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Leptospirosis outbreak following 2014 major flooding in Kelantan, Malaysia-a spatial-temporal analysis.

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Introduction

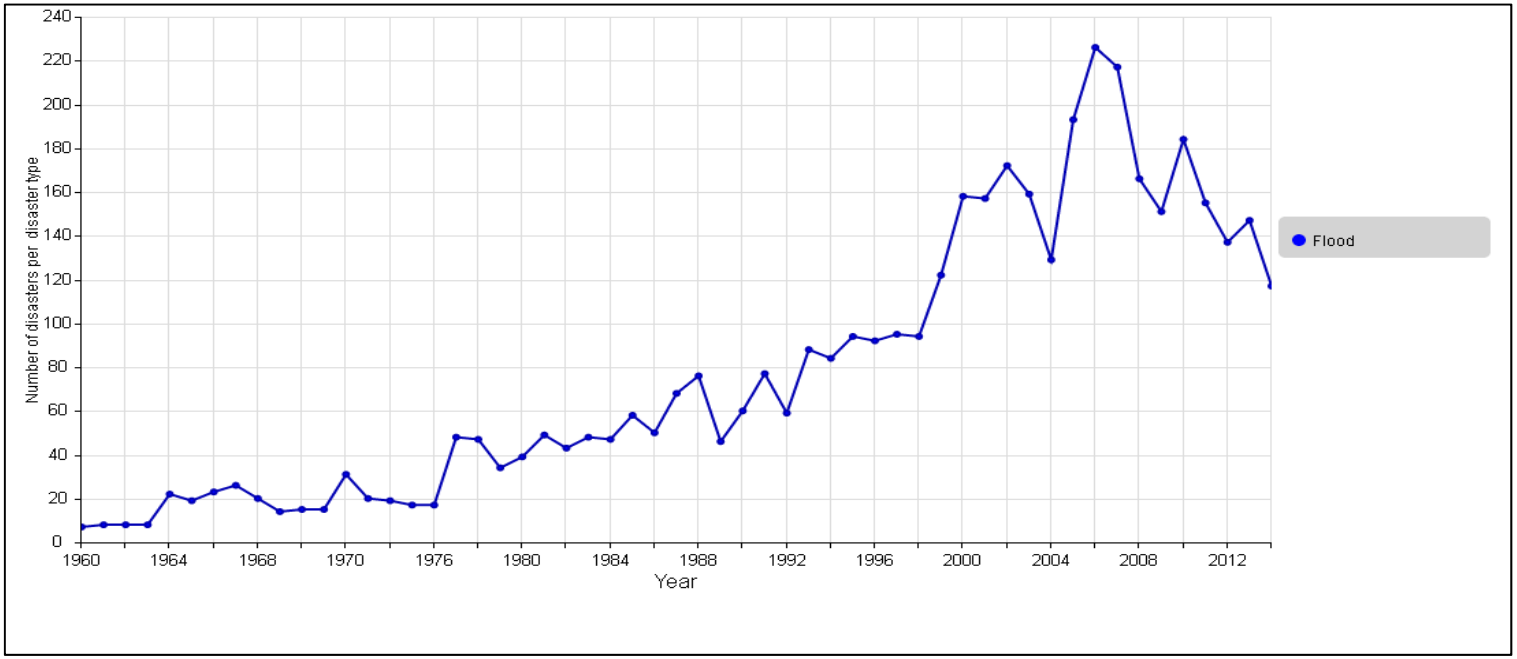
- Flood is the most common natural disaster globally.
- Many countries from least developed or developing nations which account for 80% of population exposed to river flood risk worldwide (UNISDR 2011).
- Climate change leads to more frequent and severe floodings (Hashim 2015).
- Communicable diseases are some of the commonest health effects of flood (Du et al. 2010)

Introduction

- Worldwide, the incidence of leptospirosis is recorded at around 0.1 to 100 per 100,000 population.
- Epidemics occur with incidence of over 100 per 100,000 especially in rainy seasons and flooding (WHO 2003).
- Identifying post-disaster sequential effects such as leptospirosis outbreaks is an important component in the United Nations (UN) Sendai Framework for Disaster Risk Reduction 2015-2030 (UN 2015).
- This study looks into the spatial-temporal distribution as well as clustering and vulnerability analysis of leptospirosis incidence in relation to environmental factors following the major flooding in Kelantan in 2014.

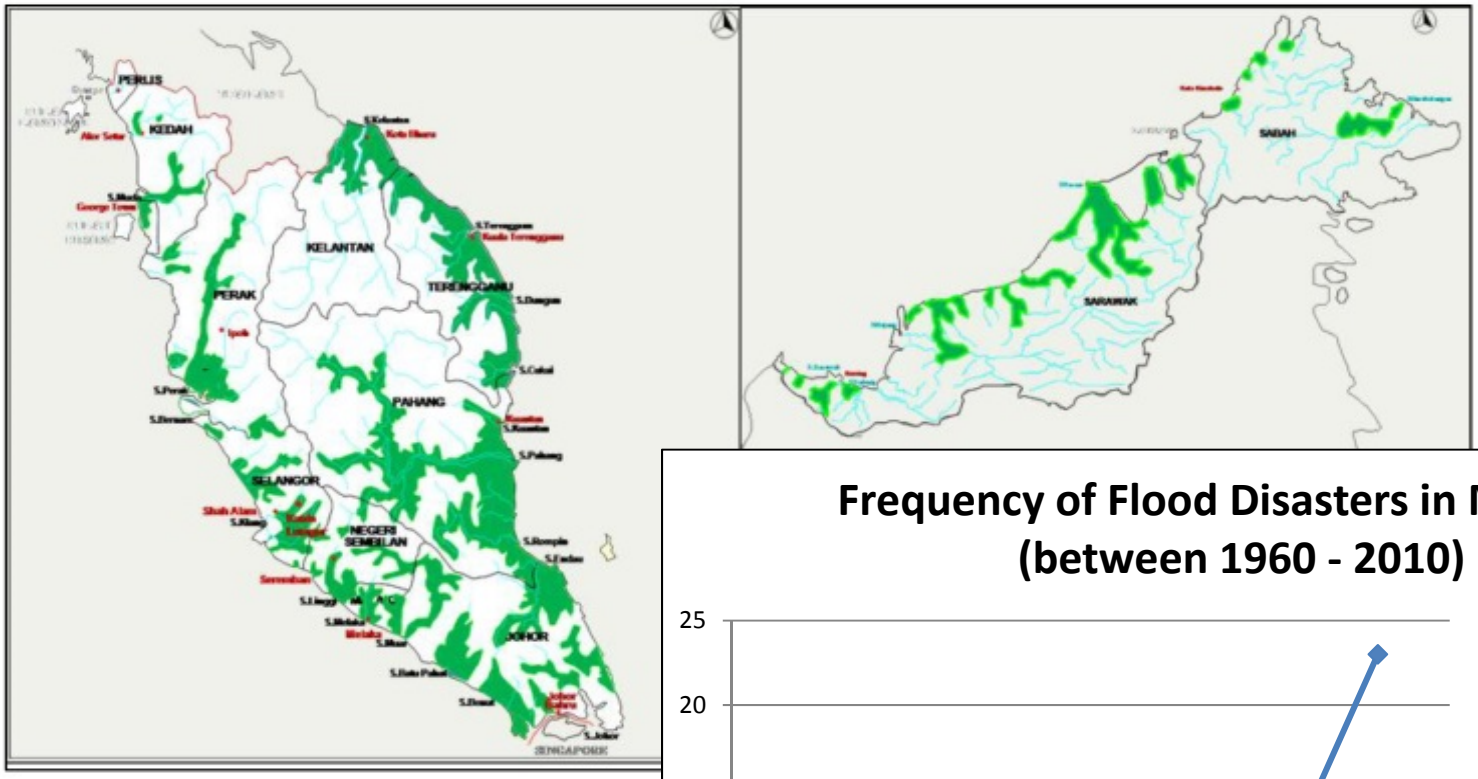
Global incidence

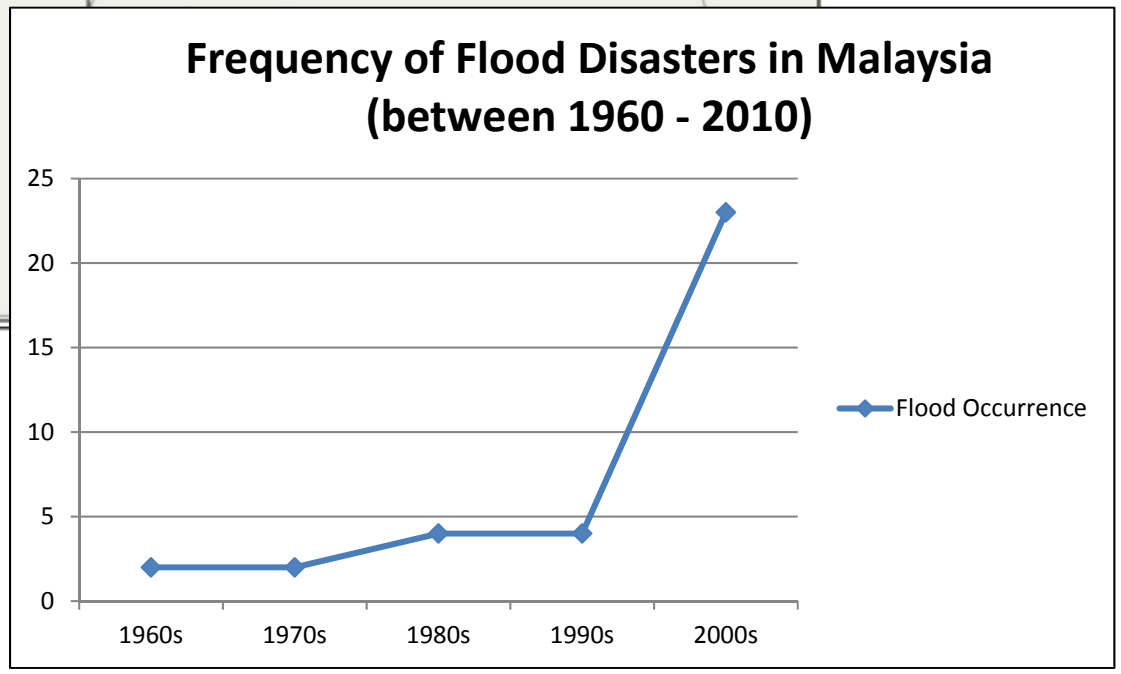
- Total number of reported floods globally between 1960 and 2014



Source: EM-DAT: The OFDA/CRED International Disaster Database, www.emdat.be - Université catholique de Louvain - Brussels - Belgium

Malaysian Flood Scenario





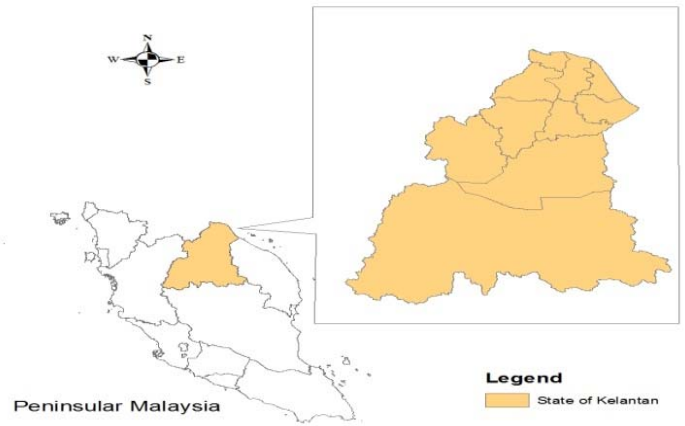
Increasing and worsening trend (EMDAT, 2015).

Kelantan River Flooding

2014 Flood in Kelantan (Credit: Daily Times)

Methodology

- Study area and period:
  - This study was conducted in Kelantan, a state in the north east of Peninsular Malaysia. This state covers an area of about 15,000 km^2 and comprises of 10 districts.
  - Study period involved was three months prior (17 September 2014-16 December 2014), during (17 December 2014 - 8 January 2015) and three months post (9 January - 9 April 2015) flood that occurred in Kelantan State.
  - During the end of year 2014 flooding, vast areas in Kelantan were severely affected and due to the extensive widespread of the flooding, the whole incident cases of leptospirosis in all districts of Kelantan during the 3 different flood periods were studied.



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Methodology

- A total of 1229 cases met the probable and confirmed case definitions in Malaysia were included in the analysis.
  - Probable case was defined as a clinical case and positive ELISA/other Rapid tests
  - Confirmed case was case with single serum specimen - titre ≥ 1:400, for paired sera - four fold or greater rise in titre Microscopic Agglutination Test (MAT) (MOH 2011) .
- All data were analysed using SPSS version 20.0. The level of significance was set at *p* value < 0.05.
- All leptospirosis cases were mapped in Kertau (RSO) Malaya coordinates system format and analysed using the software ArcGIS 10.2 (ESRI).

Methodology

- Data on flooded areas and water levels were obtained from the Malaysian Department of Irrigation and Drainage.
- Climate data from 5 gauge stations around Kelantan were obtained from the Malaysian Meteorological Department.
- Maps of Kelantan state, districts and river system were obtained from the Malaysian Department of Survey and Mapping.
- Data and maps on land use and population density census of sub-districts were obtained from the Malaysian Town and Regional Planning Department.
- Locations of garbage cleanup sites were obtained from state authority governing solid waste management.
- A total of 78 sub-districts and 10 districts were involved in this study.

Methodology

- Case clustering analysis were performed using Average Nearest Neighbourhood (ANN) and spatial autocorrelation using Global Moran's I.
- Optimized hotspot analysis as well as Kernel Density analysis were then used to determine the hotspot areas of leptospirosis cases all over Kelantan.
- An additional geographical weighted regression (GWR) was performed to look for relationships between incidence of leptospirosis cases and distance to water bodies.
- Crude incidence rates were used to visualize sub-districts more affected during different periods of time.
- In determining the relationship between meteorological parameters and the incidence of leptospirosis cases, a Poisson generalized linear regression model and negative binomial regression were used.

Results

Incidence of Communicable Diseases Before, During and After the Kelantan River Basin Flooding

Type of Communicable disease	Pre-Flood (17/9/2014-16/12/2014)	During Flood (17/12/2014-8/1/2015)	Post Flood (9/1/2015-9/4/2015)	Total
Dengue	2053	221	438	2,712
Leptospirosis	357	147	725	1,229
Malaria	19	1	26	46
Typhoid/Paratyphoid	4	2	11	17
Hepatitis A/E	3	0	4	7
Cholera	0	0	0	0
Dysentery	0	0	0	0
Tetanus	0	0	0	0

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Disease incidence period in Epid week :

- Pre Flood: Epid weeks 38/2014 to 50/2015
- During Flood: Epid weeks 51/2014 to 2/2015
- Post Flood: Epid weeks 3/2015 to 15/2015

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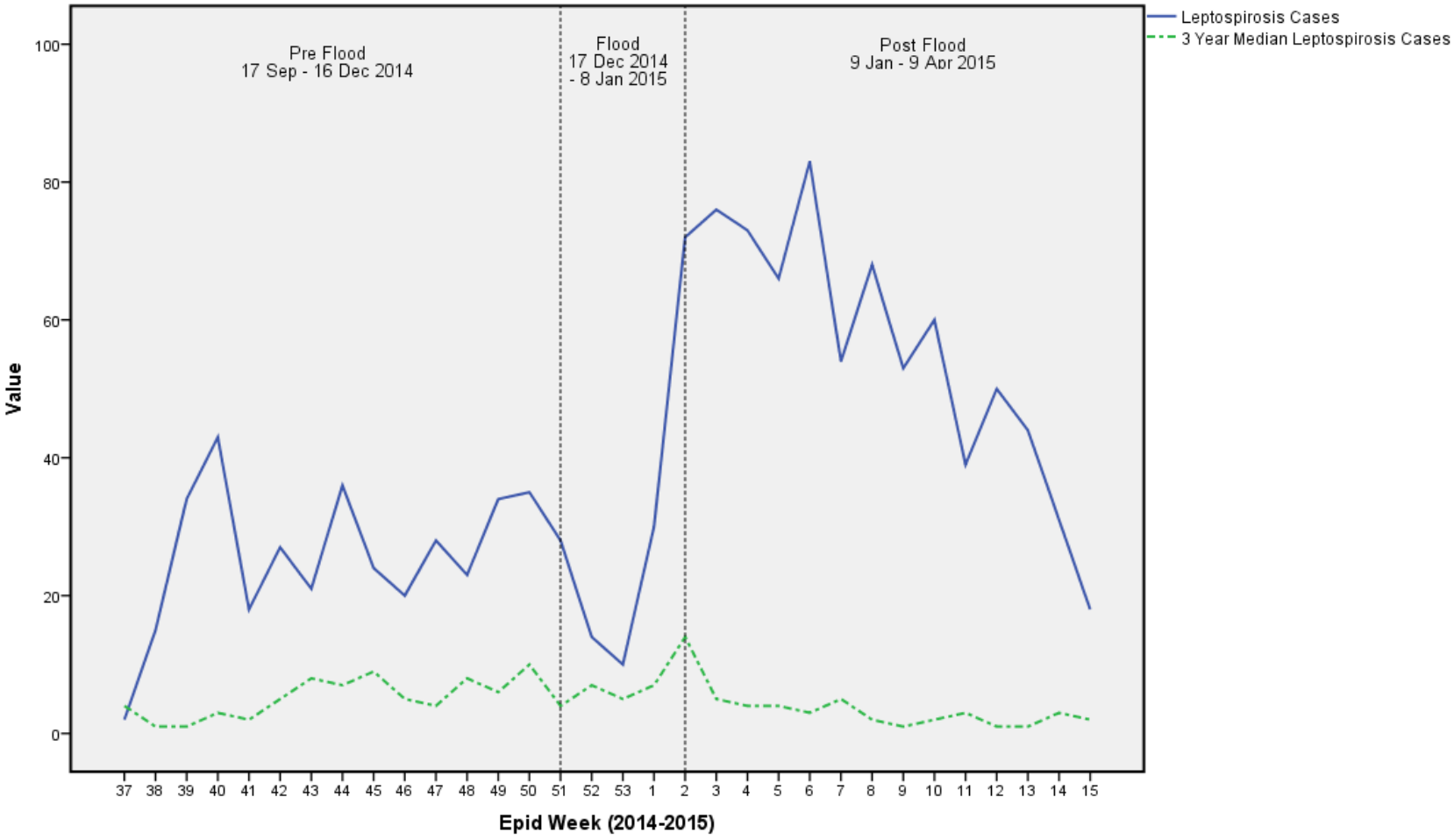
Leptospirosis Incidence Before, During and After the Kelantan Flooding



Characteristics of Leptospirosis Cases Pre, During and Post Flooding

Factors	n(%)
Age (years)	
Mean(±sd)	31.66(±19.96)
<15	275(22.4)
15 - 30	395(32.1)
31 - 45	235(19.1)
46 - 60	196(15.9)
> 60	128(10.4)
Gender	
Male	711(57.9)
Female	518(42.1)
Citizenship	
Malaysian	1182(96.2)
Non Malaysian*	47(3.8)
Race (n=1182)	
Malay	1137(96.2)
Chinese	23(1.9)
Indian	2(0.2)
Orang Asli	9(0.8)
Others	11(0.9)
Occupation (n=1128)	
Public sector	76(6.2)
Private sector	18(10.4)
Self employed	323(26.3)
Unemployed/homemaker	701(57.1)
Cases according to flood period	
Pre	357(29.0)
During	147(12.0)
Post	725(59.0)
Death (n=7)	
Pre	2(28.6)
During	1(14.3)
Post	4(57.1)

*Non Malaysian: Indonesian(17), Thailand(10), Nepal(7), Bangladesh(6), Myanmar(4), [Cambodia, India, Pakistan(1)]

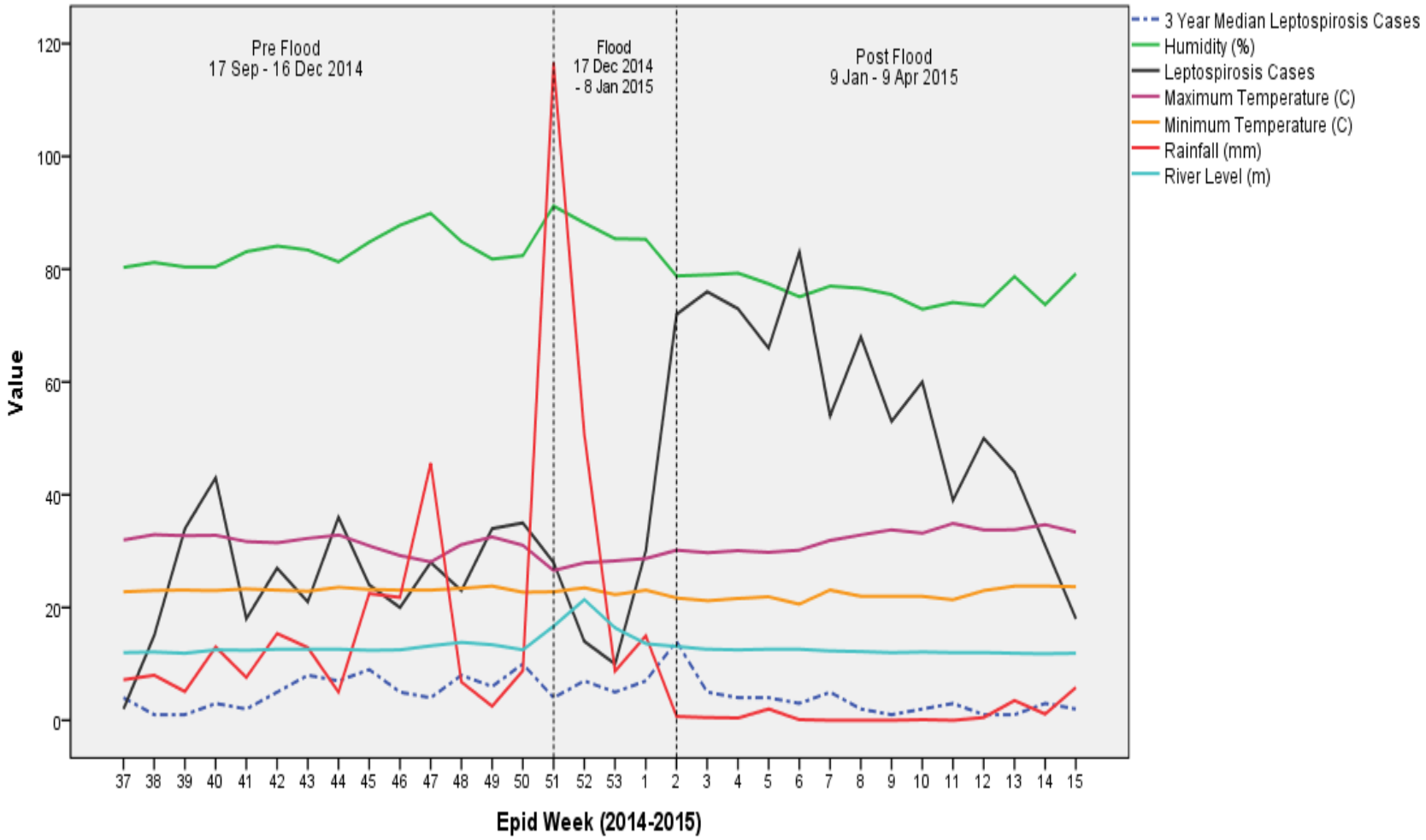
Sociodemographic factors associated with leptospirosis cases across flood period

	Leptospirosis cases according to flood period				
	Pre	During	Post		
Factors	**n(%)**	**n(%)**	**n(%)**	**χ^2(df)**	***p* value**
Age (years)					
<15	69(19.3)	27(18.4)	179(24.7)	16.79(8)	*0.032
15-30	115(32.2)	58(39.5)	222(30.6)		
31-45	70(19.6)	32(21.8)	133(18.3)		
46-60	72(20.2)	17(11.6)	107(14.8)		
>60	31(8.7)	13(8.8)	84(11.6)		
Gender					
Male	219(61.3)	99(67.3)	390(53.8)	12.07(2)	*0.002
Female	138(38.7)	48(32.7)	335(46.2)		
Race (n=1182)					
Non Malay	14(4.2)	4(2.9)	27(3.8)	0.46(2)	0.793
Malay	322(95.8)	136(97.1)	67(96.2)9		
Occupation					
Public sector	20(5.6)	12(8.2)	44(6.1)	14.78(6)	*0.022
Private sector	34(9.5)	18(12.2)	76(10.5)		
Self employed	111(31.1)	47(32.0)	165(22.8)		
Unemployed/Home maker	192(53.8)	70(47.6)	439(60.6)		

*p<0.05

** Age group of 15-30 years, being male and unemployed/homemaker contributed to these significant associations.

Climatic Parameters and Leptospirosis Cases



- Increased rainfall was observed three weeks prior to the surge in leptospirosis cases, confirming the lag phase of disease incubation.

Climatic Parameters and Leptospirosis Cases

Parameter	B	Std. Error	95% Confidence Interval		*p* value
			Lower	Upper	
(Intercept)	22.150	1.4744	19.260	25.050	0.000
Max. Temperature (˚C)	-0.145	0.0281	-0.200	-0.90	0.000
Min. Temperature (˚C)	0.134	0.0499	0.037	0.232	0.007
Humidity (%)	-0.196	0.0155	-0.226	-0.166	0.000
Rainfall (mm)	0.008	0.0025	0.003	0.013	0.002
Water Level (m)	0.097	0.0317	0.035	0.160	0.002

• Generalized Linear Model: Weekly no. of cases is positively associated with weekly rainfall, water level and minimum temperature but negatively associated with weekly humidity and maximum temperature.

[Weekly no. of cases = exp (22.150 + weekly rainfall (0.008) + weekly water level (0.097) + weekly minimum temperature (0.134) - weekly humidity (0.196) - weekly maximum temperature (0.145))]

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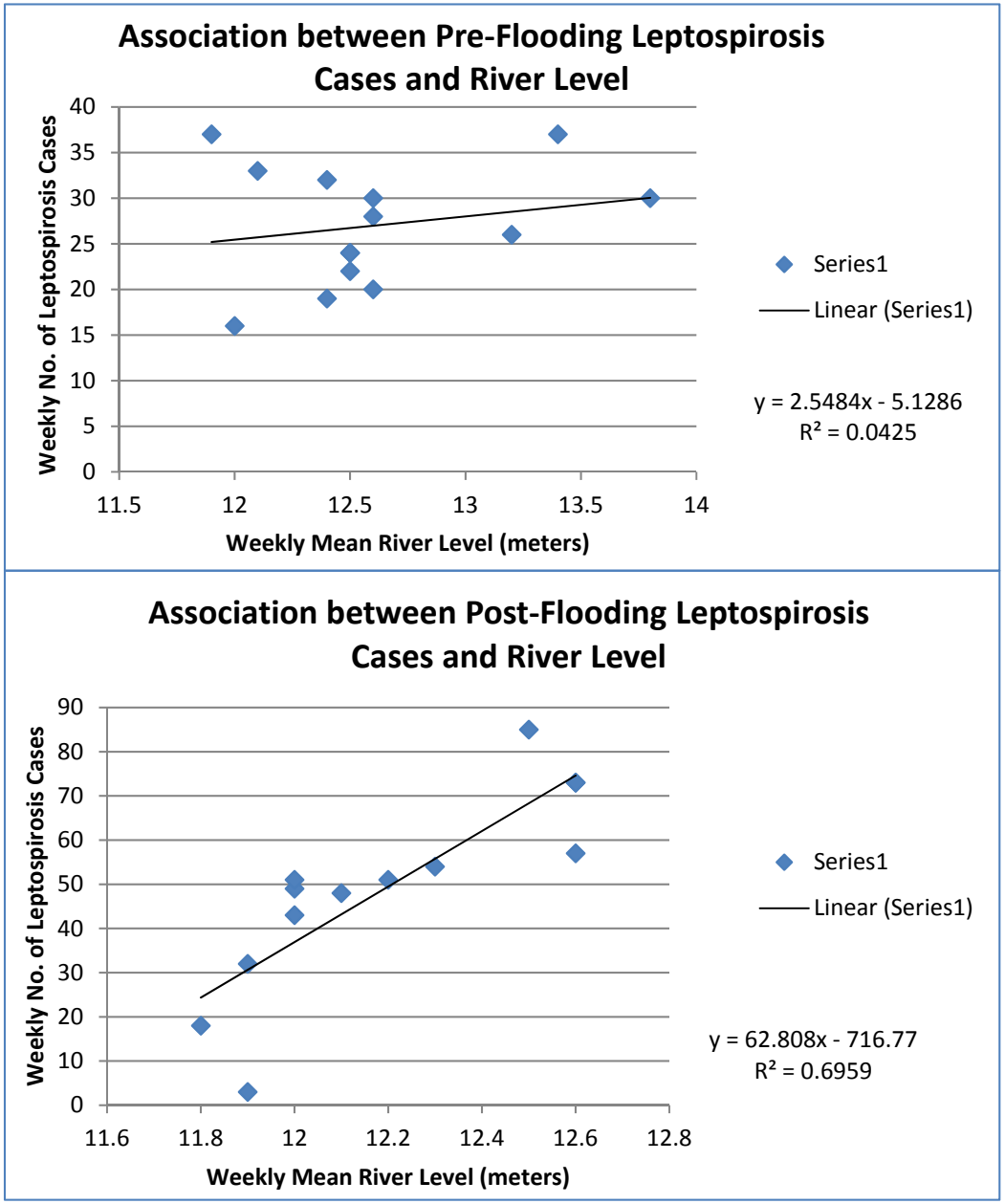
Climatic Parameters and Leptospirosis Cases



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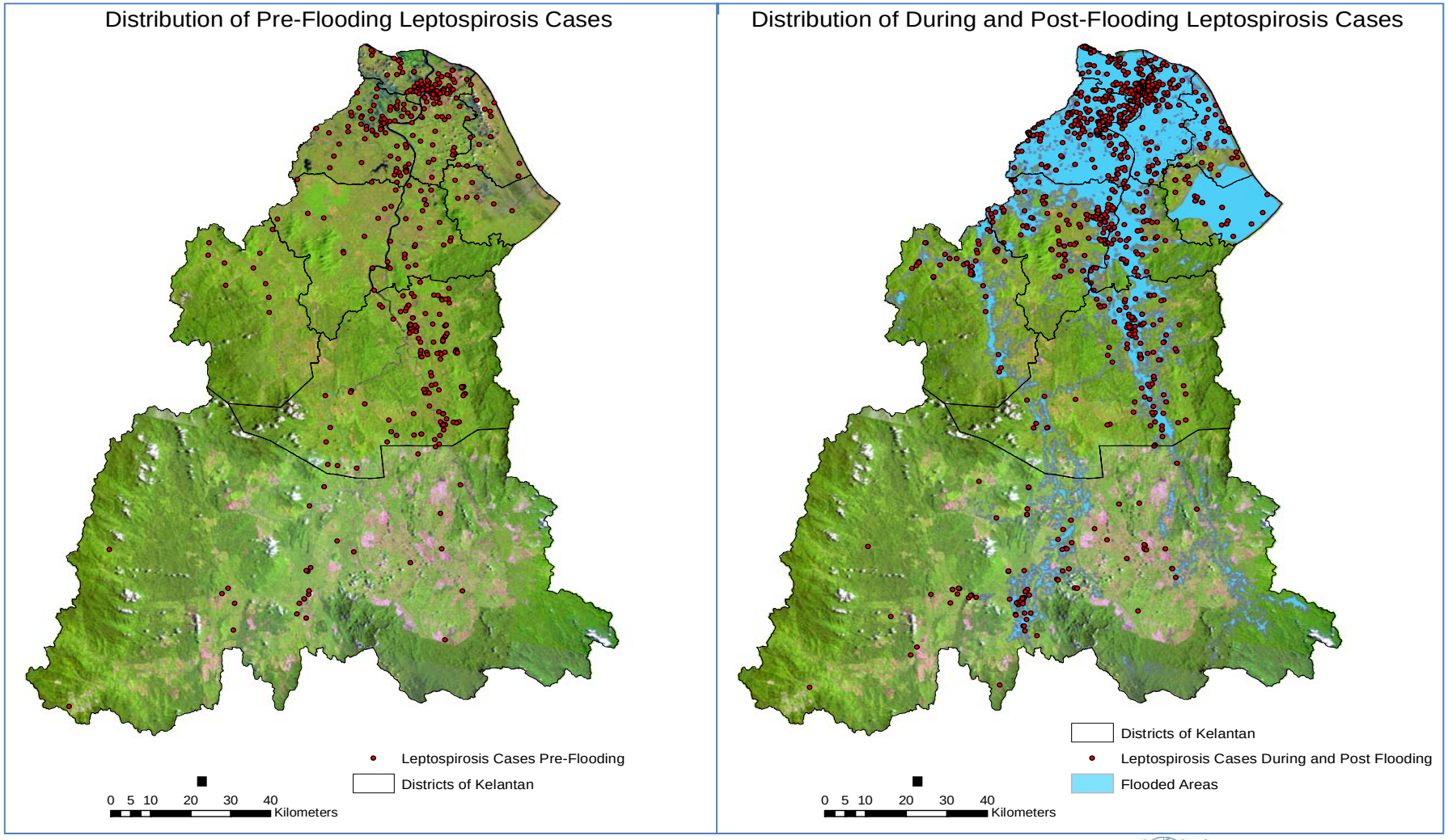
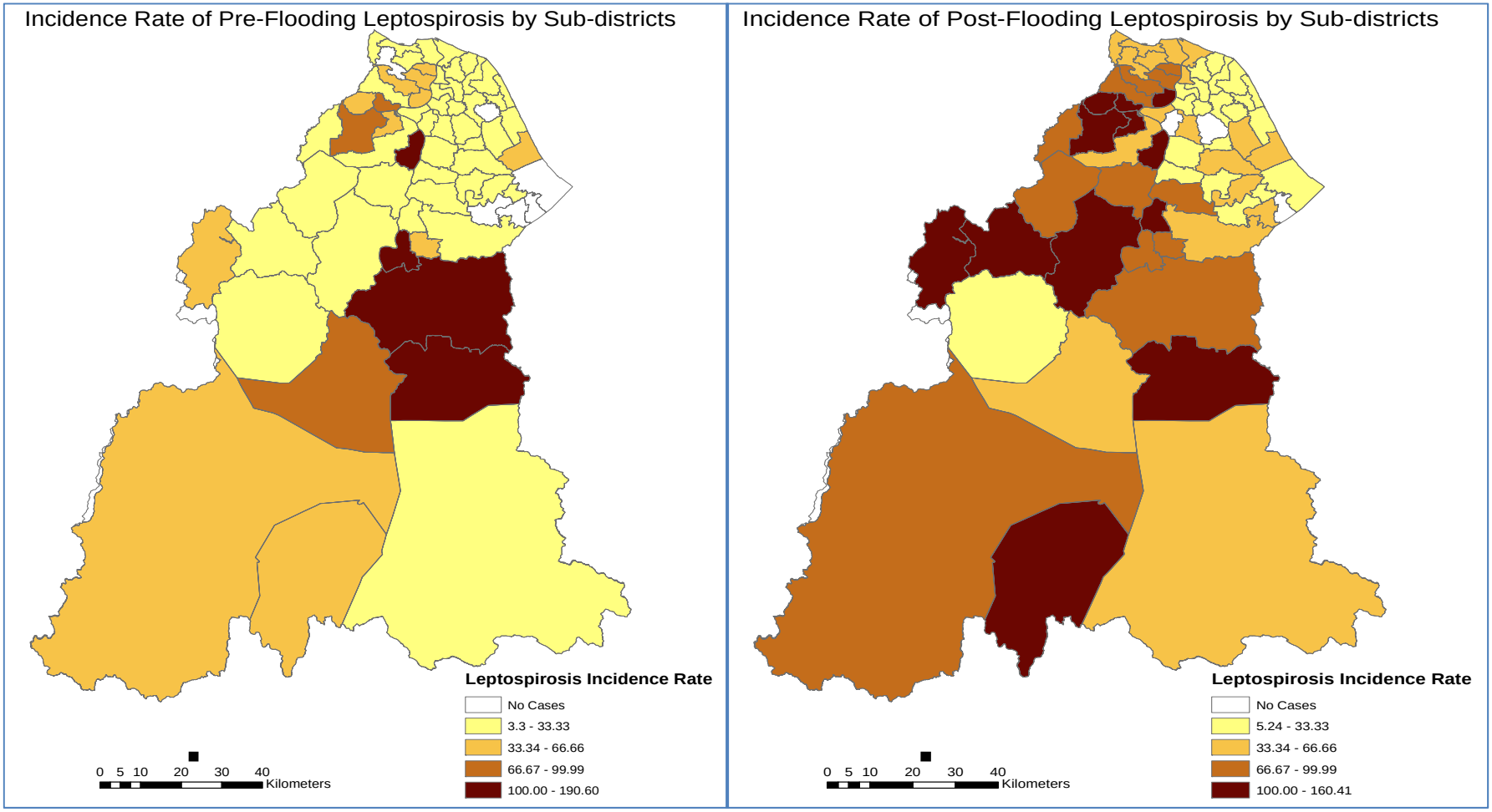
Leptospirosis Cases Distribution



Leptospirosis Incidence Rate (Pre and Post Flood)



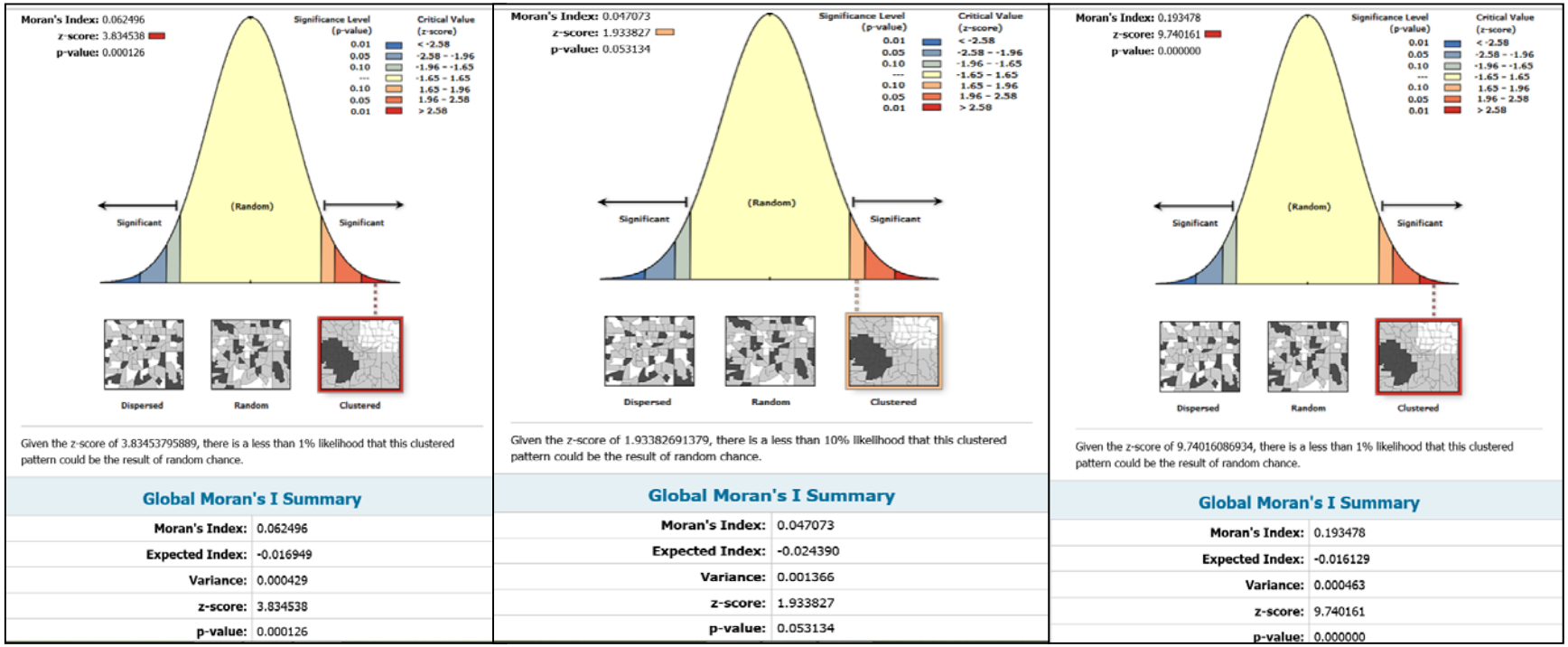
Leptospirosis Incidence Rate (Pre and Post Flood)

Incidence rates comparison between sub-districts

No	3 months pre-flooding			3 months post flooding		
	Sub-district	District	IR	Sub-district	District	IR
1	Olak Jeram	Kuala Krai	190.6	Alor Pasir	Pasir Mas	160.4
2	Chetok	Pasir Mas	119.3	Chetok	Pasir Mas	143.1
3	Batu Mengkebang	Kuala Krai	117.9	Jeli	Jeli	135.3
4	Temangan	Machang	107.0	Kubang Sepat	Pasir Mas	131.2
5	Gual Periok	Pasir Mas	83.6	Ulu Kusial	Tanah Merah	124.6
6	Dabong	Kuala Krai	80.9	Galas	Gua Musang	122.6
7	Pasir Mas	Pasir Mas	69.2	Gual Periok	Pasir Mas	122.1
8	Alor Pasir	Pasir Mas	64.2	Kuala Lemal	Pasir Mas	120.9
9	Kebakat	Tumpat	54.6	Olak Jeram	Kuala Krai	113.5
10	Panyit	Machang	48.4	Batu Melintang	Jeli	111.7

*A total of 12 out of 78 sub-districts recorded incidence rates of over 100 per 100,000 population during flood and in the post-flood periods, in comparison to only 4 sub-districts in the pre-flooding period.

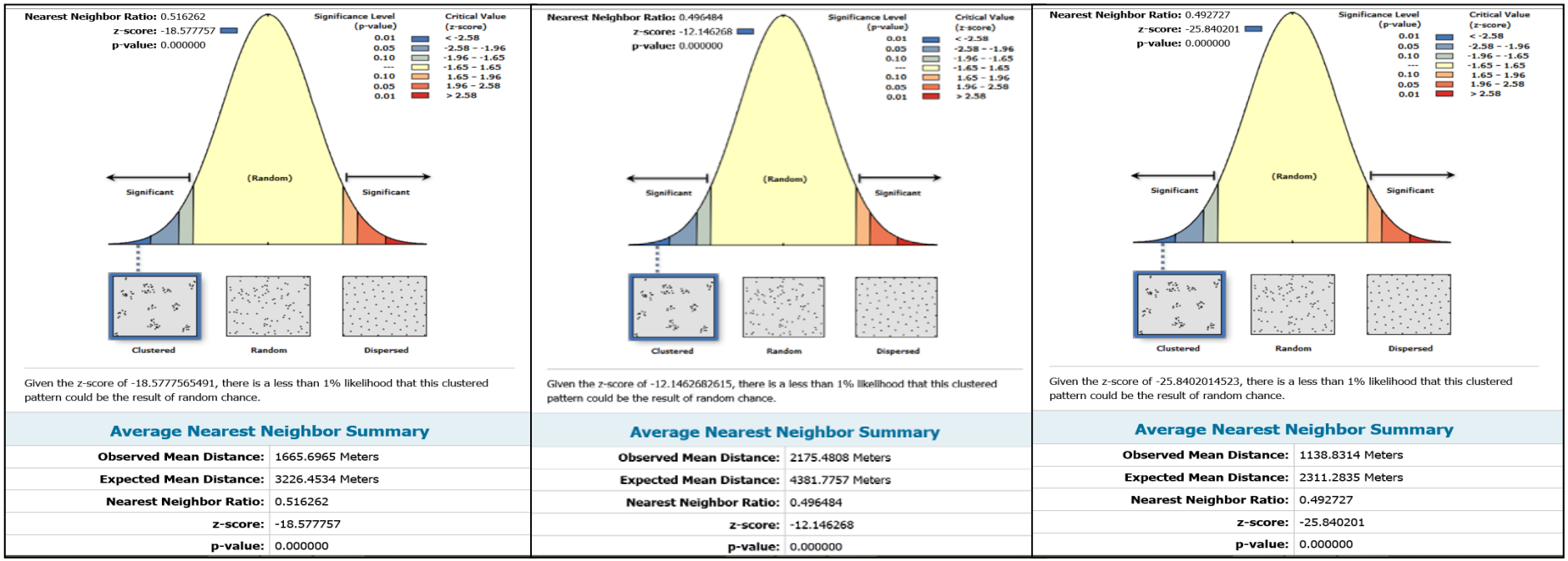
Clustering of Leptospirosis Cases



Global spatial autocorrelation analysis of leptospirosis incidence.

Period	Leptospirosis incidence rates			Pattern
	Moran's I	z-score	p-value	
Pre-flooding	0.06	3.83	< 0.01	Clustered
During	0.05	1.93	0.05	Weakly clustered
Post-flooding	0.19	9.74	< 0.01	Clustered

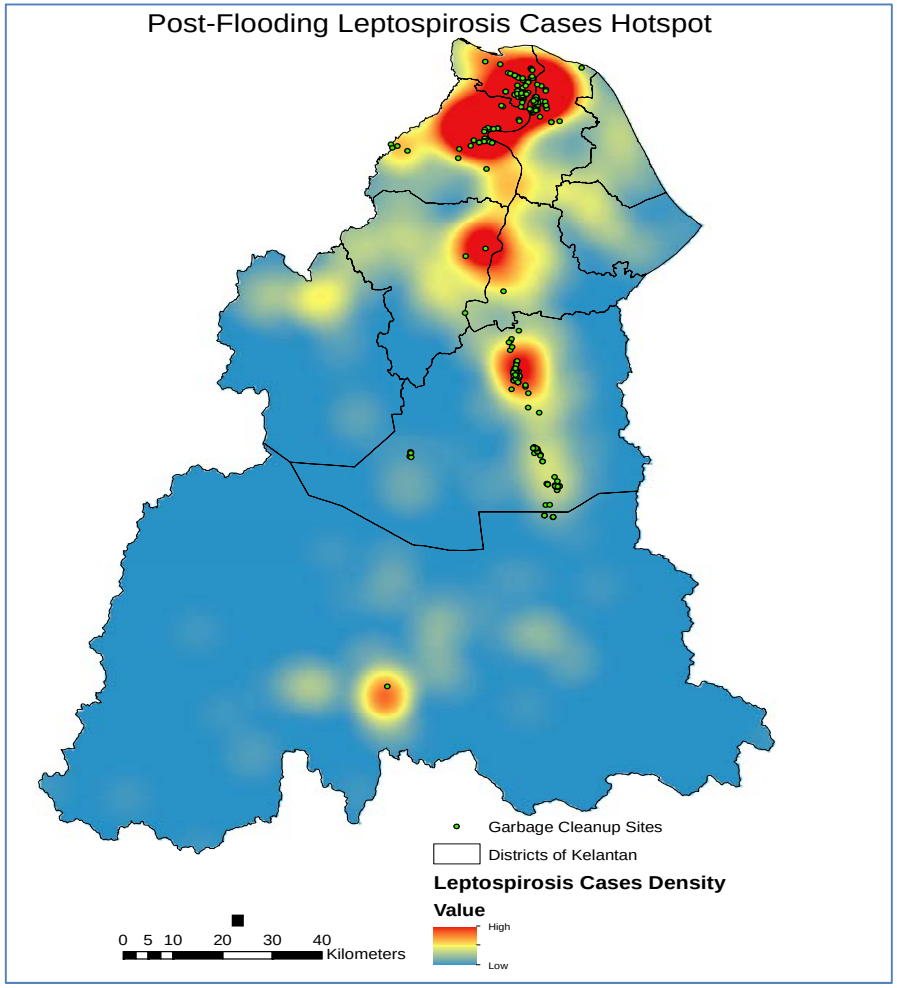
Clustering of Leptospirosis Cases

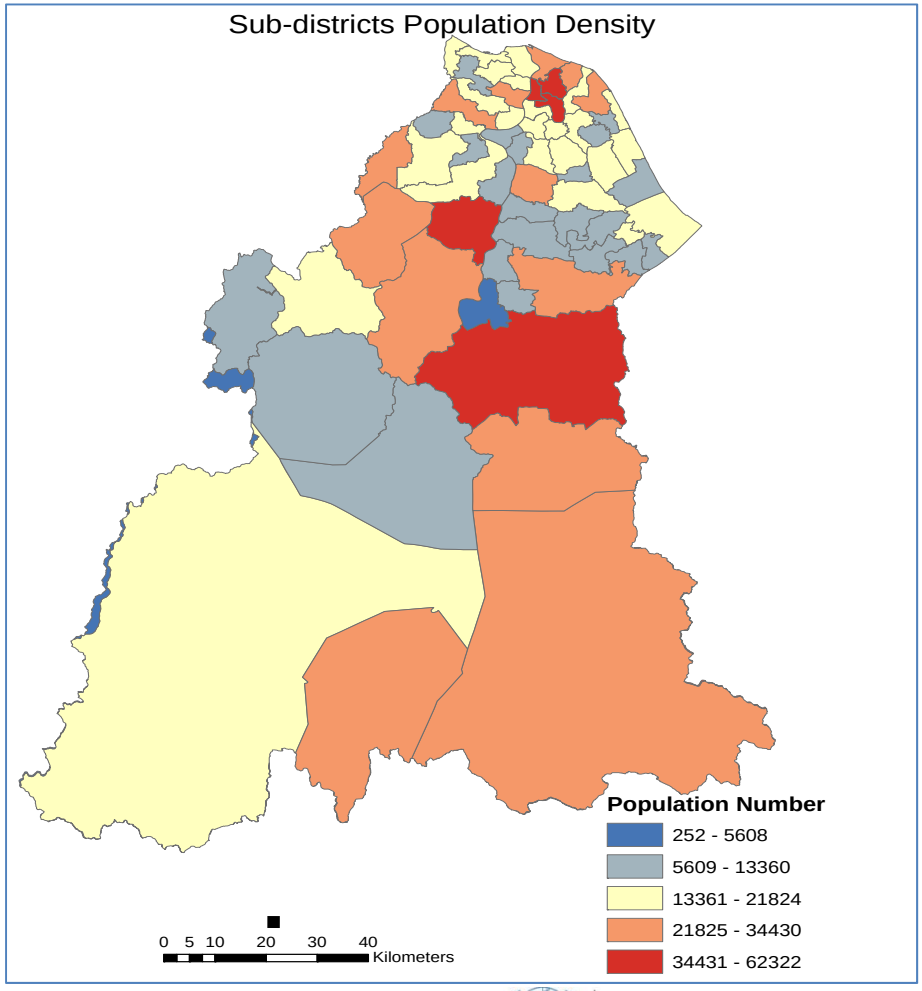


Average nearest neighbourhood analysis of cases within different flood periods.

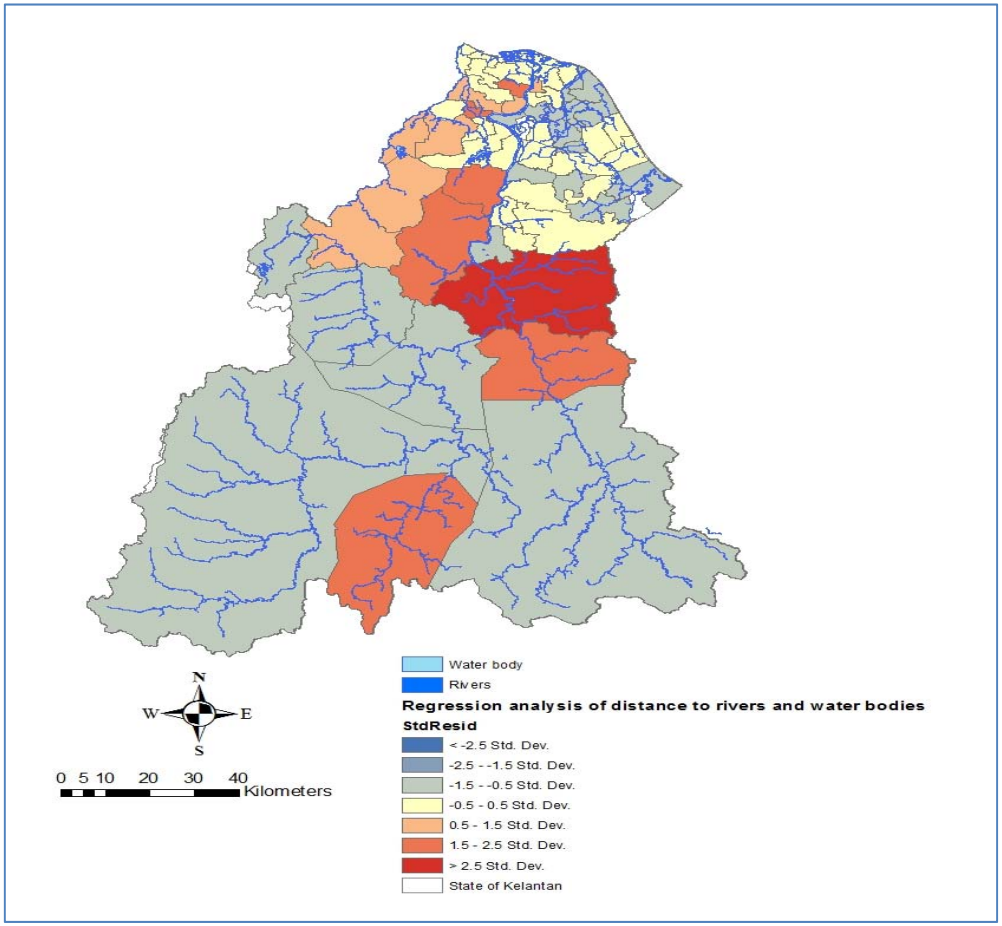
Period	Observed Mean Distance	Expected Mean Distance	Nearest Neighbourhood Ratio	z-score	p-value
Pre-flooding	1665.70	3226.45	0.52	-18.58	< 0.01
During	2175.48	4381.76	0.49	-12.15	< 0.01
Post-flooding	1138.83	2311.28	0.49	-25.84	< 0.01

Leptospirosis Incidence Association with Post Flood Garbage Collection Sites and Population Density





Leptospirosis Incidence Association with Distance to Water Bodies



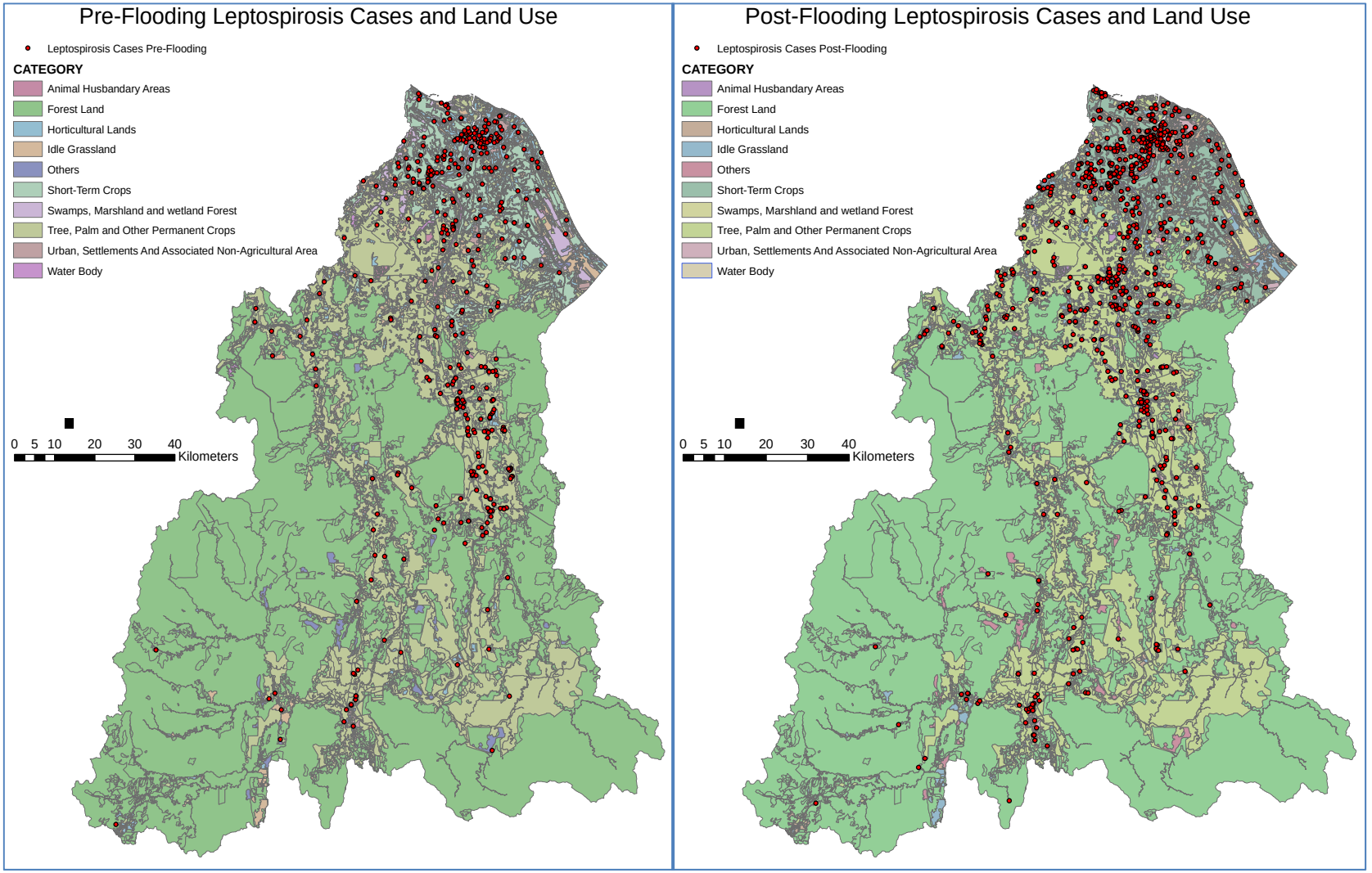
- Geographic weighted regression (GWR) showed that living close to rivers and water bodies increased the risk of contracting the disease.

Sub-district Batu Mengkebang of Kuala Krai showed the highest association.

Regression diagnostics for GWR
- AICc = 509.01
- R^2 = 0.227

Outperforming OLS (AICc = 516.76, R^2 = 0.0062)

Leptospirosis Incidence and Land Use



Leptospirosis Incidence According to Land Use

Leptospirosis cases according to land use				
	Pre	Post		
Factors	**n(%)**	**n(%)**	**χ^2(df)**	***p* value**
Land Use				
Animal Husbandary Areas	0(0.0)	1(0.1)	7.137[a](9)	0.623
Forest Land	12(3.4)	16(2.2)		
Horticultural Lands	130(36.4)	285(39.3)		
Idle Grassland	6(1.7)	24(3.3)		
Others	1(0.3)	2(0.3)		
Short Term Crops	31(8.7)	76(10.5)		
Swamps, Marshland and Wetland Forest	2(0.6)	3(0.4)		
Tree, Palm and Other Permanent Crops	88(24.6)	167(23.0)		
Urban, Settlements and Associated Non-Agricultural Area	83(23.0)	141(19.4)		
Water Body	5(1.4)	10(1.4)		
Total	357 (100.0)	725 (100.0)		

a χ^2 Test with Yates Correction

Discussion

- The Sendai Framework emphasizes that disaster risk management requires the understanding of the vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environment related to it.

- The framework also calls for Identifying post-disaster sequential effects such as leptospirosis outbreaks(United Nations 2015)

- Leptospirosis incidence ranges from 10 or more per 100,000 in tropical climates but during epidemic, incidence can soar to ≥ 100 per 100,000 (WHO 2003)

- Leptospirosis incidence has been shown to increase with:
  - Flooding (numerous outbreaks worldwide)
  - Increase rainfall and river water levels
  - Presence and proximity to garbage
  - Large cities or urban areas
  - Exposure to contaminated water bodies

  (Lau et al. 2010)

Conclusion

- The interaction between human, animal and the bacteria in the environment can be enhanced during flooding leading to outbreaks and epidemics in areas where the infection is already endemic.
- Leptospirosis incidence was associated with
  - distance to water bodies
  - garbage accumulation
  - amount of rainfall, river water levels, humidity and temperature.
- Spatial mapping of hotspots and clustering analysis of leptospirosis offer aid in improved visualization of areas that require more assistance in environmental health management and services post flooding to help reduce the outbreak of the infection.

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Thank You