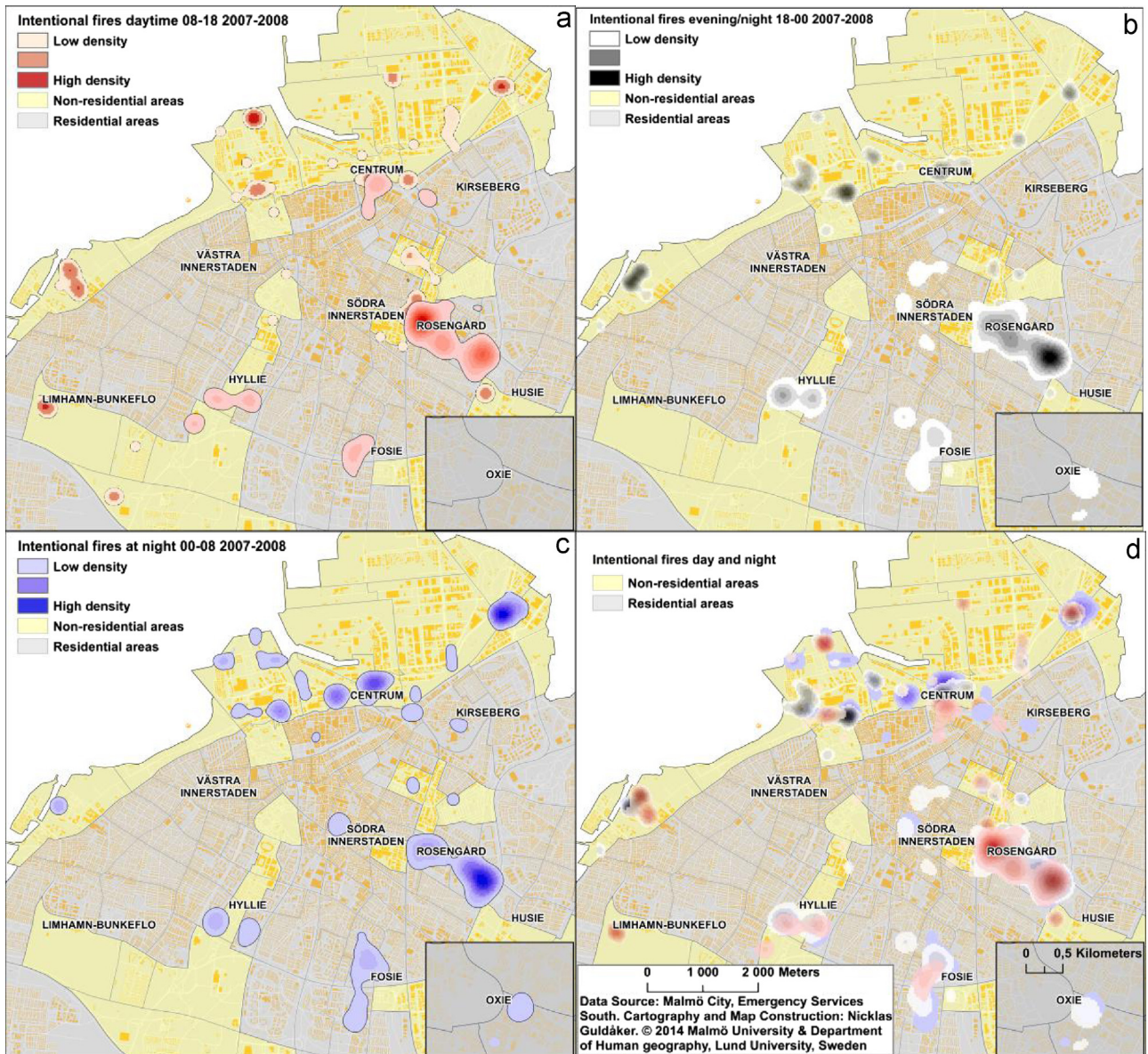


Fig. 3. a-d. Intentional fires in residential and non-residential sub-areas – three periods of the day.

Table 1
Relations between social stress factors (stressors) and variables used (indicators).

Social stress factors	Variables
Economic stress – limited economic self-sufficiency due to unemployment or insufficient education	Unemployment rate.
Ethnic segregation – ethnic segregated housing market	Proportion of the population that only has lower secondary school as education.
Severe living conditions – dwelling does not suit family needs	Proportions of inhabitants born abroad.
Family situation – high proportion of children and adolescents	Overcrowding – number of per persons per room.
	Proportion of young males, 6–18 years (risk group of potential perpetrators)

The same five variables that were used to construct the ILC were also employed in the cluster analysis. One-Way ANOVA was employed to test the hypothesis that the mean values of number of intentional fires per 1000 inhabitants do not differ significantly between the identified clusters. For all spatial and statistical analyses, the software programmes, ArcGIS and SPSS were used.

5. Analysis and results

5.1. Spatial and spatio-temporal analysis

The spatial and spatio-temporal distribution of intentional fires is concentrated within a limited number of sub-areas. Nine hot

spots of intentional fires are identified in non-residential sub-areas and six hot spots of intentional fires in residential areas (Fig. 3). Intentional fires in non-residential areas are assumed to have other causes, such as theft of copper cables and fire setting in order to expose copper, than intentional fires in residential sub-areas [41]. For that reason they are excluded in the further analysis. Several hot spots of intentional fires in residential sub-areas, such as Fosie, Hyllie and Rosengård, show high density of fires at all times of the day. It is also noteworthy that the hot spot centres, shown as the darkest red, black or blue colours, vary according to time of day (Fig. 3). Other hot spots seem to be related to evenings and, to some extent, night-time activities, such as the hot spot in Södra Innerstaden and Oxie. The hot spot in Södra Innerstaden is located in a sub-area with many restaurants, nightlife and other business activities, and consequently, the area is frequented by people in the evenings (Figs. 3b and 3c).

The results from the Nearest Neighbor (NN) analysis show that the observed mean distance is considerably lower than the estimated (hypothetical) average distance for all spatial and spatio-temporal clusters of intentional fires (Figs. 2,3 and 7). In these cases, the test probability value for statistical significance is also less than 0.01 (confidence interval 99%). The NN analysis indicates that the observed spatial pattern of intentional fires most likely can be explained by causes other than random chance.

5.2. Living conditions and intentional fires

The spatial and spatio-temporal analysis indicates that there is a relationship between intentional fires and certain residential sub-

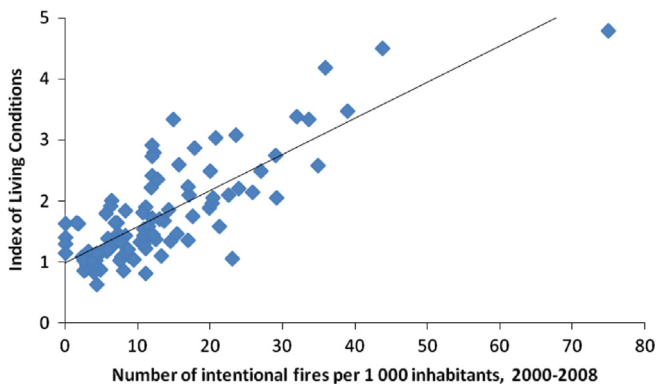


Fig. 4. Correlation between Index of Living Conditions and Intentional fires per 1000 inhabitants, 2000–2008. $N=98$, $r_s=0.714$, $p < 0.01$.

areas. But what characterize these areas, and how do they differ from other less afflicted sub-areas? In this paper, we will build on earlier research by developing an Index of Living Conditions based on exposure to social stressors. The Cronbach Alpha value is calculated at 0.808, which indicates a good internal consistency among tested variables. This index is then correlated to intentional fires. In Fig. 4, the correlation between the number of intentional fires (both structure-related and outdoor fires) per 1000 inhabitants and ILC is presented. The scale ranges from 0 to 5, where 0 is Living Conditions with low degree of exposure to Social Stressors and 5 is high exposure to Social Stressors. As is shown in the figure, there is a strong correlation between living conditions and intentional fires in residential sub-areas ($r_s=0.714$). A spatial autocorrelation test of the variables, intentional fires per 1000 inhabitants and ILC, indicates a positive and significant spatial dependence and a strong clustering of both variables. The spatial dependence is strongest between 500 and 5500 m for ILC, and between 600 and 5500 m for intentional fires. The next step in the analysis is to analyze more carefully how the sub-areas differ and whether significant clusters of sub-areas can be identified.

5.3. Clusters of sub-areas

Based on the same five variables that provided the basis for the Index of Living Conditions, a Two Step Cluster Analysis identified three clusters of sub-areas with varying degrees of exposure to social stressors (Table 2). The spatial distribution of the clusters is presented in Fig. 5. Cluster 1, with low levels of exposure to social stressors, consists of 42 sub-areas located predominantly in the western and eastern part of the city. Cluster 1 has lower rates of unemployment, lower numbers of family members per room, and lower rates of inhabitants born abroad than both Cluster 2 and Cluster 3. However, Cluster 1 has about the same proportion of young males as Cluster 3, and the same proportion of inhabitants with only secondary school education as Cluster 2. Cluster 2, with a medium level of exposure to social stressors, consists of 37 sub-areas that are primarily located in the central part of the city. Cluster 2 differs from Cluster 1 in its higher degree of unemployment, more family members per room, higher proportion of inhabitants born abroad, and a lower proportion of young males.

Cluster 2 differs from Cluster 3 in its lower rates of unemployment, less family members per room, lower proportions of inhabitants that are born abroad, and a lower proportion of the population with education at only secondary school level. Cluster 2 also differs from Cluster 3 in its lower proportion of young males. Cluster 3, with its high levels of exposure to social stressors, consists of 19 sub-areas that are located in the southern and

Table 2
Cluster characteristics (means 2000–2008) and predictor importance of variables.

Cluster of sub-areas	Number of sub-areas (%)	Proportion of unemployment	Average number of persons per room	Proportion of inhabitants born abroad	Proportion of young males, 6–18 years	Proportion of only secondary school level	Number of intentional fires per 1000 inhabitants
Cluster 1: Low Social Stress sub-areas	42 (42.9)	0.03	0.41	0.14	0.10	0.15	08.75
Cluster 2: Medium Social Stress sub-areas	37 (37.8)	0.05	0.65	0.21	0.04	0.15	10.95
Cluster 3: High Social Stress sub-areas	19 (19.4)	0.08	0.82	0.47	0.09	0.28	26.91
Overall means for sub-areas		0.05	0.58	0.23	0.08	0.18	13.1
Predictor importance	98	1.00	0.82	0.76	0.52	0.43	

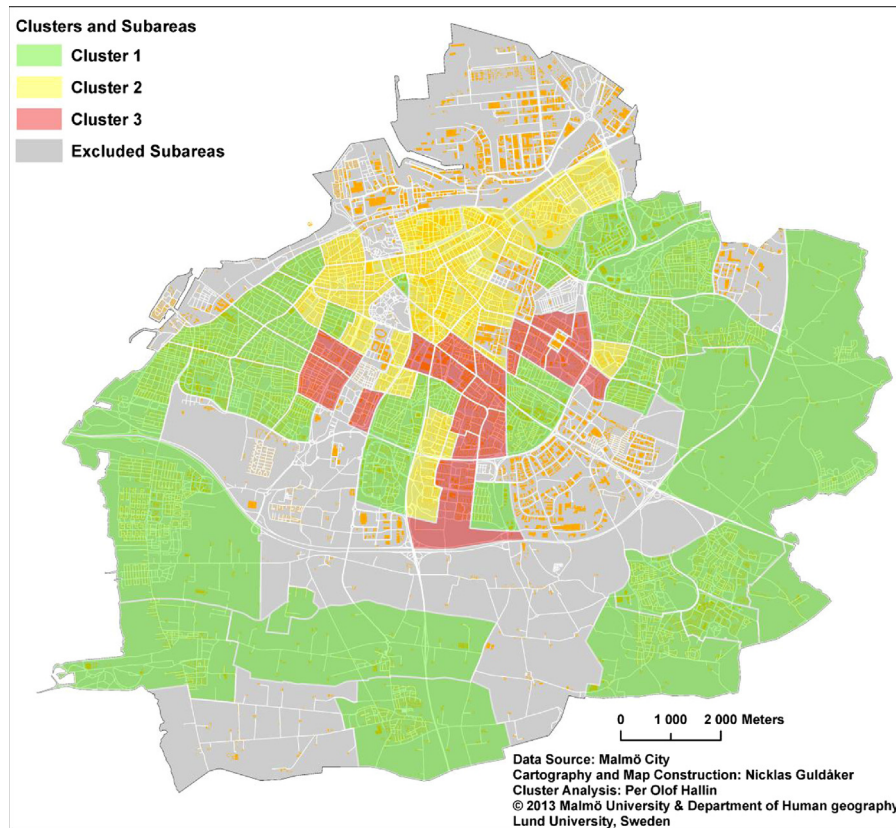


Fig. 5. Three clusters of sub-areas with varying degrees of exposure to social stressors.

Table 3
One-Way Analysis of Variance (ANOVA) regarding Clusters and Intentional fires per 1000 inhabitants.

Intentional fires per 1000 inhabitants								
Cluster	N	Mean	Std. deviation	Std. error	95% Confidence interval for mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	42	8.7483	6.78782	1.04738	6.6331	10.8635	0.00	29.17
2	37	10.9523	5.91744	0.97282	8.9793	12.9253	0.00	25.91
3	19	26.9113	15.43941	3.54204	19.4697	34.3528	11.99	74.98
Total	98	13.1018	11.13678	1.12498	10.8690	15.3346	0.00	74.98

ANOVA					
Intentional fires per 1000 inhabitants					
	Sum of Squares	df	Mean square	F	Sig.
Between Groups	4590.304	2	2295.152	29.305	0.000
Within Groups	7440.393	95	78.320		
Total	12030.697	97			

southeastern parts of the densely populated sub-areas of the city. Cluster 3 differs from Cluster 1 and Cluster 2 in its higher levels of unemployment, higher average number of persons per room, a higher proportion of the population born abroad, and a higher proportion of inhabitants with education at only secondary school level. Interestingly, Cluster 3 has about the same proportion of young men as Cluster 1. There is a clear spatial separation between the clusters, where sub-areas characterized with a low degree of social stressors are localized in the western and eastern part of the city, sub-areas with medium social stressors are to be found in the central parts of the city, and sub-areas with high exposure to social stressors are located in the southern part of the city (Fig. 5).

The three clusters differ regarding the occurrence of intentional fires per 1000 inhabitants. Cluster 1 has 8.75 intentional fires per 1000 inhabitants, Cluster 2 has 10.95 and Cluster 3 has 26.91 intentional fires per 1000 inhabitants. A one-way analysis of variance (ANOVA) shows that the difference between the means is statistically significant ($p < 0.000$) (Table 3), and a Post Hoc Test (Tukey) shows that the major difference between the clusters is between Cluster 1 and Cluster 2 on one hand and Cluster 3, on the other (Table 4 and Fig. 6). Compared with Cluster 1 and Cluster 2, Cluster 3 has higher values for all variables except the proportion of young males. On the other hand, Cluster 1 has about the same proportion of young males but has the lowest numbers of

Table 4
Post Hoc Test of Variance. Dependent Variable: Intentional fires per 1000 inhabitants. Tukey HSD.

(I) twostep cluster number	Mean difference (I-J)	Std. error	Sig.	95% Confidence interval		
				Lower bound	Upper bound	
1	2	-2.20399	1.99537	0.514	-6.9550	2.5470
	3	18.16297*	2.44681	0.000	-23.9888	-12.3371
2	1	2.20399	1.99537	0.514	-2.5470	6.9550
	3	15.95897*	2.49777	0.000	-21.9062	-10.0118
3	1	18.16297*	2.44681	0.000	12.3371	23.9888
	2	15.95897*	2.49777	0.000	10.0118	21.9062

* The mean difference is significant at the 0.05 level.

intentional fires per 1000 inhabitants. This leads to the conclusion that it is not the proportion or the number of young males in itself, but rather, the combination of high exposure to different social stressors and high proportion of young males in a sub-area that create the conditions for an increased number of intentional fires.

5.4. Spatio-temporal distribution of intentional fires and Clusters of sub-areas

In Fig. 7, the spatio-temporal distribution of intentional fires in residential sub-areas, or in their immediate vicinities, is presented for the years of 2007–2008. Three time periods of the day are analysed: daytime, evening and night-time. For each time period, the distribution of hot spots of intentional fires is presented and related to cluster membership of the sub-areas. The density within each cluster is indicated with gradually darker colours. During daytime, hot spots of intentional fires are predominantly located in Cluster 3 areas, with the exception of two low-density hot spots in Cluster 2 areas (Centrum, Kirseberg). During the evening, the number of hot spots increase and the spatial distribution become more dispersed. During this time period, hot spots identified during daytime also expand and cover larger areas. Furthermore, a new low-density cluster emerges in a Cluster 1 sub-area (Oxie) in the southwest part of Malmö housing a large number of teenagers and young men. During night-time, the number of hot spots decreases slightly but is still concentrated to Cluster 3 sub-areas with the exception of the aforementioned low density hot spot in Oxie. The spatio-temporal analysis confirms that Cluster 3 sub-areas are affected with increasingly more coherent high-density hot spots of intentional fires than Cluster 2 and Cluster 1 sub-areas. Altogether, about 9–10 Cluster 3 sub-areas are affected by hot spots of intentional fires. However, even in a limited number of Cluster 1 and Cluster 2 sub-areas, hot spots gradually emerge but with a lower density than in Cluster 3 areas.

6. Conclusions and discussion

The aim of this paper is to deepen our understanding of the underlying causes of the spatial and the spatio-temporal distribution of intentional fires in Malmö, and to analyse how different living conditions in Malmö sub-areas may determine the frequency of intentional fires. The main conclusion of the study is that spatio-temporal patterns of intentional fires are determined by different living conditions and different exposure to socio-economic stressors. People living in sub-areas with stressful living conditions are also more likely to be affected by intentional fires. The analysis shows that the combination of high exposure to

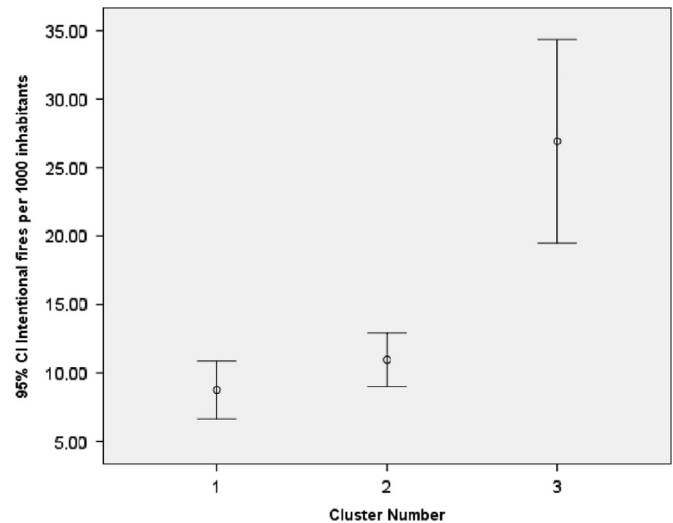


Fig. 6. Variance in intentional fires per 1000 inhabitants within each cluster.

different social stressors and high proportion of young males in a sub-area increases the risk of more frequent intentional fires. However, this is not the case for all sub-areas of this kind. The spatio-temporal hot spot analysis reveals that there are sub-areas with high-stress living conditions which are not afflicted by concentrations of intentional fires. Also a different pattern can be observed in the analysis: emerging hot spots of intentional fires are found in sub-areas with low-stress living conditions. This result emphasizes the importance of analysing more carefully the specific and local patterns of fire incidence and living conditions in order to utilize them in locally-adapted fire safety policy formulations and to implement preventive measures. In addition, to better understand and interpret spatial and temporal analyses of intentional fires and underlying living conditions, the emergency services and local authorities should be involved in the development and implementation of preventive measures.

Based on this study and on ongoing research in Malmö's western district [42], we propose three different types preventive measures. The first group of actions focuses on structural measures and how people in affected areas can be supported in improving their living conditions and thus, increasing their fire safety. Also, actions aimed at supporting the local population's initiatives to increase their capabilities to organize and execute different courses of action (collective efficacy) may be an effective measure [25]. The second group of proactive measures consists of actions focusing on specific social risk groups or individuals that may be potential fire setters. The third group of measures focuses on situational actions that, for instance, may be taken to remove flammable objects in risk-exposed places, or to improve surveillance measures and thus, increase the probability of detection.

Furthermore, the spatial dependency in the data indicates that complementary methodological approaches are needed to expand the study of underlying socio-economic and spatio-temporal processes at the local level. These include techniques such as Geographically Weighted Regression (GWR) which can be used to explore spatially varying relationships among the correlated variables. Interviews with the staff from the emergency services, the local police, the city district administration, schools, residents, adults and children living in different sub-areas may also help explain spatial differences and spatial interaction processes among residents and especially, young people, in different neighbourhoods. This research is already in process in Malmö's western district [42].

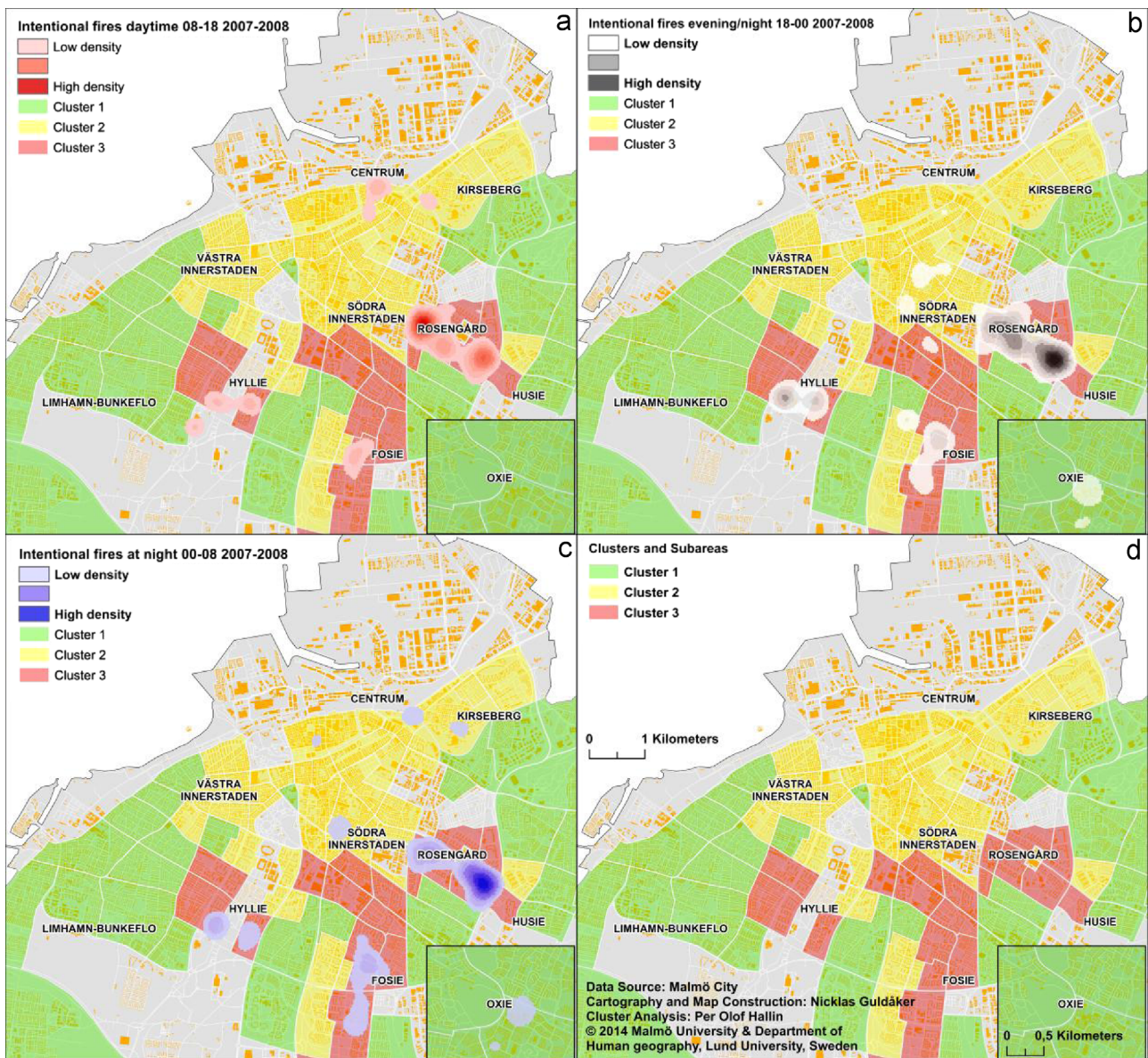


Fig. 7. a–d. Spatio-temporal hot spots of intentional fires in residential sub-areas and three Clusters of sub-areas with varying degrees of exposure to social stressors.

Acknowledgments

This work was conducted within the framework of The Swedish Fire Research Board's (Brandforsks) research program on arson in Sweden 2010–2012 (see <http://www.brandforsk.se/>). The authors would like to thank the Board for their support and feedback.

References

- [1] P. Chhetri, J. Corcoran, R. Stimson, R. Inbakaran, Modelling potential socio-economic determinants of building fires in south east Queensland, *Geogr. Res.* 48 (1) (2010) 75–85.
- [2] Federal Emergency Management Agency (FEMA), Socio-economic factors and the incidence of fire, National Fire Data Centre, United States Fire Administration, Report No. FA170, 1997.
- [3] S.E. Chandler, A. Chapman, S.J. Hallington, Fire incidence, housing and social conditions in the urban situation in Britain, *Fire Prevention* 172 (1984) 15–20.
- [4] M. Duncanson, A. Woodward, P. Reid, Socioeconomic deprivation and fatal unintentional domestic fire incidents in New Zealand 1993–1998, *Fire Saf. J.* 37 (2) (2002) 165–179.
- [5] J. Corcoran, G. Higgs, C. Brunson, A. Ware, The use of co-maps to examine the spatial and temporal dynamics of fire incidents: a case study in South Wales, UK, *Prof. Geograph.* 59 (4) (2007) 522–537.
- [6] J. Corcoran, G. Higgs, A. Higgison, Fire incidence in metropolitan areas: a comparative study of Brisbane (Australia) and Cardiff (United Kingdom), *Appl. Geogr.* 31 (2011) 65–75.
- [7] A. Asgari, A. Ghaffari, J. Levy, Spatial and temporal analyses of structural fire incidents and their causes: a case of Toronto, Canada, *Fire Saf. J.* 45 (1) (2010) 44–57.
- [8] S.-Å. Lindgren, M. Björk, H. Ekbrand, S. Persson, S. Uhnöo, Juvenile fire-setting – causes and countermeasures, Department of Sociology and Work Science (2013) 1–76 (Report in Swedish with English summary).
- [9] H. Bohman, Causes of intentional firesetting: a macro perspective, in: H. Bohman, M. Gerell, J. Lundsten, M. Tykesson (Eds.), *Fires in the city, Part 2*, Malmö University Publications in Urban Studies, Malmö, 2013, pp. 26–39 (Report in Swedish).
- [10] C.T. Putnam, J.T. Kirkpatrick, Juvenile Firesetting: A Research Overview, U.S. Department of Justice (Office of Juvenile Justice and Delinquency Prevention) (2005) 1–8.
- [11] C.R. Jennings, Socioeconomic characteristics and their relationship to fire incidence: a review of the literature, *Fire Technol.* 35 (1) (1999) 7–34.
- [12] R. Syron, An Analysis of the Collapse of the Normal Market for Fire Insurance in Substandard Urban Core Areas, Federal Reserve Bank of Boston, Research Report, Boston (1972) 159–162.

- [13] J. Corcoran, G. Higgs, C. Brunson, A. Ware, P. Norman, The use of spatial analytical techniques to explore patterns of fire incidence: a South Wales case study, *Comput. Environ. Urban Syst.* 31 (6) (2007) 623–647.
- [14] C. Aneshensel, Social stress, Theory and research, *Annual Review Sociology* 18 (1992) 15–38.
- [15] J.D. Boardman, B.K. Finch, C.G. Ellison, D.R. Williams, J.S. Jackson, Neighborhood disadvantage, stress, and drug use among adults, *J. Health Social Behav.* 42 (2) (2001) 151–165.
- [16] C.E. Cutrona, G. Wallace, K.A. Wesner, Neighborhood characteristics and depression: an examination of stress processes, *Current Directions in Psychological Science* 15 (4) (2006) 188–192.
- [17] M. Elliot, The stress process in neighborhood context, *Health Place* 6 (2000) 287–299.
- [18] C.A. Latkin, A.D. Curry, Stressful neighborhoods and depression: a prospective study of the impact of neighborhood disorder, *J. Health Social Behav.* 44 (2003) 34–44.
- [19] A. Steptoe, P.J. Feldman, Neighborhood problems as sources of chronic stress: development of a measure of neighborhood problems, and associations with socioeconomic status and health, *Annals of Behavioral Medicine* 23 (3) (2001) 177–185.
- [20] S.E. Stockdale, K.B. Wells, L. Tang, L. Zhang, C.D. Sherbourne, The importance of social context: neighborhood stressors, stress-buffering mechanisms, and alcohol, drug, and mental health disorders, *Social Science & Medicine* 65 (9) (2007) 1867–1881.
- [21] R.D. Conger, K.J. Conger, Understanding the processes through which economic hardship influences families and children, in: R. Crane, E. Marshall (Eds.), *Handbook of Families and Poverty: Interdisciplinary Perspectives*, Sage Publications, Thousand Oaks, CA, 2008, pp. 64–81.
- [22] R.D. Conger, M.B. Donnellan, An interactionist perspective on the socioeconomic context of human development, *Annu. Rev. Psychol.* 58 (2007) 175–199.
- [23] W.G. Skogan, *Disorder and Decline: Crime and the Spiral of Decay in American Neighborhoods*, Free Press, New York, 1990.
- [24] C.H. Kubrin, R. Weitzer, new directions in social disorganization theory, *Journal of research in crime and delinquency* 40 (4) (2003) 374–402.
- [25] R.J. Sampson, S.W. Raudenbusch, F. Earls, Neighborhoods and violent crime: a multilevel study of collective efficacy, *Science* 277 (5328) (1997) 918–924.
- [26] J. McLeod, R. Kessler, Socioeconomic status differences in vulnerability to undesirable life events, *J. Health Social Behav.* 31 (2) (1990) 162–172.
- [27] A. Gannon, A. Pina, Firesetting: psychopathology, theory and treatment, *Aggress. Violent Behavior* 15 (3) (2010) 224–238.
- [28] S. MacKay, A. Feldberg, A.K. Ward, P. Marton, Research and practice in adolescent firesetting, *Crim. Justice Behav.* 39 (2012) 842–864.
- [29] Malmö City's Area fact, (<http://www.malmo.se/Kommun-politik/Om-oss/Stadistik/Omradesfakta-for-Malmo-1995-2008.html>), 15.8.14.
- [30] The M-database at Lund University, (<http://anjelika.keg.lu.se/>), 15.8.14.
- [31] Z. Xie, J. Yan, Kernel density estimation of traffic accidents in a network space, *Comput. Environ. Urban Syst.* 32 (2008) 396–406.
- [32] T.K. Anderson, Kernel density estimation and K-means clustering to profile road accident hotspots, *Accident Analysis and Prevention*, *Accident Analysis and Prevention* 41 (2009) 359–364.
- [33] W.L. Gorr, K.S. Kurland, *GIS Tutorial for Crime Analysis*, ESRI Press, Redlands, California, 2012.
- [34] T. Nakaya, K. Yano, Visualising crime clusters in a space-time cube: an exploratory data-analysis approach using space-time kernel density estimation and scan statistics, *Transactions in GIS* 14 (3) (2010) 223–239.
- [35] M.S. Gerber, Predicting crime using twitter and kernel density estimation, *Decis. Support Syst.* 61 (3) (2014) 115–125.
- [36] P.A. Rogerson, *Statistical Methods for Geography*, Second edition, Sage, London, 2001.
- [37] J. Hauke, T. Kossowski, Comparison of values of Pearson's and Spearman's correlation coefficients on the same set of data, *Quaestiones Geographicae* 30 (2) (2011) 87–93.
- [38] T. Chiu, D. Fang, J. Chen, Y. Wang, & C. Jeris, A robust and scalable clustering algorithm for mixed type attributes in large database environment, in *Proceedings of the 7th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, 2001, pp. 263–268.
- [39] J. Bacher, K. Wenzig, M. Vogler, SPSS TwoStep Cluster – a First Evaluation, Retrieved July 2.7.14, from (<http://www.statisticalinnovations.com/products/twostep.pdf>) 15.08.14.
- [40] S. Okazaki, What do we know about mobile Internet adopters? A cluster analysis, *Information & Management* 43 (2006) 127–141.
- [41] N. Guldåker, P.-O. Hallin, Fires in the city, Part I: Intentional fires and the social geography of Malmö, Malmö University Publications in Urban Studies, 2013 (Report in Swedish with English summary).
- [42] M. Gerell, P.-O. Hallin, Kroksbäck – a residential area with many faces and great potential (Working paper), Department of urban studies, Malmö University, 2014.