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# Spatial Point Process Analysis of Maoist Insurgency in India

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## Abstract

Maoist insurgency is considered as the single largest internal security challenge ever faced by India since its independence. Our initial analysis showed that the intensity of Maoist insurgency was high in those districts of Chattishgarh where both the education and income index components of human development index were low. This analysis concur with recent UNESCO report “Education under attack, 2010”. This means delivering the development is a crucial step to win the battle against Maoist rebels. However, it is difficult to deliver the development in high conflict region, unless we recognize the pattern of Maoist insurgency.

Recently, central and six state governments together jointly started a massive counterinsurgency operation. As the battle between Maoist rebels and the Indian security forces intensified, both sides have suffered considerable losses. In this paper we presented a spatial point pattern analysis of the Maoist attack and the Maoist losses. We considered the location of events, i.e., Maoist attack or losses, as the random point and used spatial point process models, which account for randomness in the observed locations. Our analysis showed that the intensity of the Maoist attack is higher than their losses during the first four months of 2010.

**Keyword:** Log Gaussian Cox process, Insurgency, Poisson Regression, Spatial Regression, Public Policy Management

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# 1 Introduction

India is facing a decades-long Maoist insurgency that stretches across more than six states and has resulted more than 500 deaths annually since 2005. The stated goal of Maoist insurgency is to overthrow the democratically elected Indian government by rejecting parliamentary democracy and capturing political power through protracted armed struggle based on guerrilla warfare. Maoist insurgency has grown from the margins, four decades ago to become, in the words of Prime Minister Manmohan Singh, “the single biggest internal security challenge ever faced by our country” (Robinson, May 29, 2008).

The Maoist insurgency in India, also known as ‘Naxal-Maoist insurgency’, started as a peasant rebellion at ‘Naxalbari’, a small Indian village in 1967. The rebels say they are fighting for the poor and they operate in a large swathe of territory across the central and eastern part of India (BBC, 2009). This area, which accounts for about 50 districts of seven of different states, is economically backward and heavily populated by Dalits and Adivasi, i.e., tribal groups of India. Among many districts in India where Maoists have very strong control, Dantewada, Bastar and Rajnandgaon district of Chhattisgarh state, are the three most affected districts by the Maoist insurgency. Interestingly the Human Development Index (HDI) in 2005 for these districts were 0.441, 0.264 and 0.374 respectively (Table 1), which were as low as the countries with lowest HDI of the world, such as Afghanistan (0.347) and Niger (0.330) on the same year. Though India experienced a rapid economic growth in last two decades, inefficient local government failed to deliver the comprehensive human development in the districts which are affected by the Maoist insurgency.

Murshed and Gates (2005) showed that during the Nepalese civil war, which began in 1996, the intensity of Maoist insurgency was most severe in mid and far western region of Nepal, which were economically most disadvantaged in terms of HDI. Though several allegations were made regarding the operational link between Communist Party of Nepal (Maoist) and Communist Party of India (Maoist), both group has denied any such cooperation. We believed that since India and Nepal are neighboring countries, Indian Maoist might follow the Nepalese model to increase their sphere of

influence.

To check the hypothesis that the intensity of Maoist insurgency would be severe in the region with low HDI, we implemented the Poisson regression analysis on the data from Chhattisgarh, presented in Table 1. We consider  $Y_i$  the number of Maoist attack at the district  $i$ , as the response variable and HDI as the explanatory variable, where

$$Y_i \sim \text{Poisson}(\lambda_i), \quad \lambda_i = \exp(\beta_0 + \beta_1 \text{HDI}_i). \quad (1)$$

A likelihood analysis using ‘glm’ function of R software is presented in Table 2. The negative estimate of  $\beta_1$  (-4.4060 with P-value 0.0185), significant at 5% level, indicates that the district with low HDI have significantly higher intensity of Maoist attack.

The HDI is made up of three components, namely ‘Education index’ (Edu), ‘Income index’ (Inc) and ‘Health index’ (Health). The Poisson regression analysis with several combination of the three variables with higher order interactions was conducted. Here we presented the likelihood analysis of the following two models,

$$\lambda_i = \exp(\beta_0 + \beta_1 \text{Edu}_i + \beta_2 \text{Inc}_i + \beta_3 \text{Health}_i), \quad (2)$$

$$\lambda_i = \exp(\beta_0 + \beta_1 \text{Edu}_i + \beta_2 \text{Inc}_i + \beta_3 \text{Health}_i + \beta_4 \text{Edu}_i \times \text{Inc}_i), \quad (3)$$

which demonstrate that the intensity of Maoist attack is a function of education, income and health indices in model 2. In addition, an interaction effect between income and education is being incorporated in the model 3. The likelihood analysis presented in Table 3 for model 2, we conclude that the education is the largest significant predictor for the Maoist attack and the negative slope implies that the district with poor education indices have high intensity of Maoist attack.

The likelihood analysis presented in Table 4 for model 3 shows that the income, education and interaction between the two variables have the significant impact over the intensity of Maoist attack. Corresponding surface plot, presented in figure 1, reveals that the intensity of Maoist attack is high in those districts where both education and income indices are low.

The data was also analyzed using zero-inflated Poisson regression model with the intensity of Maoist attack as  $\lambda_i$ , modeled by (1), (2) and (3) separately. The analysis was implemented

using 'pscl' package in R software and the results are presented in Table 5, 6 and 7. Overall, conclusion of the analysis from zero-inflated Poisson regression coincide with that of the regular Poisson regression models.

This observation concurs with the recent report by UNESCO (2010) titled 'Education under Attack 2010'. The report said that the attacks on schools and teachers have intensified in last three years. It has documented that, between 2006 and 2009, more than 300 schools of Chhattisgarh, Jharkhand and Bihar were blown up by the Maoist (UNESCO 2010, page 21) and there was a significant hike in the recruitment of children by Maoists during the same time. Note that our Poisson regression analysis is based on 2005 data.

Destruction of schools is a brutal combat tactics that Maoists have always implemented since their very conception . This not only terrorize the victims to submission but also demolishes their morale. The Indian scenario was made more complicated by the routine usage of schools as military base camps by the Indian Security Force (ISF), thus blurring the line between civilian and military targets (UNESCO 2010, Page 18). This 'questionable' tactics of ISF had inevitably put the children and teachers at risk. This enraged the villagers and resulted in the loss of local support and had shrunk the sources of the strategic information. Additionally the Maoist were also given pretext to attack the schools and defend these deplorable actions as was observed in one of their public statement issued on October 2006:

“As for destroying schools used by the CRPF [Central Reserve Police Force, a state-controlled paramilitary police force] as their camps, neither the people nor our Party think is wrong. The schools, once they are occupied by these forces, are transformed into torture chambers and concentration camps and there is no hope that they will once again be used as schools in the near future. Education of the adivasis [tribal communities] is not affected by destruction of school buildings used by the security forces but by the destruction of entire villages (up to 900 villages had been uprooted since June 2005) by the state police, paramilitary forces and Salwa Judum goondas [gangs] with active police support.”

In order to fight the Maoist rebels and achieve the lasting peace in the region, it is important to bring the comprehensive education and income growth for the people of the affected region. Recently, India has passed ‘Right of Children to Free and Compulsory Education Act, 2009’ (RTEA) which will ensure the education of young children. The ISF should not use schools as military camp and must provide security to the students and teachers of the schools, which will in turn help them to win the support of the local people and the tribal community.

The ‘National Rural Employment Guarantee Act’, popularly known as NREGA scheme, is already being very successfully implemented in other parts of the country. This particular tool would be very effective to increase the income of the people in the affected region. Though central government supports the most of the cost for these schemes, state government and local village government (known as panchayat) can either opt out from these schemes or the corrupt officials of the local government corrode these schemes.

Haines (2008) articulated that ineffective local government is both an incubator of Maoist revolution and an obstacle to successful counterinsurgency. Regions affected by Maoist insurgencies in India are often considered “punishment posts” and dumping grounds for incompetent and/or corrupt officials. Incompetent institutions, headed by inept officials, have deepened public mistrust leading to failure in attempts to dissolve latent hostility directed towards the government. Many state police agencies use rudimentary weapons, and undermanned forces are housed in unfortified stations, which are often considered as sitting ducks for Maoist guerrillas. Responsibility for failing institutions falls not on just a few individuals; instead the sources often include political culture; acceptance of corruption; lack of oversight; extremely slow judiciary processes; lack of proper training; and officials and political leaders who place their own interests above those of the populace.

In order to win the conflict against Maoist rebels and establish the lasting peace in the region, the combined implementation of NREGA schemes and RTEA schemes to foster the income and education of the region, is the most important step. However, it is often difficult to deliver these schemes in high conflict regions. Therefore it is important to clear and hold a region from the Maoist rebels so that the developmental schemes could be delivered. The central Government of

India and local state Governments together started a massive joint counterinsurgency operation called ‘Operation Green Hunt’ on November 17, 2009. Since then the battle between Maoist cadres and the ISF has been intensified and both sides have suffered considerable losses.

Rest of the paper focuses on the understanding and learning the spatial pattern of the ‘Maoist attack’ and the ‘Maoist losses’. Given the enormous complexity of the problem, we mainly focus on the analysis of recent conflicts during January 1, 2010 to April 30, 2010. Rest of the paper is presented in the following way. Section 2, present the data structure and exploratory data analysis of the problem. Section 3 presents spatial point pattern models. Section 4 presents the analysis of spatial point pattern models in context of the recent local politics. Section 5 concludes the paper with brief remarks and policy recommendations.

## 2 Exploratory Data Analysis

In this section we first present the data and then we present an exploratory data analysis (EDA) of the problem. Since the beginning of ‘Operation Green Hunt’; Maoist rebels have carried out several attacks. However, at the same time they suffered some considerable losses as well.

### 2.1 Understanding the Data

“South Asia Terrorism Portal” (<http://www.satp.org/>) developed and maintained by “Institute of Conflict Management” has detailed data on the Maoist attack. However, most of the data is available in textual report format, we organized and presented the data in Excel format. First we will discuss, what we really mean by ‘Maoist attack’ and ‘Maoist losses’.

**Maoist Attack:** In remote villages, the Maoist cadres often dragged people out of their houses, then sentenced them to death in a kangaroo court and killed them in front of the other villagers; the charge was ‘salwa judum member’ (anti-Maoist activist) or police informer. They often burnt down whole villages if they thought the village was not trustworthy. They also took hostages and later killed the villagers and police officers. They often blew up the train track, road, strategic bridges, radio and cell phone towers with bombs. Maoist also attacked the ISF personnel, para-military

forces with assault rifles (e.g., AK-47), grenades and rockets.

We have recorded the ‘number of victims’ from such attacks. The name of the district, where these attacks were made, is available; but the exact location of these attacks were not reported. We recorded the longitude and latitude of the center of these districts, as representative of the location of these attacks, using the available online ‘Google Earth’ software. Since more than 30 districts over several states were heavily affected by the Maoist insurgency, we expected a spatial association in the ‘number of victims’.

**Maoist Losses:** There has been a serious effort to control and dismantle the Maoist insurgency by ISF. Several Maoist cadres and commanders were killed in action, or were arrested, or surrendered over the last several months. Maoist camps have been destroyed and large caches of arms, ammunition and Maoist literatures have been seized by ISF. All these Maoist setbacks (with the number of Maoist cadres killed, arrested or surrendered) were recorded along with the longitude and latitude of the center of the corresponding districts. Often, many human right activists complained that the ISF has arrested and detained innocent villagers, who may sympathize with Maoist cause, or may have helped the Maoists under duress. ‘South Asia Terrorism Portal’ reported that doctors and health care providers were arrested by police for treating the wounded Maoist guerillas. Given the information and the complexity of the situation, it is difficult to distinguish these cases from the cases where true Maoist guerillas were arrested. We reported all these cases together as Maoist losses.

## 2.2 Exploratory Data Analysis

To analyze ‘number of victims’ of the Maoist attacks, we fit the following spatial regression model,

$$Y(s) = X^T \beta + W(s) + e, \quad (4)$$

where  $Y(s)$  denote the ‘number of victims’ of the Maoist attacks at the location  $s$ ,  $X^T = (1, \textit{Longitude}, \textit{Latitude})$ ,  $W(s) \sim GP(0, \sigma^2 \exp\{-\phi \|s - s'\| \})$  and  $e \sim N(0, \tau^2 \mathbf{I})$ . Note that  $W(s)$  is the spatial random effect, which is a realization from mean-zero Gaussian process, where  $GP(\cdot)$  stands for Gaussian process. This model was implemented using the Markov Chain Monte



Carlo (MCMC) algorithm coded in ‘spBayes’ package in R. We ran multiple chains with different starting points to monitor convergence of the MCMC updates. After a burn-in period of 5000 updates, 10000 subsequent updates were used for model inference. The MCMC estimates of parameters of model (4) are presented in Table (8). Figure 2, (part a, left panel) shows a strong spatial pattern in the number of victims of Maoist attack. Clearly, the southern Chhattisgarh area, specially the Dantewada district is the epicenter of all these attacks.

In a separate analysis we fit the spatial regression model (4) to analyze the number of Maoist cadres, who were killed, arrested or surrendered (where  $Y(s)$  denoted as Maoist losses). The MCMC estimates of parameters are presented in Table (9). Figure 2, (part b, right panel) shows a strong spatial pattern that the Maoists have suffered heavy setback in the state of Andhrapradesh.

### 3 Spatial Point Pattern Models

We are interested in modeling the point patterns of the ‘Maoist Attack’ and the ‘Maoist Losses’. Statistical models must account for randomness in the observed locations, and expected spatial association between the points. Spatial point processes (Diggle, 2003) are employed to model a set of events at random locations within a bounded region. These locations are represented through coordinates in, say,  $D \subset \mathbb{R}^d$  for some  $d > 0$ ;  $d = 2$  provides the usual spatial setting. We are interested in learning how incidences of ‘Maoist attack’ and ‘Maoist losses’ varies over the affected region. The “null” behavior assumed for complete spatial randomness for point patterns, characterized by a homogeneous Poisson process. Alternatives are often specified through a nonhomogeneous Poisson process characterized by an intensity function which is the approach we adopt here.

In point patterns, “intensity” surface reflect the expectation of more points (i.e., attack or losses) in some portion of the region and fewer in others. Such models, based on nonconstant intensity surfaces, are called nonhomogeneous Poisson process (NHPP). When these intensity surfaces are realizations of a stochastic process, the models are usually referred to as Cox processes (Møller and Waagepetersen, 2002). In general the intensities are modeled as a process realization, e.g., from a log-Gaussian process.

To model the set of locations inside a bounded domain  $D \in \mathbb{R}^2$  we use a spatial nonhomogeneous Poisson process, NHPP (Van Lieshout, 2000) with intensity  $\lambda : D \rightarrow \mathbb{R}^+ \cup \{0\}$ , i.e. we are making two basic assumptions about distribution of points in  $D$ .

- (i) Given any Borel set  $A \subseteq D$ , number of locations inside  $A$ ,  $\mathcal{N}(A) \sim Poi(\int_A \lambda(s)ds)$ .
- (ii) If  $A_1, A_2, \dots, A_k$  are disjoint Borel subset of  $D$  for any  $k$  in  $\mathbb{N}$ , then  $\mathcal{N}(A_1), \mathcal{N}(A_2), \dots, \mathcal{N}(A_k)$  are independent.

We need  $\lambda(\cdot)$  to be Borel measure, and  $\int_D \lambda(x)dx < \infty$ . To specify the likelihood associated with a realization  $\{s_1, s_2, \dots, s_n; n \in \mathbb{N} \cup \{0\}, s_i \in D\}$ , we use the fact that, conditional on number of events in  $D$ , locations inside  $D$  are independent draws from  $\lambda(\cdot)$ , normalized to a density over  $D$ . Thus we have

$$L(\lambda(s), s \in D | n; s_1, s_2, \dots, s_n) \propto \exp\left(-\int_D \lambda(s)ds\right) \prod_{i=1}^n \lambda(s_i). \quad (5)$$

From the conditional independence property stated above, the NHPP can be thought as a two stage process, first determining the count and then conditional on the count, generating that number of points from a density over  $D$ .

Often,  $\lambda(s)$  is specified as a parametric function, for example, using a basis representation or a tiled surface. Adding a prior distribution on these parameters, say,  $\theta$ , yields a posterior distribution for making inferences about the intensity surface. For us,  $\lambda(s)$  is thought of as a log Gaussian process realization, resulting in the familiar class of Cox processes (Moller and Waagepetersen (2004), page 57). To specify this prior distribution, we require  $\mu(s)$  the mean surface, along with  $\sigma^2$  and  $\phi$ , the GP covariance parameters. Below, we express  $\mu(s)$  in part with a form  $z(s)^T \beta$ , so that the process mean can depend on spatially referenced covariates  $z(s)$ . We model the intensity  $\lambda(s)$  on the log-scale as

$$\lambda(s) = \exp\{z(s)^T \beta + w(s)\}, \quad (6)$$

where  $w(s)$  is a zero-centered Gaussian process,  $\beta$  is unknown vector of regression coefficients. Such point process is known as *log Gaussian Cox process* model. Inference proceeds from the posterior

$$p(\beta, w_D | S) \propto L(\beta, w_D : S)p(\beta)p(w_D), \quad (7)$$

where  $L(\beta, w_D : S)$  takes the form specified in equation (5),  $p(\beta)$ , and  $p(w_D)$  are the priors on the  $\beta$ , and  $w_D$ , where  $\beta \sim MN(0, k\mathbf{I})$ ,  $\sigma^2 \sim \text{gamma}(a, b)$  and  $\exp\{-\phi\} \sim \text{Unif}(0, 1)$ , which completes the Bayesian specification.

A common class of estimation methods for nonhomogeneous spatial point process models avoids full likelihood evaluations by formulating estimating equations (Waagepetersen (2007), Waagepetersen and Guan (2009)). Guan (2006) developed a composite likelihood method based on the second-order intensity function of the underlying process. In all of these approaches, inference on spatial associations and second-order variations proceeds not from the intensity surface, but from pairwise correlation functions and transforms thereof [e.g., the  $g$  and  $K$  functions in Waagepetersen (2007)]. As such, they do not deal with the intensity surface estimation problem, needed for inference regarding the fitted surface itself.

Wolpert and Ickstadt (1998) offered one of the first fully Bayesian approaches for spatially nonhomogeneous Poisson process data. Benas et al. (2002) illustrate one possible Bayesian analysis of a log Gaussian Cox process model. While they assume  $\lambda(s)$  constant over grid cells, they do utilize the notion of the population intensity surface, and obtain fitted disease maps under a variety of models (constant, Gaussian kernel, etc.) for this surface.

We adopt a fully Bayesian approach that yields posterior distributions for the intensity surface associated with the point pattern. Such inference does not rely upon spatial asymptotics. Note that if  $\lambda(s)$  is modeled as a random realization of a spatial process, then the likelihood integral is stochastic, precluding explicit evaluation. Further computational challenges include the large collection of spatial locations, and a prior specification that is only available through finite dimensional distributions.

## 4 Analysis of Results in Context of Politics

In our analysis, we specify  $MN(0, k\mathbf{I})$ ,  $k = 10$ , over  $\beta$  and assumed exponential covariance function for  $w$  with  $\text{Gamma}(2,1)$  on  $\sigma^2$  and  $\text{Unif}(0, 1)$  on  $\exp\{-\phi\}$  for the spatial point process model presented by (5), (6) and (7). This model was implemented using the Markov Chain Monte Carlo

(MCMC) algorithm coded in matlab. We ran multiple chains with different starting points to monitor convergence of the MCMC updates. After a burn-in period of 2000 updates, 10000 subsequent updates were used for model inference.

The intensity surface of the Maoist attack is presented in figure 3, (part a, left panel ). It is clear from the plot that insurgency has concentrated in two regions. The epicenter of region 1 (denoted as ‘R 1’ in the graph) is Dantewada, Bastar, Kanker, Rajnandgaon district of Chattishgarh and Gadchireli district of Mahrastra. The epicenter of the region 2 (denoted as ‘R 2’) is the vast collection of districts which are spread over four states, namely West Bengal, Bihar, Jharkhand and Orissa. These districts share the state border, which makes the problem complicated for the ISF. Because after committing the crime, Maoist rebels cross the state border and hide inside in the deep jungle. This creates jurisdiction problem between the state polices.

On April 6, 2010, seventy six CRPF [Central Reserve Police Force] personel were ambushed and killed by the Maoist rebels in the deep jungle of Dantewada district of Chattishgarh. This incidence got attention of international media and most of the attention is still now over Dantewada district of Chhattishgarh. However, our spatial point process analysis is showing that the intensity of Maoist attack is much more stronger in the shared border region of West Bengal, Bihar, Jharkhand and Orissa than the South Chhattishgarh and Andhrapradesh.

Bihar state assembly election will be held in October 2010 and West Bengal state assembly election will be held in 2011. In both state, the election campaign is on its way. The administration often act like a lame duck and some times some political parties, which are in opposition takes stance that weaken the position of the ruling party in the state government and in effect it creates confusion among the officials working at ground levels.

Currently, the central government of India is lead by the “United Progressive Allance” (UPA), a coalition government presided by the prime minister Dr. Manmohan Singh and his party “Indian National Congress” (INC). Interestingly, the state government of all four states of the region 2, i.e., Bihar, West Bengal, Jharkhand and Orissa are lead by political parties or alliances which are essentialy political oponent of INC. Hence often pittty politics resulted into heavy headed, inept

governance.

The intensity surface of Maoist losses, in figure 3 (part b, right panel ), shows that the Maoist rebels have suffered significant losses. However, Maoist attacks and losses were plotted under the same color scale and the intensity of Maoist attack was uniformly higher than that of their loss. During the first four months of 2010, Maoist rebels gained ground over the ISF.

## 5 Conclusion and Policy Recommendations

In this paper, we presented the Poisson regression analysis for the data on Chhattishgarh from the year 2005 (Table 1), which shows that the intensity of Maoist attack is high in those districts where both education and income components of HDI are low. This means a comprehensive development of income and education are most important components to fight against the Maoist rebels. Hence the implementation of schemes, such as NREGA and RTEA, are important to bring the progress in the region and nullify the influence of the Maoist rebels.

However, it is often difficult to deliver the developmental scheme like NREGA and RTEA, in high conflict region. Therefore it is important that ISF should clear and hold a region from the Maoist rebels and take an active role in delivering the development. The ISF should not use school as military camp, rather ISF should provide security to school and encourage the villagers to send their children to school. Central and state government should build more new schools in the affected districts and ISF should take part in that developmental process. The ISF also need to execute the security and developmental operation while protecting the human rights as well. In addition, as Haines (2008) pointed out that ISF and civil administration should not consider the insurgency affected districts as punishment ground for inept officials. Indian authority should set out the good officers with leadership quality should be brought into these districts and inept officers should go into probation to enhance their skill.

Spatial point pattern analysis can be used to learn about the pattern of the Maoist attack and losses to prepare a fair assessment of the ground situation. During the first four months of 2010, our analysis showed that the intensity of Maoist attack is higher than their losses, the Maoist rebels

gained ground during this time.

The Maoist generally choose the districts with low income, low education, poor road and lack of basic infrastructure as their battle ground. Given the enormous complexity of the problem, it requires more comprehensive teamwork between the state or central police agencies and developmental agencies at all ranks. Its being recognized that the Dantewada massacre on April 6, 2010 was result of failure of leadership at every levels and lack of inclusive teamwork between the central and state agencies. Not every officials are corrupt or inept in India, those who are not, they should take the leadership at their own level and it is clear that education is the path to lasting peace in the region.

## References

- S. Robinson, *India's secret war*, Time Magazine (May 29, 2008). <http://www.time.com/time/magazine/article/0,9171,1810169-1,00.html>.
- India is 'losing maoist battle'*, BBC News Website, 2009. <http://news.bbc.co.uk/2/hi/8256692.stm>.
- S. M. Murshed and S. Gates, *Spatial-horizontal inequality and the maoist insurgency in nepal*, Review of Development Economics **9** (2005), 121–134.
- UNESCO, *Education Under Attack*, 2010. A global study on targeted political and military violence against education staff, students, teachers, union and government officials, aid workers and institutions.
- D. R. Haines, *Coin in the real world*, Parameters, US Army War College Quarterly **XXXVI Winter** (2008), 43–59.
- P. Diggle, *Statistical Analysis of Spatial Point Patterns.*, Arnold, 2nd edn., 2003.
- J. Møller and R. P. Waagepetersen, *Statistical inference for cox processes.*, in *Spatial Cluster Modeling*, Chapman and Hall/CRC. (2002) .

- M. N. M. Van Lieshout, *Markov point processes and their applications*, Imperial College Press, London, 1st edn., 2000.
- J. Møller and R. P. Waagepetersen, *Statistical Inference and Simulation for Spatial Point Processes*, Chapman and Hall/CRC Press, Boca Raton, FL, 2004.
- R. Waagepetersen, *An estimating function approach to inference for inhomogeneous neymanscott processes.*, *Biometrics* **63** (2007), 252–258.
- R. Waagepetersen and Y. Guan, *Two-step estimation for inhomogeneous spatial point processes.*, *J. Roy. Statist. Soc. Ser. B* **71** (2009), 685–702.
- Y. Guan, *A composite likelihood approach in fitting spatial point process models.*, *J. Amer. Statist. Assoc.* **101** (2006), 1502–1512.
- R. L. Wolpert and K. Ickstadt, *Poisson/gamma random field models for spatial statistics.*, *Biometrika* **85** (1998), 251–269.
- V. Benas, K. Bodlák, J. Møller, and R. Waagepetersen, *Bayesian analysis of log gaussian cox processes for disease mapping.*, Tech. Rep. Research Report R-02-2001, Dept. Mathematical Sciences, Aalborg Univ., Aalborg., 2002.
- Chhattisgarh Human Development Report 2005*, Government of Chhattisgarh, 2005. <http://www.im4change.org/viewstatedata.php?stateid=5>.

Table 1: Human Development Index (HDI) of districts of Chhattisgarh for the year 2005 (Cha, 2005). The number of Maoist attacks on the same year is enumerated from “South Asia Terrorism Portal”.

| District            | Attack | HDI   | Education Index | Health Index | Income Index |
|---------------------|--------|-------|-----------------|--------------|--------------|
| Bastar              | 3      | 0.264 | 0.527           | 0.132        | 0.134        |
| Bilaspur            | 0      | 0.449 | 0.723           | 0.411        | 0.214        |
| Dantewada           | 20     | 0.441 | 0.413           | 0.514        | 0.396        |
| Dhamtari            | 0      | 0.496 | 0.781           | 0.412        | 0.295        |
| Durg                | 0      | 0.578 | 0.828           | 0.545        | 0.362        |
| Janjgir-Champa      | 0      | 0.500 | 0.739           | 0.580        | 0.181        |
| Jashpur             | 0      | 0.455 | 0.570           | 0.621        | 0.173        |
| Uttar Bastar Kanker | 5      | 0.397 | 0.758           | 0.280        | 0.152        |
| Kabirdham           | 0      | 0.326 | 0.681           | 0.193        | 0.104        |
| Korba               | 0      | 0.625 | 0.603           | 0.293        | 0.980        |
| Korea               | 0      | 0.391 | 0.714           | 0.140        | 0.318        |
| Mahasamund          | 0      | 0.577 | 0.773           | 0.697        | 0.262        |
| Raigarh             | 0      | 0.430 | 0.790           | 0.295        | 0.205        |
| Raipur              | 1      | 0.534 | 0.782           | 0.558        | 0.262        |
| Rajnandgaon         | 2      | 0.374 | 0.838           | 0.063        | 0.221        |
| Surguja             | 3      | 0.418 | 0.590           | 0.532        | 0.132        |

Table 2: Poisson Regression Analysis of Model 1.

| Parameters | Estimate | Std. Error | z value | P-value |
|------------|----------|------------|---------|---------|
| Intercept  | 2.6681   | 0.7961     | 3.351   | 0.0008  |
| HDI        | -4.4060  | 1.8703     | -2.356  | 0.0185  |

Table 3: Poisson Regression Analysis of Model 2.

| Parameters | Estimate | Std. Error | z value | P-value  |
|------------|----------|------------|---------|----------|
| Intercept  | 7.3842   | 1.1091     | 6.658   | < 0.0001 |
| Education  | -10.3874 | 1.5502     | -6.701  | < 0.0001 |
| Income     | -0.7410  | 0.9848     | -0.753  | 0.452    |
| Health     | -0.2030  | 1.0286     | -0.197  | 0.844    |



Table 4: Poisson Regression Analysis of Model 3.

| Parameters                | Estimate | Std. Error | z value | P-value |
|---------------------------|----------|------------|---------|---------|
| Intercept                 | -6.073   | 3.810      | -1.594  | 0.1109  |
| Education                 | 12.714   | 6.066      | 2.096   | 0.0361  |
| Income                    | 44.438   | 12.008     | 3.701   | 0.0002  |
| Health                    | -1.922   | 1.517      | -1.268  | 0.2049  |
| Education $\times$ Income | -78.341  | 21.059     | -3.720  | 0.0002  |

Table 5: Zero-inflated Poisson Regression Analysis of Model 1.

| Parameters | Estimate | Std. Error | z value | P-value |
|------------|----------|------------|---------|---------|
| Intercept  | 1.0138   | 0.9244     | 1.097   | 0.273   |
| HDI        | 1.7468   | 2.1798     | 0.801   | 0.423   |

Table 6: Zero-inflated Poisson Regression Analysis of Model 2.

| Parameters | Estimate | Std. Error | z value | P-value |
|------------|----------|------------|---------|---------|
| Intercept  | 2.7522   | 1.4096     | 1.952   | 0.0509  |
| Education  | -3.5980  | 1.6375     | -2.197  | 0.0280  |
| Income     | 5.0087   | 2.5421     | 1.970   | 0.0488  |
| Health     | -0.5662  | 1.4666     | -0.386  | 0.6995  |

Table 7: Zero-inflated Poisson Regression Analysis of Model 3.

| Parameters                | Estimate | Std. Error | z value | P-value |
|---------------------------|----------|------------|---------|---------|
| Intercept                 | -8.216   | 3.704      | -2.218  | 0.0266  |
| Education                 | 17.896   | 6.595      | 2.713   | 0.0067  |
| Income                    | 50.937   | 14.877     | 3.424   | 0.0006  |
| Health                    | -1.356   | 2.021      | -0.671  | 0.5021  |
| Education $\times$ Income | -95.753  | 28.936     | -3.309  | 0.0009  |

Table 8: MCMC estimates of the parameters of the model 4, when  $Y(s)$  denote the number of victims of the Maoist attack at location  $s$ .

| Parameters | Intercept<br>$\beta_0$ | Latitude<br>$\beta_1$ | Longitude<br>$\beta_2$ | $\sigma^2$ | $\tau^2$ | $\phi$ |
|------------|------------------------|-----------------------|------------------------|------------|----------|--------|
| mean       | 4.2604                 | -0.01451              | -0.0057                | 1.0982     | 18.1238  | 1.5710 |
| sd         | 17.8493                | 0.2753                | 0.2559                 | 1.3683     | 2.4747   | 0.7967 |
| 2.5%       | -32.2019               | -0.5444               | -0.4935                | 0.1758     | 14.0465  | 0.3386 |
| 97.5%      | 37.7541                | 0.5393                | 0.5044                 | 4.9196     | 23.8329  | 2.9272 |

Table 9: MCMC estimates of the parameters of the model 4, when  $Y(s)$  denote the number of Maoist cadres arrested, killed or surrendered (denoted as ‘Maoist losses’) at location  $s$ .

| Parameters | Intercept<br>$\beta_0$ | Latitude<br>$\beta_1$ | Longitude<br>$\beta_2$ | $\sigma^2$ | $\tau^2$ | $\phi$ |
|------------|------------------------|-----------------------|------------------------|------------|----------|--------|
| mean       | 12.7613                | -0.3246               | -0.0401                | 0.5155     | 53.0594  | 1.6694 |
| sd         | 28.3883                | 0.3996                | 0.3985                 | 0.3267     | 6.5705   | 0.6180 |
| 2.5%       | -43.3572               | -1.1029               | -0.8188                | 0.1538     | 41.1678  | 0.6430 |
| 97.5%      | 68.3899                | 0.4617                | 0.7452                 | 1.4155     | 67.5718  | 2.7865 |

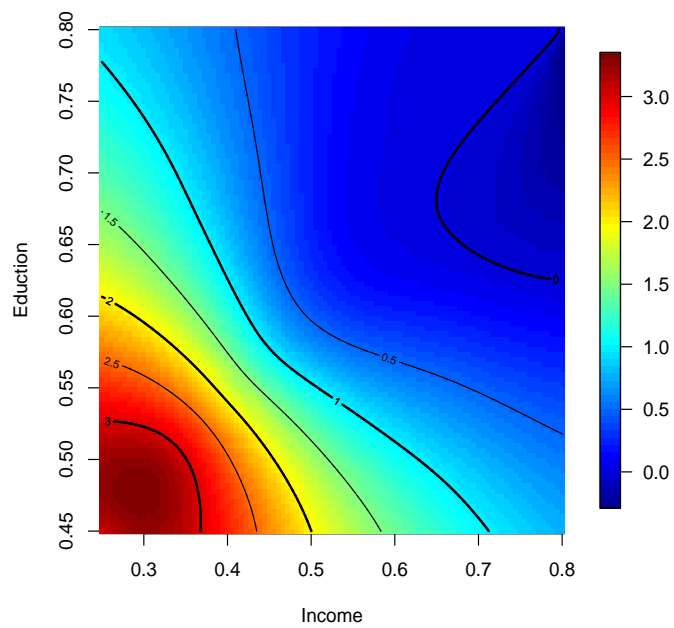


Figure 1: Surface plot of the 'intensity of Maoist attack' with respect to Education index and Income index from model 3.

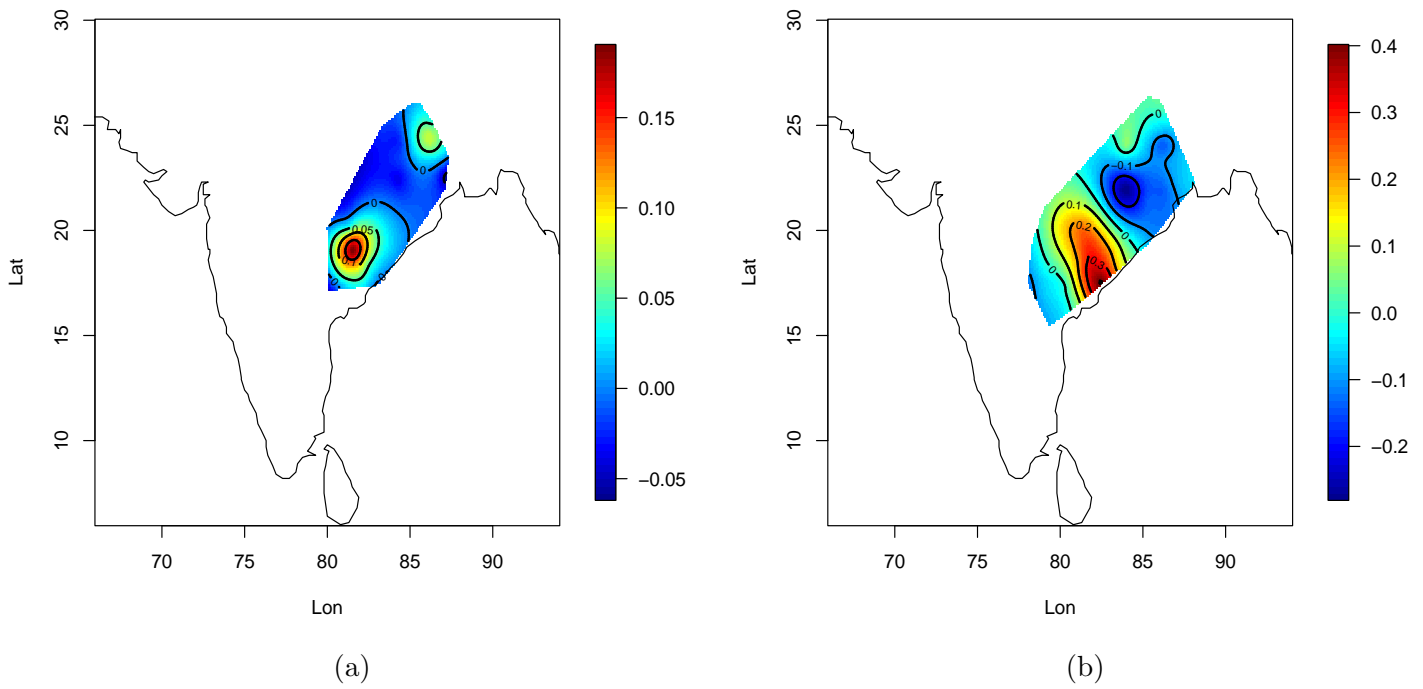


Figure 2: (a) MCMC estimates of spatial random effects of number of victims of Maoist attack from model 4. (b) MCMC estimates of spatial random effects of Maoist Losses from model 4.

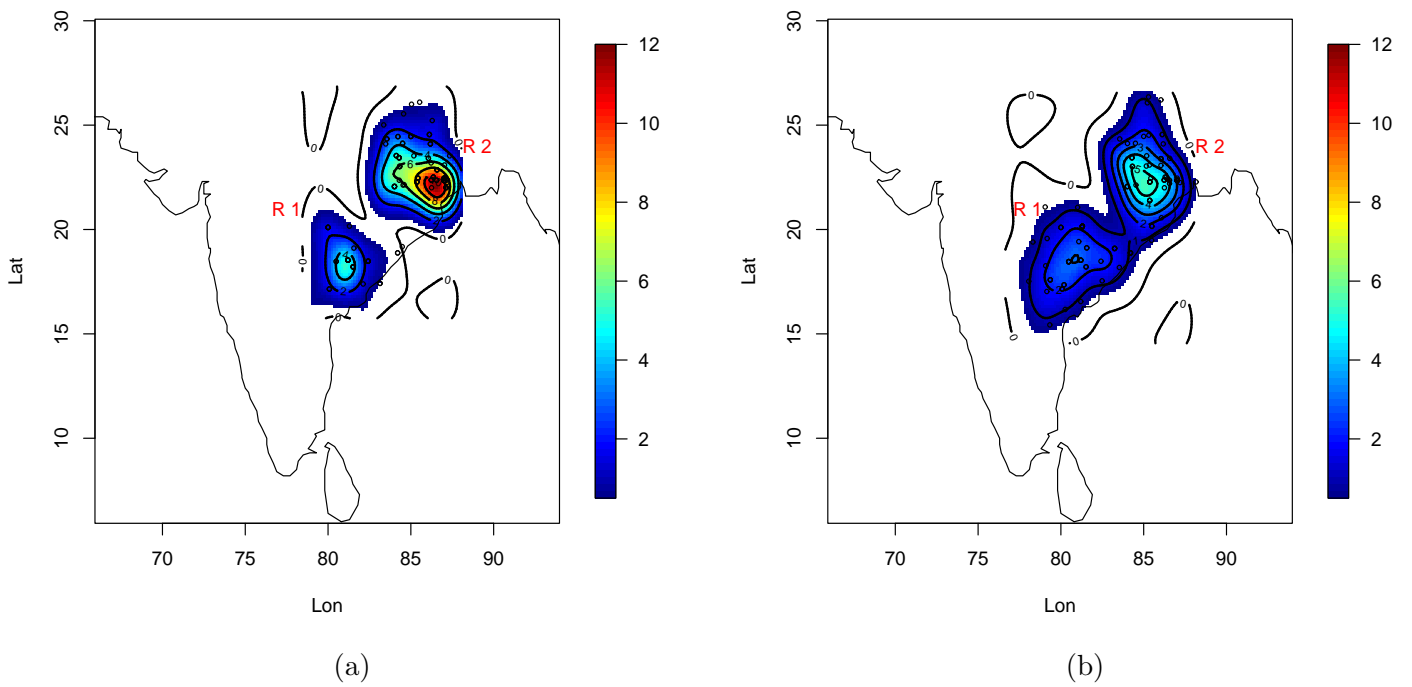


Figure 3: (a) MCMC estimates of intensity of point processes for Maoist attacks. (b) MCMC estimates of intensity of point processes for Maoist losses. R 1: Region 1 and R 2: Region 2